SBIR/STTR 2011-1

National Aeronautics and Space Administration

SMALL BUSINESS INNOVATION RESEARCH (SBIR) & SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)

Program Solicitations

Opening Date: July 18, 2011
Closing Date: September 8, 2011

The electronic version of this document is at: http://sbir.nasa.gov

2011 SBIR/STTR Solicitation Noteworthy Changes

Changes for both Phase I and Phase II SBIR/STTR Solicitations:

Phase I and Phase II Instructions

The instructions for both Phase I and Phase II have been separated into two separate documents for a consolidated view of what is required for each phase.

1.2 Program Authority and Executive Order

Public Law 112-17, extending authorization of the SBIR/STTR Programs until September 30, 2011.

1.3 Program Management

The management function of the NASA SBIR/STTR programs has been transitioned to the newly established Office of the Chief Technologist.

1.5.3 Principal Investigator (PI)

The definition of the PI has been revised to further clarify what NASA considers to be fulltime employment of the PI with the firm (or research institution for those in the STTR Program).

1.6 NASA SBIR"TAV" Subtopics

A new initiative for SBCs to utilize NASA-owned/NASA IP, which are patented technologies that NASA is offering under a non-exclusive, royalty-free research license for use under specific SBIR subtopics for award. Further description can be found in Sections 2.12, Section 3.2.4 (Part 3), 5.7.6, and Form B).

2.5 Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs)

A definition on the new legislation that was passed to encourage the participation of EDWOSBs.

1.5.2 Place of Performance

The description on the place of performance has been expanded.

3.2.2 Format Requirements

Proposals that do not follow the formatting requirement are subject to rejection during administrative screening. Any page(s) going over the required page limited will be deleted and omitted from the proposal review.

3.2.3 Forms

Forms A, B, C will all be done electronically, with each form counting as 1 page towards the page limit and accounting for pages 1-3 of the proposal regardless of the length. So all submitted technical proposals should start on page 4 with the table of contents.

3.2.4 Technical Content

Part 3: Technical Objectives
As stated above, here there is further description of the TAV initiative.

Part 8: Facilities/Equipment
The description and requirements for facilities and equipment has been further clarified and defined.

Part 9: Subcontracts and Consultants
The description and requirements for Subcontracts and Consultants has been further clarified and defined.

Part 11: Essentially Equivalent and Duplicate Proposals and Awards
The title, definition(s), and what is required in this section has been expanded upon. There is now a Part 11a and Part 11b. Part 11b will not be included in the page count and is meant to capture related research and development work that is being proposed, and to protect the SBC by showing full disclosure.

3.2.9 (for Phase I) and 3.2.8 (for Phase II) Briefing Chart

The briefing chart will now be submitted through an online form during the submissions process rather than being uploaded.

Note: Companies with Prior NASA SBIR/STTR Awards
NASA has instituted a comprehensive commercialization survey/data that firms must fill out. The survey will be done electronically during the submission process.

4.1.2 Phase I and Phase II Evaluation Criteria

Some of the descriptions for the evaluation criteria have minor edits and Factor 5 (below) was added.

Factor 5. Price Reasonableness
During the negotiation process, the offeror’s cost proposal will be evaluated for price reasonableness based on the information provided in Form C. NASA will comply with the FAR and NASA FAR Supplement (NFS) to evaluate the proposed price/cost to be fair and reasonable. After completion of evaluation for price reasonableness and determination of responsibility the contracting officer shall submit a recommendation for award to the Source Selection Official.

5.7.2 Proprietary Data

The description has been clarified further.

5.7.5 Invention Reporting, Election of Title and Patent Application Filing

The description has been clarified further.

5.10 (for Phase I) and 5.11 (for Phase II) Essentially Equivalent Awards and Prior Work

The description has been expanded to further clarify what is considered “Essentially Equivalent”.

5.11.8 (for Phase I) and 5.12.13 (for Phase II) 52.225-1 Buy American Act-Supplies

The description has been expanded to further clarify what is considered “Buy American Act-Supplies”.

Firm Certifications
As stated above, Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs) has been added to the certifications.

Forms A, B, and C

Have all been revamped with significant changes and different requirements, so please look at each one carefully.

Specific Phase I Changes:

1.4 Three-Phase Program

The maximum value for a Phase I has increased from $100,000 to $125,000.

3.2.6 Prior Awards Addendum

An electronic form will now be provided during the submission process.

3.2.10 Contractor Responsibility Information

A new section on the contractor responsibilities and what is required no later than 10 days after the notification of the selection for negotiation.

5.3 Payment Schedule for Phase I

The exact payment terms for Phase I will be included in the contract.

Specific Phase II Changes:

1.1 Program Description

Note: The information in the Phase II instructions is subject to revision and if necessary, updated Phase II proposal instructions will be provided to the SBCs 6 weeks prior to the due date of the Phase II proposal.

1.4 Three-Phase Program

The maximum value for a Phase II-E has increased from $150,000 to $250,000. The total cumulative award for the Phase II contract plus the Phase II-E match is not expected to exceed $1,000,000.00 of SBIR/STTR funding. The description of brief policy for the Phase II-E initiative has changed as well.

3.2.4 Technical Proposal

Part 4: Work Plan

The Work Plan part has been elaborated further than previously before for clarification.

Part 6: Key Personnel and Bibliography of Directly Related Work

The Key Personnel and Bibliography of Directly Related Work part has been elaborated further than previously before for clarification. **Note: If the Phase II PI is different than that proposed under the Phase I, please provide rational for the change.**

3.2.6 Phase III Awards resulting from NASA SBIR/STTR Awards

An electronic form will now be provided during the submission process.

3.2.9 Contractor Responsibility Information

A new section on the contractor responsibilities and what is required no later than 10 days after the notification of the selection for negotiation.

5.3 Payment Schedule for Phase II

The exact payment terms for Phase II will be included in the contract. The progress payment method will not be authorized, but other forms of financing arrangements will be considered.

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2011 NASA SBIR/STTR Program Solicitations

1. Program Description

1.1 Introduction

This document includes two NASA program solicitations with separate research areas under which small business concerns (SBCs) are invited to submit proposals: the Small Business Innovation Research (SBIR) Program and the Small Business Technology Transfer (STTR) Program. Program background information, eligibility requirements for participants, information on the three program phases, and information for submitting responsive proposals is contained herein. The 2011 Solicitation period for Phase I proposals begins July 18, 2011 and ends September 8, 2011.

The purposes of the SBIR/STTR programs, as established by law, are to stimulate technological innovation in the private sector; to strengthen the role of SBCs in meeting Federal research and development needs; to increase the commercial application of these research results; and to encourage participation of socially and economically disadvantaged persons and women-owned small businesses.

Technological innovation is vital to the performance of the NASA mission and to the Nation's prosperity and security. To be eligible for selection, a proposal must present an innovation that meets the technology needs of NASA programs and projects as described herein and has significant potential for successful commercialization. Commercialization encompasses the transition of technology into products and services for NASA mission programs, other U.S. Government agencies, and non-Government markets.

NASA considers every technology development investment dollar critical to the ultimate success of NASA's mission and strives to ensure that the research topic areas described in this solicitation are in alignment with its Mission Directorate high priorities and technology needs. In addition, the Solicitation is structured such that SBIR/STTR investments are complementary to other NASA technology investments. NASA'S ultimate objective is to achieve infusion of the technological innovations developed in the SBIR/STTR programs into its Mission Directorates programs and projects.

The NASA SBIR/STTR programs do not accept proposals solely directed towards system studies, market research, routine engineering development of existing product(s), proven concepts, or modifications of existing products without substantive innovation.

It is anticipated that SBIR and STTR Phase I proposals will be selected for negotiation of firm-fixed-price contracts around the November/December 2011 timeframe. Historically, the ratio of Phase I proposals to awards is approximately 8:1 for SBIR and STTR, and approximately 45% of the selected Phase I contracts are selected for Phase II follow-on efforts.

NASA will not accept more than 10 proposals to either program from any one company in order to ensure the broadest participation of the small business community. NASA does not plan to award more than 5 SBIR contracts and 2 STTR contracts to any offeror.

Proposals must be submitted online via the Proposal Submissions Electronic Handbook at http://sbir.nasa.gov and include all relevant documentation. Unsolicited proposals will not be accepted.

1.2 Program Authority and Executive Order

SBIR and STTR opportunities are solicited annually pursuant to the Small Business Innovation Development Act of 1982 (Public Law 97-219), Small Business Innovation Research Program Reauthorization Act of 2000 (Public Law 106-554), the Small Business Research and Development Act of 1992 (Public Law 102-564), the Small Business Technology Transfer Program Reauthorization Act of 2001 (Public Law 107-50), and as most recently amended by Congress has extended the SBIR and STTR programs through September 30, 2011 (P.L. 112-17). A new authorization or extension is anticipated prior to this end date.

Executive Order: This Solicitation complies with Executive Order 13329 (issued February 26, 2004) directing Federal agencies that administer the SBIR and STTR programs to encourage innovation in manufacturing related research and development consistent with the objectives of each agency and to the extent permitted by law.

On February 26, 2004, the President issued Executive Order 13329 (69 FR 9181) entitled “Encouraging Innovation in Manufacturing.” In response to this Executive Order, NASA encourages the submission of applications that deal with some aspect of innovative manufacturing technology. If a proposal has a connection to manufacturing this should be indicated in the Part 5 (Related R/R&D) of the proposal and a brief explanation of how it is related to manufacturing should be provided.

Energy Independence and Security Act of 2007, section 1203, stated that federal agencies shall give high priority to small business concerns that participate in or conduct energy efficiency or renewable energy system research and development projects. If a proposal has a connection to energy efficiency or alternative and renewable energy this should be indicated in Part 5 (Related R/R&D) of the proposal and a brief explanation of how it is related to energy efficiency and alternative and renewable energy should be provided.

1.3 Program Management

The Office of the Chief Technologist under the Office of the NASA Associate Administrator provides overall policy direction for implementation of the NASA SBIR/STTR programs. The NASA SBIR/STTR Program Management Office, which operates the programs in conjunction with NASA Mission Directorates and Centers, is hosted at the NASA Ames Research Center. NASA Shared Services Center (NSSC) provides the overall procurement management for the programs. All of the NASA Centers actively participate in the SBIR/STTR programs; and to reinforce NASA’s objective of infusion of SBIR/STTR developed technologies into its programs and projects, each Center has personnel focused on that activity.

NASA research and technology areas to be solicited are identified annually by Mission Directorates. The Directorates identify high priority research and technology needs for their respective programs and projects. The needs are explicitly described in the topics and subtopics descriptions developed by technical experts at NASA’s Centers. The range of technologies is broad, and the list of topics and subtopics may vary in content from year to year. See section 9.1 for details on the Mission Directorate research topic descriptions.

The STTR Program Solicitation is aligned with needs and associated core competencies of the NASA Centers as described in Section 9.2.

Information regarding the Mission Directorates and the NASA Centers can be obtained at the following web sites:

NASA Mission Directorates	
Aeronautics Research	http://www.aeronautics.nasa.gov/
Exploration Systems	http://www.nasa.gov/exploration/home/index.html
Science	http://nasascience.nasa.gov
Space Operations	http://www.nasa.gov/directorates/somd/home/

NASA Centers	
Ames Research Center (ARC)	http://www.nasa.gov/centers/ames/home/index.html
Dryden Flight Research Center (DFRC)	http://www.nasa.gov/centers/dryden/home/index.html
Glenn Research Center (GRC)	http://www.nasa.gov/centers/glenn/home/index.html
Goddard Space Flight Center (GSFC)	http://www.nasa.gov/centers/goddard/home/index.html
Jet Propulsion Laboratory (JPL)	http://www.nasa.gov/centers/jpl/home/index.html
Johnson Space Center (JSC)	http://www.nasa.gov/centers/johnson/home/index.html
Kennedy Space Center (KSC)	http://www.nasa.gov/centers/kennedy/home/index.html
Langley Research Center (LaRC)	http://www.nasa.gov/centers/langley/home/index.html
Marshall Space Flight Center (MSFC)	http://www.nasa.gov/centers/marshall/home/index.html
Stennis Space Center (SSC)	http://www.nasa.gov/centers/stennis/home/index.html

1.4 Three-Phase Program

Both the SBIR and STTR programs are divided into three funding and development stages.

Phase I: The purpose of Phase I is to determine the scientific, technical, commercial merit and feasibility of the proposed innovation, and the quality of the SBC's performance. Phase I work and results should provide a sound basis for the continued development, demonstration and delivery of the proposed innovation in Phase II and follow-on efforts. Successful completion of Phase I objectives is a prerequisite to consideration for a Phase II award.

Phase II: The purpose of Phase II is the development, demonstration and delivery of the innovation. Only SBCs awarded Phase I contracts are eligible for Phase II funding agreements. Phase II projects are chosen as a result of competitive evaluations and based on selection criteria provided in the Phase II instructions.

Maximum value and period of performance for Phase I and Phase II contracts:

Phase I Contracts	**SBIR**	**STTR**
Maximum Contract Value	$ 125,000	$ 125,000
Period of Performance	6 months	12 months
Phase II Contracts	**SBIR**	**STTR**
Maximum Contract Value	$ 700,000	$ 700,000
Period of Performance	24 months	24 months

* Nominal period of performance for a Phase II is 24 months. If your period of performance is less than 18 months, you may not be eligible for a Phase II Enhancement as described below.

Phase II Enhancement (PII-E): The objective of the Phase II-E Option is to further encourage the transition of Phase II contracts into Phase III awards by providing a cost share extension of R/R&D efforts to the current Phase II contract with new Phase III contracts. Eligible firms must secure a 3rd party investor to partner and invest in enhancing their technology for further research, infusion, and/or commercialization. Under this option, NASA will match with SBIR/STTR funds up to $250,000 of non-SBIR/non-STTR investment from a NASA project, NASA contractor, or 3rd party commercial investor to extend an existing Phase II project for up to a minimum of 4 months to perform additional R/R&D. The total cumulative award for the Phase II contract plus the Phase II-E match is not expected to exceed $1,000,000.00 of SBIR/STTR funding. The non-SBIR or non-STTR contribution is not limited since it is regulated under the guidelines for Phase III awards.

Additional details, including specific submission dates and how to apply for the Phase II-E, will be provided no later than the 15th month of the performance of the Phase II contract. Select applicants will also be notified on when they can submit their application packages and will have a period of 2 weeks to get them submitted. Application packages will not be accepted before or after the notified 2-week submission period.

Phase III: NASA may award Phase III contracts for products or services with non-SBIR/STTR funds. The competition for SBIR/STTR Phase I and Phase II awards satisfies any competition requirement of the Armed Services Procurement Act, the Federal Property and Administrative Services Act, and the Competition in Contracting Act. Therefore, an agency that wishes to fund a Phase III project is not required to conduct another competition in order to satisfy those statutory provisions. Phase III work may be for products, production, services, R/R&D, or any combination thereof that is derived from, extends, or logically concludes efforts performed under prior SBIR/STTR funding agreements. A Federal agency may enter into a Phase III agreement at any time with a Phase I or Phase II awardee.

There is no limit on the number, duration, type, or dollar value of Phase III awards made to a business concern. There is no limit on the time that may elapse between a Phase I or Phase II and a Phase III award. The small business size limits for Phase I and Phase II awards do not apply to Phase III awards.

1.5 Eligibility Requirements

1.5.1 Small Business Concern

Only firms qualifying as SBCs, as defined in Section 2.19, are eligible to participate in these programs. Socially and economically disadvantaged and women-owned SBCs are particularly encouraged to propose.

1.5.2 Place of Performance

R/R&D must be performed in the United States (Section 2.24). However, based on a rare and unique circumstance (for example, if a supply or material or other item or project requirement is not available in the United States), NASA may allow a particular portion of the research or R&D work to be performed or obtained in a country outside of the United States. Proposals must clearly indicate if any work will be performed outside the United States. Prior to award, approval by the Contracting Officer for such specific condition(s) must be in writing.

Note: Offerors are responsible for ensuring that all employees who will work on this contract are eligible under export control and International Traffic in Arms (ITAR) regulations. Any employee who is not a U.S. citizen or a permanent resident may be restricted from working on this contract if the technology is restricted under export control and ITAR regulations unless the prior approval of the Department of State or the Department of Commerce is obtained via a technical assistance agreement or an export license. Violations of these regulations can result in criminal or civil penalties.

1.5.3 Principal Investigator (PI)

The primary employment of the Principal Investigator (PI) shall be with the SBC under the SBIR Program, while under the STTR Program, either the SBC or RI shall employ the PI. Primary employment means that more than 50% of the PI's total employed time (including all concurrent employers, consulting, and self-employed time) is spent with the SBC or RI at time of award and during the entire period of performance. Primary employment with a small business concern precludes full-time employment at another organization. If the PI does not currently meet these primary employment requirements, then the offeror must explain how these requirements will be met if the proposal is selected for contract negotiations that may lead to an award. Co-PI's are not allowed.

Note: NASA considers a fulltime workweek to be nominally 40 hours and we consider 19.9-hour workweek elsewhere to be in conflict with this rule.

REQUIREMENTS	SBIR	STTR
Primary Employment	PI must be with the SBC	PI must be employed with the RI or SBC
Employment Certification	The offeror must certify in the proposal that the primary employment of the PI will be with the SBC at the time of award and during the conduct of the project.	The offeror must certify in the proposal that the primary employment of the PI will be with the SBC or the RI at the time of award and during the conduct of the project.
Co-Principal Investigators	Not Allowed	Not Allowed
Misrepresentation of Qualifications	Shall result in rejection of the proposal or termination of the contract	Shall result in rejection of the proposal or termination of the contract
Substitution of PIs	Shall receive advanced written approval from NASA	Shall receive advanced written approval from NASA

1.6 NASA SBIR"TAV" Subtopics

Subtopics listed in Section 9. (S3.05 and S3.08) of this solicitation have Technology Available (TAV) with NASA IP. Subtopics with the "TAV" designation address the objective of increasing the commercial application of innovations derived from Federal R&D. While NASA scientists and engineers conduct breakthrough research that leads to innovations, the range of NASA's effort does not extend to product development in any of its intramural research areas. Additional work is necessary to exploit these NASA technologies for either infusion or commercial viability and likely requires innovation on behalf of the private sector. However, NASA provides these technologies "as is" and makes no representation or guarantee that additional effort will result in infusion or commercial viability. As with all SBIR awards, these TAV subtopics are intended to cultivate innovation in the private sector and to identify a commercially promising NASA technology and the technological gaps that must be filled in order to transition it to the marketplace.

The NASA technologies identified in "TAV" subtopics are either protected by NASA-owned patents (NASA IP) or if not patented, are dedicated to the public domain. If a TAV subtopic cites a patent, a non-exclusive, royalty-free research license will be required to use the NASA IP during the SBIR performance period. If there is no patent cited, the technology is freely available for use without the need for any license.

> **Disclaimer**: TAV subtopics may include an offer to license NASA IP on a non-exclusive, royalty-free basis, for research use under the SBIR contract. When included in a TAV subtopic as an available technology, use of the NASA IP is strictly voluntary. Whether or not a firm uses NASA IP within their proposed effort will not in any way be a factor in the selection for award.

All offerors submitting proposals addressing TAV subtopic, citing NASA IP must submit a non-exclusive, royalty-free license application if the use of the NASA IP is desired. The NASA license application is available on the NASA SBIR website: http://sbir.gsfc.nasa.gov/SBIR/research_license_app.doc. Only those research license applications accompanying proposals that result in an SBIR award under this solicitation will be granted.

SBIR awards resulting from TAV subtopics that list NASA IP will include, as necessary, the grant of a non-exclusive research license to use the NASA IP under the SBIR contract awarded. SBIR offerors are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NASA IP will be granted unless an SBIR awardee applies for and receives such a license in accordance with the Federal patent licensing regulations at 37 CFR Part 404. Awardees with contracts for subtopics that identify specific

NASA IP will be given the opportunity to negotiate a non-exclusive commercialization license or if available, an exclusive commercialization license to the NASA IP.

An SBIR awardee that has been granted a non-exclusive, royalty-free research license to use NASA IP under the SBIR award may, if available and on a non-interference basis, also have to access NASA personnel knowledgeable about the NASA IP. For further information, see Section 5.7.6.

1.7 General Information

1.7.1 Solicitation Distribution

This 2011 SBIR/STTR Program Solicitation is available via the NASA SBIR/STTR Website (http://sbir.nasa.gov), SBCs are encouraged to check the website for program updates and information. Any updates or corrections to the Solicitation will be posted there. If the SBC has difficulty accessing the Solicitation, please contact the Help Desk (Section 1.7.2).

1.7.2 Means of Contacting NASA SBIR/STTR Program

(1) NASA SBIR/STTR Website: **http://sbir.nasa.gov**

(2) Help Desk: The NASA SBIR/STTR Help Desk can answer any questions regarding clarification of proposal instructions and any administrative matters. The Help Desk may be contacted by:

E-mail: sbir@reisys.com
Telephone: 301-937-0888 between 9:00 a.m.-5:00 p.m. (Mon.-Fri., Eastern Time)
Facsimile: 301-937-0204

The requestor must provide the name and telephone number of the person to contact, the organization name and address, and the specific questions or requests.

(3) NASA SBIR/STTR Program Manager: Specific information requests that could not be answered by the Help Desk should be mailed or e-mailed to:

Dr. Gary C. Jahns, Program Manager
NASA SBIR/STTR Program Management Office
MS 202A-3, Ames Research Center
Moffett Field, CA 94035-1000
Gary.C.Jahns@nasa.gov

1.7.3 Questions About This Solicitation

To ensure fairness, questions relating to the intent and/or content of research topics in this Solicitation cannot be addressed during the Phase I solicitation period. Only questions requesting clarification of proposal instructions and administrative matters will be addressed.

2. Definitions

2.1 Allocation of Rights Agreement

A written agreement negotiated between the Small Business Concern and the single, partnering Research Institution, allocating intellectual property rights and rights, if any, to carry out follow-on research, development, or commercialization.

2.2 Commercialization

Commercialization is a process of developing markets, producing and delivering products or services for sale (whether by the originating party or by others). As used here, commercialization includes both Government and non-Government markets.

2.3 Cooperative Research or Research and Development (R/R&D) Agreement

A financial assistance mechanism used when substantial Federal programmatic involvement with the awardee during performance is anticipated by the issuing agency. The Cooperative R/R&D Agreement contains the responsibilities and respective obligations of the parties.

2.4 Cooperative Research or Research and Development (R/R&D)

For purposes of the NASA STTR Program, cooperative R/R&D is that which is to be conducted jointly by the SBC and the RI in which a minimum of 40 percent of the work (before any cost sharing or fee/profit proposed by the firm) is performed by the SBC and a minimum of 30 percent of the work is performed by the RI.

2.5 Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs)

To be an eligible EDWOSB, a company must:

(1) Be a WOSB that is at least 51% owned by one or more women who are “economically disadvantaged”. (2) Have one or more economically disadvantaged women manage the day-to-day operations, make long-term decisions for the business, hold the highest officer position in the business and work at the business full-time during normal working hours. A woman is presumed economically disadvantaged if she has a personal net worth of less than $700,000 (with some exclusions), her adjusted gross yearly income averaged over the three years preceding the certification less than $350,000, and the fair market value of all her assets is less than $6 million.

Please note that for both WOSB and EDWOSB, the 51% ownership must be unconditional and direct. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.6 Essentially Equivalent Work

The “scientific overlap,” which occurs when (1) substantially the same research is proposed for funding in more than one contract proposal or grant application submitted to the same Federal agency; (2) substantially the same research is submitted to two or more different Federal agencies for review and funding consideration; or (3) a specific research objective and the research design for accomplishing an objective are the same or closely related in two or more proposals or awards, regardless of the funding source.

2.7 Funding Agreement

Any contract, grant, cooperative agreement, or other funding transaction entered into between any Federal agency and any entity for the performance of experimental, developmental, research and development, services, or research work funded in whole or in part by the Federal Government.

2.8 Historically Underutilized Business Zone (HUBZone) Small Business Concern

A HUBZone small business concern means a small business concern that appears on the List of Qualified HUBZone Small Business Concerns maintained by the Small Business Administration. To see the full definition of a HUBzone see the FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html) or go to the SBA HUBzone site (www.sba.gov/hubzone) for more details.

2.9 Infusion

The integration of SBIR/STTR developed knowledge or technologies within NASA programs and projects, other Government agencies and/or commercial entities. This includes integration with NASA program and project funding, development and flight and ground demonstrations.

2.10 Innovation

An innovation is something new or improved, having marketable potential, including: (1) development of new technologies, (2) refinement of existing technologies, or (3) development of new applications for existing technologies.

2.11 Intellectual Property (IP)

The separate and distinct types of intangible property that are referred to collectively as "intellectual property," including but not limited to: patents, trademarks, copyrights, trade secrets, SBIR/STTR technical data (as defined in Section 2.16), ideas, designs, know-how, business, technical and research methods, other types of intangible business assets, and including all types of intangible assets either proposed or generated by the SBC as a result of its participation in the SBIR/STTR Program.

2.12 NASA Intellectual Property (NASA IP)

NASA IP is NASA-owned, patented technologies that NASA is offering under a non-exclusive, royalty-free research license for use under the SBIR award.

2.13 Principal Investigator (PI)

The one individual designated by the applicant to provide the scientific and technical direction to a project supported by the funding agreement.

2.14 Research Institution (RI)

A U.S. research institution is one that is: (1) a contractor-operated Federally funded research and development center, as identified by the National Science Foundation in accordance with the Government-wide Federal Acquisition Regulation issued in Section 35(c)(1) of the Office of Federal Procurement Policy Act (or any successor legislation thereto), or (2) a nonprofit research institution as defined in Section 4(5) of the Stevenson-Wydler Technology Innovation Act of 1980, or (3) a nonprofit college or university.

2.15 Research or Research and Development (R/R&D)

Creative work that is undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture, and society, and the use of this stock of knowledge to devise new applications. It includes administrative expenses for R&D. It excludes physical assets for R&D, such as R&D equipment and facilities. It also excludes routine product testing, quality control, mapping, collection of general-purpose statistics, experimental production, routine monitoring and evaluation of an operational program, and training of scientific and technical personnel.

> **Basic Research:** systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind. Basic research, however, may include activities with broad applications in mind.
>
> **Applied Research:** systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
>
> **Development:** systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

Note: NASA SBIR/STTR programs do not accept proposals solely directed towards system studies, market research, routine engineering development of existing products or proven concepts and modifications of existing products without substantive innovation (See Section 1.1).

2.16 SBIR/STTR Technical Data

Technical data includes all data generated in the performance of any SBIR/STTR funding agreement.

2.17 SBIR/STTR Technical Data Rights

The rights an SBC obtains for data generated in the performance of any SBIR/STTR funding agreement that an awardee delivers to the Government during or upon completion of a federally funded project, and to which the Government receives a license.

2.18 Service Disabled Veteran-Owned Small Business

A Service-Disabled Veteran-Owned Small Business is one that is: (1) Not less than 51% of which is owned by one or more service-disabled veterans or, in the case of any publicly owned business, not less than 51% of the stock of which is owned by one or more service-disabled veterans; (2) management and daily business operations, which are controlled by one or more service-disabled veterans or, in the case of a service-disabled veteran with permanent and severe disability, the spouse or permanent caregiver of such veteran; and (3) is small as defined by e-CFR §125.11.

Service-disabled veteran means a veteran, as defined in 38 U.S.C. 101(2), with a disability that is service connected, as defined in 38 U.S.C. 101(16). For a general definition, see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.19 Small Business Concern (SBC)

An SBC is one that, at the time of award of Phase I and Phase II funding agreements, meets the following criteria:

(1) Is organized for profit, with a place of business located in the United States, which operates primarily within the United States or which makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor;

(2) is in the legal form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust or cooperative; except that where the form is a joint venture, there can be no more than 49 percent participation by business entities in the joint venture;
(3) is at least 51 percent owned and controlled by one or more individuals who are citizens of, or permanent resident aliens in, the United States: except in the case of a joint venture, where each entity to the venture must be 51 percent owned and controlled by one or more individuals who are citizens of, or permanent resident aliens in, the United States; and
(4) has, including its affiliates, not more than 500 employees.

The terms “affiliates” and “number of employees” are defined in greater detail in 13 CFR Part 121. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.20 Socially and Economically Disadvantaged Individual

A socially and economically disadvantaged individual is defined as a member of any of the following groups: Black Americans, Hispanic Americans, Hawaiian Natives, Alaskan Natives, Native Americans, Asian- Pacific Americans, Subcontinent Asian Americans, or any other individual found to be socially and economically disadvantaged by the Small Business Administration (SBA) pursuant to Section 8(a) of the Small Business Act, 15 U.S. Code (U.S.C.) 637(a).

Economically disadvantaged individuals are socially disadvantaged and their ability to compete in the free enterprise system has been impaired due to diminished capital and credit opportunities, as compared to others in the same or similar line of business who are not socially disadvantaged.

2.21 Socially and Economically Disadvantaged Small Business Concern

A socially and economically disadvantaged small business concern is one that is at least 51% owned and controlled by one or more socially and economically disadvantaged individuals, or an Indian tribe, including Alaska Native Corporations (ANCs), a Native Hawaiian Organization (NHO), or a Community Development Corporation (CDC). Control includes both the strategic planning (as that exercised by boards of directors) and the day-to-day management and administration of business operations. See 13 CFR 124.109, 124.110, and 124.111 for special rules pertaining to concerns owned by Indian tribes (including ANCs), NHOs, or CDCs, respectively. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.22 Subcontract

Any agreement, other than one involving an employer-employee relationship, entered into by an awardee of a funding agreement calling for supplies or services for the performance of the original funding agreement.

2.23 Technology Readiness Level (TRLs)

Technology Readiness Level (TRLs) is a uni-dimensional scale used to provide a measure of technology maturity.

Level 1: Basic principles observed and reported.
Level 2: Technology concept and/or application formulated.
Level 3: Analytical and experimental critical function and/or characteristic proof of concept.
Level 4: Component and/or breadboard validation in laboratory environment.
Level 5: Component and/or breadboard validation in relevant environment.
Level 6: System/subsystem model or prototype demonstration in a relevant environment (Ground or Space).
Level 7: System prototype demonstration in an operational (space) environment.
Level 8: Actual system completed and (flight) qualified through test and demonstration (Ground and Space).
Level 9: Actual system (flight) proven through successful mission operations.

Additional information on TRLs is available in Appendix B.

2.24 United States

Includes the 50 States, the territories and possessions of the Federal Government, the Commonwealth of Puerto Rico, the District of Columbia, the Republic of the Marshall Islands, the Federated States of Micronesia, and the Republic of Palau.

2.25 Veteran-Owned Small Business

A veteran-owned SBC is a small business that: (1) is at least 51% unconditionally owned by one or more veterans, as defined at 38 U.S.C. 101(2); or in the case of any publicly owned business, at least 51% of the stock of which is unconditionally owned by one or more veterans; and (2) whose management and daily business operations are controlled by one or more veterans. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.26 Women-Owned Small Business

To be an eligible WOSB, a company must: (1) be a small business that is at least 51% percent unconditionally and directly owned and controlled by one or more women who are United States citizens. (2) have one or more women who manage the day-to-day operations, make long-term decisions for the business, hold the highest officer position in the business and work at the business full-time during normal working hours.

Please note that for a WOSB the 51% ownership must be unconditional and direct. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

3. Proposal Preparation Instructions and Requirements

3.1 Fundamental Considerations

Multiple Proposal Submissions
Each proposal submitted must be based on a unique innovation, must be limited in scope to just one subtopic and shall be submitted only under that one subtopic within each program. An offeror shall not submit more than 10 proposals to each of the SBIR or STTR programs, and may submit more than one unique proposal to the same subtopic; however, an offeror should not submit the same (or substantially equivalent) proposal to more than one subtopic. *Submitting substantially equivalent proposals to several subtopics may result in the rejection of all such proposals.* In order to enhance SBC participation, NASA does not plan to select more than 5 SBIR proposals and 2 STTR proposals from any one offeror.

STTR: All Phase I proposals must provide sufficient information to convince NASA that the proposed SBC/RI cooperative effort represents a sound approach for converting technical information resident at the Research Institution (RI) into a product or service that meets a need described in a Solicitation research topic. SBCs shall submit a cooperative research agreement with a Research Institution.

Contract Deliverables
All Phase I contracts shall require the delivery of reports that present: (1) the work and results accomplished; (2) the scientific, technical and commercial merit and feasibility of the proposed innovation, and Phase I results; (3) its relevance and significance to one or more NASA needs (Section 9); and (4) the strategy for development, transition of the proposed innovation, and Phase I results into products and services for NASA mission programs and other potential customers. Phase I deliverables may also include the demonstration of the proposed innovation and/or the delivery of a prototype or test unit, product or service for NASA testing and utilization. See section 5.2 for gaining access to the Electronic Handbook (EHB) and submitting reports.

Report deliverables shall be submitted electronically via the Electronic Handbook (EHB). NASA requests the submission of report deliverables in PDF format. Other acceptable formats are MS Word, MS Works, and WordPerfect.

3.2 Phase I Proposal Requirements

3.2.1 General Requirements

A competitive proposal will clearly and concisely: (1) describe the proposed innovation relative to the state of the art; (2) address the scientific, technical and commercial merit and feasibility of the proposed innovation, and its relevance and significance to NASA needs as described in Section 9: and (3) provide a preliminary strategy that addresses key technical, market and business factors pertinent to the successful development, demonstration of the proposed innovation, and its transition into products and services for NASA mission programs and other potential customers.

3.2.2 Format Requirements

Proposals that do not follow the formatting requirement are subject to rejection during administrative screening.

Page Limitations and Margins
Any page(s) going over the required page limited will be deleted and omitted from the proposal review. A Phase I proposal shall not exceed a total of 25 standard 8 1/2 x 11 inch (21.6 x 27.9 cm) pages inclusive of the technical content and the required forms. Forms A, B, and C count as one page each, regardless of whether the

completed forms print as more than one page. Each page shall be numbered consecutively at the bottom. Margins shall be 1.0 inch (2.5 cm). All required items of information must be covered in the proposal and will count towards the total page count. The space allocated to each part of the technical content will depend on the project chosen and the offeror's approach.

Each proposal submitted must contain the following items in the order presented:

(1) Cover Sheet (Form A), electronically endorsed, counts as 1 page towards the 25-page limit;
(2) Proposal Summary (Form B), counts as 1 page towards the 25-page limit;
(3) Budget Summary (Form C), counts as 1 page towards the 25-page limit;
(4) Cooperative R/R&D Agreement between the SBC and RI **(STTR only)**, counts as 1 page towards the 25-page limit;
(5) Technical Content (11 parts in order as specified in Section 3.2.4, **not to exceed 22 pages for SBIR and 21 pages for STTR**), including all graphics, with a table of contents,
(6) Briefing Chart (not included in the 25-page limit and must not contain proprietary data).

Website references, product samples, videotapes, slides, or other ancillary items will not be considered during the review process. Offerors are requested not to use the entire 25-page allowance unless necessary.

Type Size
No type size smaller than 10 point shall be used for text or tables, except as legends on reduced drawings. Proposals prepared with smaller font sizes will be rejected without consideration.

Header/Footer Requirements
Header must include firm name, proposal number, and project title. Footer must include the page number and proprietary markings if applicable. Margins can be used for header/footer information.

Classified Information
NASA does not accept proposals that contain classified information.

3.2.3 Forms

This part of the submission is all done electronically, with each form counting as 1 page towards the 25-page limit and accounting for pages 1-3 of the proposal regardless of the length.

3.2.3.1 Cover Sheet (Form A)

A sample Cover Sheet form is provided in Section 8. The offeror shall provide complete information for each item and submit the form as required in Section 6. The proposal project title shall be concise and descriptive of the proposed effort. The title should not use acronyms or words like "Development of" or "Study of." The NASA research topic title must not be used as the proposal title. Form A counts as one page towards the 25-page limit.

Note: The Cover Sheet (Form A) is public information and may be disclosed. Do not include proprietary information on Form A.

3.2.3.2 Proposal Summary (Form B)

A sample Proposal Summary form is provided in Section 8. The offeror shall provide complete information for each item and submit Form B as required in Section 6. Form B counts as one page towards the 25-page limit.

Note: Proposal Summary (Form B), including the Technical Abstract, is public information and may be disclosed. Do not include proprietary information on Form B.

3.2.3.3 Budget Summary (Form C)

A sample of the Budget Summary form is provided in Section 8. The offeror shall complete the Budget Summary following the instructions provided with the sample form. The total requested funding for the Phase I effort shall not exceed $125,000. A text box is provided on the electronic budget form for additional explanation. Information shall be submitted to explain the offeror's plans for use of the requested funds to enable NASA to determine whether the proposed price is fair and reasonable. Form C counts as one page towards the 25-page limit.

Note: The Government is not responsible for any monies expended by the applicant before award of any contract.

3.2.4 Technical Content

This part of the submission shall not contain any budget data and must consist of all eleven (11) parts listed below in the given order. All eleven parts of the technical proposal must be numbered and titled. Parts that are not applicable must be included and marked "Not Applicable." A proposal omitting any part will be considered non-responsive to this Solicitation and will be rejected during administrative screening. The required table of contents is provided below:

Phase I Table of Contents

Part 1: Table of Contents……………………………………………………………………………Page 4
Part 2: Identification and Significance of the Innovation
Part 3: Technical Objectives
Part 4: Work Plan
Part 5: Related R/R&D
Part 6: Key Personnel and Bibliography of Directly Related Work
Part 7: Relationship with Phase II or Future R/R&D
Part 8: Facilities/Equipment
Part 9: Subcontracts and Consultants
Part 10: Potential Post Applications
Part 11: Essentially Equivalent and Duplicate Proposals and Awards

Part 1: Table of Contents

The technical content shall begin with a brief table of contents indicating the page numbers of each of the parts of the proposal and should start on page 4 because Forms A, B, and C account for pages 1-3.

Part 2: Identification and Significance of the Proposed Innovation

Succinctly describe:

(1) The proposed innovation;
(2) the relevance and significance of the proposed innovation to a need or needs, within a subtopic described in Section 9; and
(3) the proposed innovation relative to the state of the art.

Part 3: Technical Objectives

State the specific objectives of the Phase I R/R&D effort including the technical questions posed in the subtopic description that must be answered to determine the feasibility of the proposed innovation.

Note: All offerors submitting proposals addressing TAV subtopics that are planning to use NASA IP must describe their planned developments with the IP. The NASA Research License Application should be added as an attachment at the end of the proposal and will not count towards the page limit.

Part 4: Work Plan
Include a detailed description of the Phase I R/R&D plan to meet the technical objectives. The plan should indicate what will be done, where it will be done, and how the R/R&D will be carried out. Discuss in detail the methods planned to achieve each task or objective. Task descriptions, schedules, resource allocations, estimated task hours for each key personnel and planned accomplishments including project milestones shall be included.

STTR: In addition, the work plan will specifically address the percentage and type of work to be performed by the SBC and the RI. The plan will provide evidence that the SBC will exercise management direction and control of the performance of the STTR effort, including situations in which the PI may be an employee of the RI.

Part 5: Related R/R&D
Describe significant current and/or previous R/R&D that is directly related to the proposal including any conducted by the PI or by the offeror. Describe how it relates to the proposed effort and any planned coordination with outside sources. The offeror must persuade reviewers of his or her awareness of key recent R/R&D conducted by others in the specific subject area. As an option, the offer may use this section to include bibliographic references.

Part 6: Key Personnel and Bibliography of Directly Related Work
Identify key personnel involved in Phase I activities whose expertise and functions are essential to the success of the project. Provide bibliographic information including directly related education and experience.

The PI is considered key to the success of the effort and must make a substantial commitment to the project. The following requirements are applicable:

> **Functions:** The functions of the PI are: planning and directing the project; leading it technically and making substantial personal contributions during its implementation; serving as the primary contact with NASA on the project; and ensuring that the work proceeds according to contract agreements. Competent management of PI functions is essential to project success. The Phase I proposal shall describe the nature of the PI's activities and the amount of time that the PI will personally apply to the project. The amount of time the PI proposes to spend on the project must be acceptable to the Contracting Officer.
>
> **Qualifications:** The qualifications and capabilities of the proposed PI and the basis for PI selection are to be clearly presented in the proposal. NASA has the sole right to accept or reject a PI based on factors such as education, experience, demonstrated ability and competence, and any other evidence related to the specific assignment.
>
> **Eligibility:** This part shall also establish and confirm the eligibility of the PI, and indicate the extent to which other proposals recently submitted or planned for submission in 2011 and existing projects commit the time of the PI concurrently with this proposed activity. Any attempt to circumvent the restriction on PIs working more than half time for an academic or a nonprofit organization by substituting an ineligible PI will result in rejection of the proposal. However, for an STTR the PI can be primarily employed by either the SBC or the RI. Please see section 1.5.3 for further explanation.

Part 7: Relationship with Future R/R&D
State the anticipated results of the proposed R/R&D effort if the project is successful (through Phase I and Phase II). Discuss the significance of the Phase I effort in providing a foundation for the Phase II R/R&D effort and for follow-on development, application and commercialization efforts (Phase III).

Part 8: Facilities/Equipment
General: Describe available equipment and physical facilities necessary to carry out the proposed Phase I, projected Phase II, and Phase III efforts. Items of equipment or facilities to be purchased (as detailed in the cost proposal) shall be justified under this section.

Use of Government facilities or property: In accordance with the Federal Acquisition Regulations (FAR) Part 45, it is NASA's policy not to provide facilities (capital equipment, tooling, test and computer facilities, etc.) for the performance of work under SBIR/STTR contracts. Generally an SBC will furnish its own facilities to perform the proposed work on the contract. Government-wide SBIR and STTR policies restrict the use of any SBIR/STTR funds for the use of Government equipment and facilities. This does not preclude an SBC from utilizing a Government facility or Government equipment, but any charges for such use may not be paid for with SBIR/STTR funds (SBA SBIR Policy Directive, Section 9 (f) (3)). In rare and unique circumstances, SBA may issue a case-by-case waiver to this provision after review of an agency's written justification. NASA may not and cannot fund the use of the Federal facility or personnel for the SBIR/STTR project with NASA program or project money.

When a proposed project or product demonstration requires the use of unique Government facilities or equipment, but does not require funding from the SBIR/STTR programs, then the offeror must provide a letter from the Government agency that verifies the availability. Failure to provide the site manager's written authorization of use of Government property may invalidate any proposal selection.

When a proposed project or product demonstration requires the use of unique Government facilities or equipment to be funded by the SBIR/STTR programs, then the offeror must provide a) a letter from the SBC Official explaining why the SBIR/STTR research project requires the use of the Federal facility or personnel, including data that verifies the absence of non-Federal facilities or personnel capable of supporting the research effort, and b) a statement, signed by the appropriate Government official at the facility, verifying that it will be available for the required effort. Failure to provide this explanation and the site manager's written authorization of use may invalidate any proposal selection. Additionally, any proposer requiring the use of Government property or facilities must, within five (5) days of notification of selection for negotiations, provide to the NASA Shared Services Center Contracting Officer all required documentation, to include, an agreement by and between the Contractor and the appropriate Government facility, executed by the Government official authorized to approve such use. The Agreement must delineate the terms of use, associated costs, property and facility responsibilities and liabilities.

A waiver from the SBA is required before a proposer can use SBIR/STTR funds for Government equipment or facilities. Proposals requiring waivers must explain why the waiver is appropriate. NASA will provide this explanation to SBA during the Agency waiver process. NASA cannot guarantee that a waiver from this policy can be obtained from SBA.

Part 9: Subcontracts and Consultants
Subject to the restrictions set forth below**,** the SBC may establish business arrangements with other entities or individuals to participate in performance of the proposed R/R&D effort. The offeror must describe all subcontracting or other business arrangements, and identify the relevant organizations and/or individuals with whom arrangements are planned. The expertise to be provided by the entities must be described in detail, as well as the functions, services, and number of hours. Offerors are responsible for ensuring that all organizations and individuals proposed to be utilized are actually available for the time periods required. Subcontract costs should be documented in the subcontractor/consultant budget section in Form C. Subcontractors' and consultants' work has the same place of performance restrictions as stated in Section 1.5.2. The following restrictions apply to the use of subcontracts/consultants:

SBIR Phase I	STTR Phase I
The proposed subcontracted business arrangements must not exceed 33 percent of the research and/or analytical work (as determined by the total cost of the proposed subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any)	A minimum of 40 percent of the research or analytical work must be performed by the proposing SBC and 30 percent by the RI. The subcontracted business effort must not exceed 30 percent of the research and/or analytical work (as determined by the total cost of the subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort ((total contract price including cost sharing, if any, less profit if any).

Example: Total price to include profit - $99, 500
Profit - $3,000
Total price less profit - $99,500 - $3,000 = $96,500
Subcontractor cost - $29,500
G&A - 5%
G&A on subcontractor cost - $29,500 x 5% = $1,475
Subcontractor cost plus G&A - $29,500 + $1,475 = $30,975
Percentage of subcontracting effort – subcontractor cost plus G&A / total price less profit - $30,975/$96,500 = 32.1%

For an SBIR Phase I this is acceptable since it is below the limitation of 33%.
For an STTR Phase I this is unacceptable since it is above 30% limitation.

Part 10: Potential Post Applications (Commercialization)
The Phase I proposal shall (1) forecast the potential and targeted application(s) of the proposed innovation and associated products and services relative to NASA needs (infusion into NASA mission needs and projects) (Section 9), other Government agencies and commercial markets, (2) identify potential customers, and (3) provide an initial commercialization strategy that addresses key technical, market and business factors for the successful development, demonstration and utilization of the innovation and associated products and services. Commercialization encompasses the transition of technology into products and services for NASA mission programs, other Government agencies and non-Government markets.

Part 11a: Essentially Equivalent and Duplicate Proposals and Awards
WARNING – While it is permissible with proposal notification to submit identical proposals or proposals containing a significant amount of essentially equivalent work for consideration under numerous Federal program solicitations, it is unlawful to enter into funding agreements requiring essentially equivalent work. Offerors are at risk for submitting essentially equivalent proposals and therefore, are strongly encouraged to disclose these issues to the soliciting agency to resolve the matter prior to award. See Part 11b.

If an applicant elects to submit identical proposals or proposals containing a significant amount of essentially equivalent work under other Federal program solicitations, a statement must be included in each such proposal indicating:

1) The name and address of the agencies to which proposals were submitted or from which awards were received.
2) Date of proposal submission or date of award.
3) Title, number, and date of solicitations under which proposals were submitted or awards received.
4) The specific applicable research topics for each proposal submitted for award received.
5) Titles of research projects.
6) Name and title of principal investigator or project manager for each proposal submitted or award received.

A summary of essentially equivalent work information is also required on Form A.

Part 11b: Related Research and Development Proposals and Awards

All federal agencies have a mandate to reduce waste, fraud, and abuse in federally funded programs. The submission of essentially equivalent work and the acceptance of multiple awards for essentially equivalent work in the SBIR/STTR program has been identified as an area of abuse. SBIR/STTR funding agencies and the Office of the Inspector General are actively evaluating proposals and awards to eliminate this problem. Related research and development includes proposals and awards that do not meet the definition of "Essentially Equivalent Work" (see Section 2.6), but are related to the technology innovation in the proposal being submitted. Related research and development could be interpreted as essentially equivalent work by outside reviewers without additional information. Therefore, if you are submitting closely related proposals or your firm has closely related research and development that is currently or previously funded by NASA or other federal agencies, it is to your advantage to describe the relationships between this proposal and related efforts clearly delineating why this should not be considered an essentially equivalent work effort. These explanations should not be longer than one page, will not be included in the page count, and will not be part of the technical evaluation of the proposal.

3.2.5 Cooperative R/R&D Agreement (Applicable for STTR proposals only)

The Cooperative R/R&D Agreement (different from the Allocation of Rights Agreement, Section 2.1) is a single-page document electronically submitted and endorsed by the SBC and Research Institution (RI). A model agreement is provided, or firms can create their own custom agreement. The Cooperative R/R&D Agreement should be submitted as required in Section 6. This agreement counts as one page toward the 25-page limit.

3.2.6 Prior Awards Addendum

If the SBC has received more than 15 Phase II awards in the prior 5 fiscal years, submit name of awarding agency, date of award, funding agreement number, amount, topic or subtopic title, follow-on agreement amount, source, and date of commitment and current commercialization status for each Phase II. The addendum is not included in the 25-page limit and content should be limited to information requested above. An electronic form will be provided during the submissions process.

3.2.7 Phase III Awards Resulting From NASA SBIR/STTR Awards

If the SBC has received any Phase III awards resulting from work on any NASA SBIR or STTR awards, provide the related Phase I or Phase II contract number, name of Phase III awarding agency, date of award, funding agreement number, amount, project title, period of performance and current commercialization status for each award. This listing is not included in the 25-page limit and content should be limited to information requested above. An electronic form will be provided during the submissions process.

3.2.8 TAV Subtopic Application

If proposing to use a TAV application, then offeror must submit a NASA Research License Application described in Section 1.6 and describe the technical objectives in Part 3 of the proposal (see Section 3.2.4, Part 3). This application will not be counted against the 25-page limit.

3.2.9 Briefing Chart

A one-page briefing chart is required to assist in the ranking and advocacy of proposals prior to selection. It is not counted against the 25-page limit, and *must not* contain any proprietary data or ITAR restricted data. An example chart is provided in Appendix A. An electronic form will be provided during the submissions process.

3.2.10 Contractor Responsibility Information

No later then 10 days after the notification of selection for negotiations the offeror shall provide a signed statement from your financial institutions stating whether or not your firm is in good standing and how long you have been with the institution will be required. In addition the offeror shall provide three references with a point of contact, e-mail address, telephone number, contract/reference number. Firms must ensure that the information provided is current and accurate.

Note: Companies with Prior NASA SBIR/STTR Awards

NASA has instituted a comprehensive commercialization survey/data gathering process for companies with prior NASA SBIR/STTR awards. Information received from SBIR/STTR awardees completing the survey is kept confidential, and will not be made public except in broad aggregate, with no company-specific attribution. The commercialization metrics survey is a required part of the proposal submissions process and must be completed via the Proposal Submission Electronic Handbook.

3.2.11 Allocation of Rights Agreement (STTR awards only)

No more than 10 working days after the Selection Announcement for negotiation, the offeror should provide to the Contracting Officer, a completed **Allocation of Rights Agreement (ARA),** which has been signed by authorized representatives of the SBC, RI and subcontractors and consultants, as applicable. The ARA shall state the allocation of intellectual property rights with respect to the proposed STTR activity and planned follow-on research, development and/or commercialization. A sample ARA is available in Section 8 of this Solicitation.

In compliance with the SBA STTR Policy Directive 8.(c) (1) STTR proposers are notified that a completed Allocation of Rights Agreement (ARA), which has been signed by authorized representatives of the SBC, RI and subcontractors and consultants, as applicable is required to be completed and executed prior to commencement of work under the STTR program. The ARA shall state the allocation of intellectual property rights with respect to the proposed STTR activity and planned follow-on research, development and/or commercialization. The SBC must certify in all proposals that the agreement is satisfactory to the SBC.

4. Method of Selection and Evaluation Criteria

4.1 Phase I Proposals

All proposals will be evaluated and ranked on a competitive basis. Proposals will be initially screened to determine responsiveness. Proposals determined to be responsive to the administrative requirements of this Solicitation and having a reasonable potential of meeting a NASA need, as evidenced by the technical abstract included in the Proposal Summary (Form B), will be technically evaluated by NASA personnel to determine the most promising technical and scientific approaches. Each proposal will be reviewed on its own merit. NASA is under no obligation to fund any proposal or any specific number of proposals in a given topic. It also may elect to fund several or none of the proposed approaches to the same topic or subtopic.

4.1.1 Evaluation Process

Proposals shall provide all information needed for complete evaluation. Evaluators will not seek additional information. NASA scientists and engineers will perform evaluations. Also, qualified experts outside of NASA (including industry, academia, and other Government agencies) may assist in performing evaluations as required to determine or verify the merit of a proposal. Offerors should not assume that evaluators are acquainted with the firm, key individuals, or with any experiments or other information. Any pertinent references or publications should be noted in Part 5 of the technical proposal.

4.1.2 Phase I Evaluation Criteria

NASA intends to select for award those proposals offering the most advantageous technology to the Government and the SBIR/STTR Program. NASA will give primary consideration to the scientific and technical merit and feasibility of the proposal and its benefit to NASA. Each proposal will be evaluated and scored on its own merits using the factors described below:

Factor 1: Scientific/Technical Merit and Feasibility
The proposed R/R&D effort will be evaluated on whether it offers a clearly innovative and feasible technical approach to the described NASA problem area. Proposals must clearly demonstrate relevance to the subtopic as well as one or more NASA mission and/or programmatic needs. Specific objectives, approaches and plans for developing and verifying the innovation must demonstrate a clear understanding of the problem and the current state of the art. The degree of understanding and significance of the risks involved in the proposed innovation must be presented.

Factor 2: Experience, Qualifications and Facilities
The technical capabilities and experience of the PI, project manager, key personnel, staff, consultants and subcontractors, if any, are evaluated for consistency with the research effort and their degree of commitment and availability. The necessary instrumentation or facilities required must be shown to be adequate and any reliance on external sources, such as Government furnished equipment or facilities, addressed (Section 3.2.4).

Factor 3: Effectiveness of the Proposed Work Plan
The work plan will be reviewed for its comprehensiveness, effective use of available resources, labor distribution, and the proposed schedule for meeting the Phase I objectives. The methods planned to achieve each objective or task should be discussed in detail. The proposed path beyond Phase I for further development and infusion into a NASA mission or program will also be reviewed. Please see Factor 5 for price evaluation criteria.

STTR: The clear delineation of responsibilities of the SBC and RI for the success of the proposed cooperative R/R&D effort will be evaluated. The offeror must demonstrate the ability to organize for effective conversion of intellectual property into products and services of value to NASA and the commercial marketplace.

Factor 4. Commercial Potential and Feasibility
The proposal will be evaluated for the commercial potential and feasibility of the proposed innovation and associated products and services. The offeror's experience and record in technology commercialization, co-funding commitments from private or non-SBIR funding sources, existing and projected commitments for Phase III funding, investment, sales, licensing, and other indicators of commercial potential and feasibility will be considered along with the initial commercialization strategy for the innovation. Commercialization encompasses the infusion of innovative technology into products and services for NASA mission programs, other Government agencies and non-Government markets.

Factor 5. Price Reasonableness
The offeror's cost proposal will be evaluated for price reasonableness based on the information provided in Form C. NASA will comply with the FAR and NASA FAR Supplement (NFS) to evaluate the proposed price/cost to be fair and reasonable.

After completion of evaluation for price reasonableness and determination of responsibility the contracting officer shall submit a recommendation for award to the Source Selection Official.

Scoring of Factors and Weighting: Factors 1, 2, and 3 will be scored numerically with Factor 1 worth 50 percent and Factors 2 and 3 each worth 25 percent. The sum of the scores for Factors 1, 2, and 3 will comprise the Technical Merit score. The evaluation for Factor 4, Commercial Potential and Feasibility, will be in the form of an adjectival rating (Excellent, Very Good, Average, Below Average, Poor). For Phase I proposals, Technical Merit is more important than Commercial Merit. Factors 1 - 4 will be evaluated and used in the selection of proposals for negotiation. Factor 5 will be evaluated and used in the selection for award.

4.1.3 Selection

Proposals recommended for negotiations will be forwarded to the Program Management Office for analysis and presented to the Source Selection Official and Mission Directorate Representatives. The Source Selection Official has the final authority for choosing the specific proposals for contract negotiation. The selection decisions will consider the recommendations as well as overall NASA priorities, program balance and available funding. Each proposal selected for negotiation will be evaluated for cost/price reasonableness, the terms and conditions of the contract will be negotiated and a responsibility determination made. The contracting officer will advise the Source Selection Official on matters pertaining to cost reasonableness and responsibility. The Source Selection Official has the final authority for selecting the specific proposals for award.

The list of proposals selected for negotiation will be posted on the NASA SBIR/STTR Website (http://sbir.nasa.gov). All firms will receive a formal notification letter. A Contracting Officer will negotiate an appropriate contract to be signed by both parties before work begins.

4.2 Debriefing of Unsuccessful Offerors

After Phase I selections for negotiation have been announced, all unsuccessful offerors will be notified. Debriefings will be automatically e-mailed to the designated business official within 60 days of the selection announcement. If you have not received your debriefing by this time, contact the SBIR/STTR Program Support Office at sbir@reisys.com. Telephone requests for debriefings will not be accepted. Debriefings are not opportunities to reopen selection decisions. They are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal in order to help offerors identify constructive future action by the offeror. Debriefings will not disclose the identity of the proposal evaluators, proposal scores, the content of, or comparisons with other proposals.

5. Considerations

5.1 Awards

5.1.1 Availability of Funds

All Phase I awards are subject to availability of funds. NASA has no obligation to make any specific number of awards based on this Solicitation, and may elect to make several or no awards in any specific technical topic or subtopic.

SBIR	STTR
➢ Phase I contracts will be firm-fixed-price, for values not exceeding $125,000, and contractors will have up to 6 months to carry out their projects, prepare their final reports, and submit Phase II proposals.	➢ Phase I contracts will be firm-fixed-price, for values not exceeding $125,000, and contractors will have up to 12 months to carry out their projects, prepare their final reports, and submit Phase II proposals.

5.1.2 Contracting

To simplify contract award and reduce processing time, all contractors selected for Phase I contracts should ensure that:

(1) All information in your proposal is current, e.g., your address has not changed, the proposed PI is the same, etc.
(2) Your firm is registered in CCR and all information is current. NASA uses the CCR to populate its contract and payment systems; if the information in the CCR is not current your award and payments will be delayed.
(3) The representations and certifications in ORCA (Online Representations and Certifications Application) are current.
(4) The VETS 100 report submitted by your firm to the Department of Labor is current.
(5) Your firm HAS NOT proposed a Co-Principal Investigator.
(6) STTR awardees should execute their Allocation of Rights Agreement within 10 days of the Selection for Negotiation Announcement.
(7) Your firm has a timely response to all communications from the NSSC Contracting Officer.

From the time of proposal selection for negotiation until the award of a contract, all communications shall be submitted electronically to NSSC-SBIR-STTR@nasa.gov.

Note: Costs incurred prior to and in anticipation of award of a contract are entirely the risk of the contractor in the event that a contract is not subsequently awarded. A Selection for Negotiation Announcement is not to be misconstrued as an award notification to commence work.

5.2 Phase I Reporting

The technical reports are required as described in the contract and are to be provided to NASA. These reports shall document progress made on the project and activities required for completion. Periodic certification for payment will be required as stated in the contract. A final report must be submitted to NASA upon completion of the Phase I R/R&D effort in accordance with applicable contract provisions.

All reports are required to be submitted electronically via the EHB. Everyone with access to the NASA network will be required to use the NASA Account Management System (NAMS). This is the Agency's centralized system for requesting and maintaining accounts for NASA IT systems and applications. The system contains user account information, access requests, and account maintenance processes for NASA employees, contractors, and remote users such as educators and foreign users. A basic background check is required for this account.

5.3 Payment Schedule for Phase I

All NASA SBIR and STTR contracts are firm-fixed-price contracts. The exact payment terms for Phase I will be included in the contract. Financing arrangements are normally as follows: $30,000.00 at 30 days after award, $30,000.00 at project mid-point, and the remainder upon acceptance of the final report, new technology report and any other deliverables by NASA.

Invoices: All invoices are required to be submitted electronically via the SBIR/STTR website in the EHB.

5.4 Release of Proposal Information

In submitting a proposal, the offeror agrees to permit the Government to disclose publicly the information contained on the Proposal Cover (Form A) and the Proposal Summary (Form B). Other proposal data is considered to be the property of the offeror, and NASA will protect it from public disclosure to the extent permitted by law including the Freedom of Information Act (FOIA).

5.5 Access to Proprietary Data by Non-NASA Personnel

5.5.1 Non-NASA Reviewers

In addition to Government personnel, NASA, at its discretion and in accordance with 1815.207-71 of the NASA FAR Supplement, may utilize qualified individuals from outside the Government in the proposal review process. Any decision to obtain an outside evaluation shall take into consideration requirements for the avoidance of organizational or personal conflicts of interest and the competitive relationship, if any, between the prospective contractor or subcontractor(s) and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

5.5.2 Non-NASA Access to Confidential Business Information

In the conduct of proposal processing and potential contract administration, the Agency may find it necessary to provide proposal access to other NASA contractor and subcontractor personnel. NASA will provide access to such data only under contracts that contain an appropriate NFS 1852.237-72 Access to Sensitive Information clause that requires the contractors to fully protect the information from unauthorized use or disclosure.

5.6 Proprietary Information in the Proposal Submission

If proprietary information is provided by an applicant in a proposal, which constitutes a trade secret, proprietary commercial or financial information, confidential personal information or data affecting the national security, it will be treated in confidence to the extent permitted by law. This information must be clearly marked by the applicant as confidential proprietary information. NASA will treat in confidence pages listed as proprietary in the following legend that appears on Cover Sheet (Form A) of the proposal:

"This data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal, provided that a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ____ of this proposal."

Note: Do not label the entire proposal proprietary. The Proposal Cover (Form A), the Proposal Summary (Form B), and the Briefing Chart should not contain proprietary information**;** and any page numbers that would correspond to these must not be designated proprietary in Form A.

Information contained in unsuccessful proposals will remain the property of the applicant. The Government will, however, retain copies of all proposals.

5.7 Limited Rights Information and Data

The clause at FAR 52.227-20, Rights in Data—SBIR/STTR Program, governs rights to data used in, or first produced under, any Phase I or Phase II contract. The following is a brief description of FAR 52.227-20, it is not intended to supplement or replace the FAR.

5.7.1 Non-Proprietary Data

Some data of a general nature are to be furnished to NASA without restriction (i.e., with unlimited rights) and may be published by NASA. This data will normally be limited to the project summaries accompanying any periodic progress reports and the final reports required to be submitted. The requirement will be specifically set forth in any contract resulting from this Solicitation.

5.7.2 Proprietary Data

When data that is required to be delivered under an SBIR/STTR contract qualifies as “proprietary,” i.e., either data developed at private expense that embody trade secrets or are commercial or financial and confidential or privileged, or computer software developed at private expense that is a trade secret, the contractor, if the contractor desires to continue protection of such proprietary data, shall not deliver such data to the Government, but instead shall deliver form, fit, and function data.

5.7.3 Non-Disclosure Period

For a period of 4 years after acceptance of all items to be delivered under an SBIR /STTR contract, the Government agrees to use these data for Government purposes only and they shall not be disclosed outside the Government (including disclosure for procurement purposes) during such period without permission of the Contractor, except that subject to the foregoing use and disclosure prohibitions, such data may be disclosed for use by support Contractors. After the aforesaid 4-year period, the Government has a royalty-free license to use, and to authorize others to use on its behalf, these data for Government purposes, but is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of these data by third parties.

5.7.4 Copyrights

Subject to certain licenses granted by the contractor to the Government, the contractor receives copyright to any data first produced by the contractor in the performance of an SBIR/STTR contract.

5.7.5 Invention Reporting, Election of Title and Patent Application Filing

NASA SBIR and STTR contracts will include FAR 52.227-11 Patent Rights – Ownership by the Contractor, which requires the SBIR/STTR contractors to do the following. Contractors must disclose all subject inventions to NASA within two (2) months of the inventor’s report to the awardees. A subject invention is any invention or discovery which is or may be patentable, and is conceived or first actually reduced to practice in the performance of the contract. Once the contractor discloses a subject invention, the contractor has up to 2 years to notify the Government whether it elects to retain title to the subject invention. If the contractor elects to retain title, a patent application covering the subject invention must be filed within 1 year. If the contractor fails to do any of these within time specified periods, the Government has the right to obtain title. To the extent authorized by 35 USC 205, the Government will not make public any information disclosing such inventions, allowing the contractor the permissible time to file a patent.

The awardee may use whatever format is convenient to report inventions. NASA prefers that the awardee use either the electronic or paper version of NASA Form 1679, Disclosure of Invention and New Technology (Including Software), to report inventions. Both the electronic and paper versions of NASA Form 1679 may be accessed at the electronic New Technology Reporting Web site http://ntr.ndc.nasa.gov/. A New Technology Summary Report (NTSR) listing all inventions developed under the contract or certifying that no inventions were developed must be also be submitted. Both reports shall also be uploaded to the SBIR/STTR Electronic Handbook (EHB) at https://ehb8.gsfc.nasa.gov/contracts/public/firmHome.do

5.7.6 NASA-owned Patents (NASA IP)

SBIR awards on TAV subtopics in this Solicitation, will, upon submission of a NASA license application, include the grant of a non-exclusive, royalty-free research license to use the NASA IP, which are specifically identified within the subtopic being awarded. SBIR offerors are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NASA background invention is granted until an SBIR awardee applies for, negotiates and receives such a license. Awardees of solicited subtopics that identify specific NASA-owned patented background inventions will be given the opportunity to negotiate a non-exclusive or if available, an exclusive commercialization license to such background inventions. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 CFR Part 404.

5.8 Profit or Fee

Phase I contracts may include a reasonable profit. The reasonableness of proposed profit is determined by the Contracting Officer during contract negotiations. Reference FAR 15.404-4.

5.9 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as an SBC in accordance with the definition in Section 2.19. A statement of how the workload will be distributed, managed, and charged should be included in the proposal. A copy or comprehensive summary of the joint venture agreement or partnership agreement should be appended to the proposal. This will not count as part of the 25-page limit for the Phase I proposal.

5.10 Essentially Equivalent Awards and Prior Work

If an award is made pursuant to a proposal submitted under either SBIR or STTR Solicitations, the firm will be required to certify that it has not previously been paid nor is currently being paid for essentially equivalent work by any agency of the Federal Government. Failure to report essentially equivalent or duplicate efforts can lead to the termination of contracts or civil or criminal penalties.

5.11 Contractor Commitments

Upon award of a contract, the contractor will be required to make certain legal commitments through acceptance of numerous clauses in the Phase I contract. The outline of this section illustrates the types of clauses that will be included. This is not a complete list of clauses to be included in Phase I contracts, nor does it contain specific wording of these clauses. Copies of complete provisions will be made available prior to contract negotiations.

5.11.1 Standards of Work

Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.

5.11.2 52.246-9 Inspection of Research and Development (Short Form)

Work performed under the contract is subject to Government inspection and evaluation at all reasonable times.

5.11.3 52.213-4 Term and Conditions – Simplified Acquisition (Other Than Commercial Items) and 52.249-9 Default (Firm-fixed-price Research and Development)

The Government may terminate the contract if the contractor fails to perform the contracted work.

5.11.4 52.213-4 Term and Conditions – Simplified Acquisition (Other Than Commercial Items) 52.249-2, Termination for Convenience of the Government (Firm-fixed-Price)

The contract may be terminated by the Government at any time if it deems termination to be in its best interest, in which case the contractor will be compensated for work performed and for reasonable termination costs.

5.11.5 52.233-1 Disputes

Any disputes concerning the contract that cannot be resolved by mutual agreement shall be decided by the Contracting Officer with right of appeal.

5.11.6 52.222-26 Equal Opportunity for Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

The contractor will not discriminate against any employee or applicant for employment because of race, color, religion, age, sex, or national origin.

5.11.7 52.222-35 Equal Opportunity for Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.

5.11.8 52.225-1 Buy American Act-Supplies

Congress intends that the awardee of a funding agreement under the SBIR/STTR Program should, when purchasing any equipment or a product with funds provided through the funding agreement, purchase only American-made equipment and products, to the extent possible, in keeping with the overall purposes of this program.

5.11.9 1852.225-70 Export Licenses

The contractor shall comply with all U.S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR). Offerors are responsible for ensuring that all employees who will work on this contract are eligible under export control and International Traffic in Arms (ITAR) regulations. Any employee who is not a U.S. citizen or a permanent resident may be restricted from working on this contract if the technology is restricted under export control and ITAR regulations unless the prior approval of the Department of State or the Department of Commerce is obtained via a technical assistance agreement or an export license. Violations of these regulations can result in criminal or civil penalties. For further information on ITAR visit http://www.pmddtc.state.gov/regulations_laws/itar.html. For additional assistance, refer to http://sbir.gsfc.nasa.gov/SBIR/export_control.html or contact the ARC export control administrator, Mary Williams, at mary.p.williams@nasa.gov.

5.11.10 Government Furnished and Contractor Acquired Property

Title to property furnished by the Government or acquired with Government funds will be vested with the NASA, unless it is determined that transfer of title to the contractor would be more cost effective than recovery of the equipment by NASA.

5.12 Additional Information

5.12.1 Precedence of Contract Over Solicitation

This Program Solicitation reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR/STTR contract, the terms of the contract are controlling.

5.12.2 Evidence of Contractor Responsibility

In addition to the information required to be submitted in Section 3.2.10, before award of an SBIR or STTR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to establish responsibility of the offeror. Contractor responsibility includes all resources required for contractor performance, i.e., financial capability, work force, and facilities.

5.13 Required Registrations and Submissions

5.13.1 Central Contractor Registration

Offerors should be aware of the requirement to register in the Central Contractor Registration (CCR) database prior to contract award. **To avoid a potential delay in contract award, offerors are required to register prior to submitting a proposal. Additionally, firms must certify the NAICS code of 541712.**

The CCR database is the primary repository for contractor information required for the conduct of business with NASA. It is maintained by the Department of Defense. To be registered in the CCR database, all mandatory information, which includes the DUNS or DUNS+4 number, and a CAGE code, must be validated in the CCR system. The DUNS number or Data Universal Number System is a 9-digit number assigned by Dun and Bradstreet Information Services (http://www.dnb.com) to identify unique business entities. The DUNS+4 is similar, but includes a 4-digit suffix that may be assigned by a parent (controlling) business concern. The CAGE code or Commercial Government and Entity Code is assigned by the Defense Logistics Information Service (DLIS) to identify a commercial or Government entity. If an SBC does not have a CAGE code, one will be assigned during the CCR registration process.

The DoD has established a goal of registering an applicant in the CCR database within 48 hours after receipt of a complete and accurate application via the Internet. However, registration of an applicant submitting an application through a method other than the Internet may take up to 30 days. Therefore, offerors that are not registered should consider applying for registration immediately upon receipt of this solicitation. Offerors and contractors may obtain information on CCR registration and annual confirmation requirements via the Internet at http://www.ccr.gov or by calling 888-CCR-2423 (888-227-2423).

5.13.2 52.204-8 Annual Representations and Certifications

Offerors should be aware of the requirement that the Representation and Certifications required from Government contractors must be completed through the Online Representations and Certifications Application (ORCA) website https://orca.bpn.gov/login.aspx. FAC 01-26 implements the final rule for this directive and requires that all offerors provide representations and certifications electronically via the BPN website; to update the representations and certifications as necessary, but at least annually, to keep them current, accurate and complete. NASA will not enter into any contract wherein the Contractor is not compliant with the requirements stipulated herein.

5.13.3 52.222-37 Employment Reports on Special Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

In accordance with Title 38, United States Code, Section 4212(d), the U.S. Department of Labor (DOL), Veterans' Employment and Training Service (VETS) collects and compiles data on the Federal Contractor Program Veterans' Employment Report (VETS-100 Report) from Federal contractors and subcontractors who receive Federal contracts that meet the threshold amount of $100,000.00. The VETS-100 reporting cycle begins annually on August 1 and ends September 30. Any federal contractor or prospective contractor that has been awarded or will be awarded a federal contract with a value of $100,000.00 or greater must have a current VETS 100 report on file. Please visit the DOL VETS 100 website at http://www.dol.gov/vets/programs/fcp/main.htm. NASA will not enter into any contract wherein the firm is not compliant with the requirements stipulated herein.

5.13.4 Software Development Standards

Offerors proposing projects involving the development of software should comply with the requirements of NASA Procedural Requirements (NPR) 7150.2, “NASA Software Engineering Requirements” are available online at http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7150&s=2.

5.13.5 Human and/or Animal Subject

Due to the complexity of the approval process, use of human and/or animal subjects is not recommended during a Phase I and may significantly delay contract award for possible award.

Offerors should be aware of the requirement that an approved protocol by a NASA Review Board is required if the proposed work include human or animal subject. An approved protocol shall be provided to the Contracting Officer before an award can be made. Offerors shall identify the use of human or animal subject on Form A. For additional information, contact the NASA SBIR/STTR Program Management Office at ARC-SBIR-PMO@mail.nasa.gov. Reference 14 CFR 1230 and 1232.

5.13.6 Toxic Chemical

Submission of this certification is a prerequisite for making or entering into this contract imposed by Executive Order 12969, August 8, 1995. Offerors shall identify the use of toxic chemical(s) on Form A. Reference FAR 52.223-13 Certification of Toxic Chemical Release Reporting.

5.13.7 Hazardous Materials

Offerors must list any hazardous material to be delivered under this contract. The apparently successful offeror agrees to submit, for each item as required prior to award, a Material Safety Data Sheet, meeting the requirements of 29 CFR 1910.1200(g) and the latest version of Federal Standard No. 313, for all hazardous material identified in paragraph (b) of this clause. Data shall be submitted in accordance with Federal Standard No. 313, whether or not the apparently successful offeror is the actual manufacturer of these items. Failure to submit the Material Safety Data Sheet prior to award may result in the apparently successful offeror being considered non-responsible and ineligible for award. Offerors shall identify the use of hazardous materials on Form A. Reference FAR 52.223-3 Hazardous Material identification and Material Safety Identification.

5.13.8 HSPD-12

Firms that require access to federally controlled facilities for six consecutive months or more must adhere to the following:

PIV Card Issuance Procedures in accordance with FAR clause 52.204-9 Personal Identity Verification of Contractor Personnel

Purpose: To establish procedures to ensure that recipients of contracts are subject to essentially the same credentialing requirements as Federal Employees when performance requires physical access to a federally-controlled facility or access to a Federal information system **for six consecutive months or more**. (Federally - controlled facilities and Federal information system are defined in FAR 2.101(b)(2)).

Background: Homeland Security Presidential Directive 12 (HSPD-12), "Policy for a Common Identification Standard for Federal Employees and Contractors", and Federal Information Processing Standards Publication (FIPS PUB) Number 201, "Personal Identity Verification (PIV) of Federal Employees and Contractors" require agencies to establish and implement procedures to create and use a Government-wide secure and reliable form of identification NLT October 27, 2005. See: http://csrc.nist.gov/publications/fips/fips201-1/FIPS-201-1-chng1.pdf. In accordance with the FAR clause 52.204-9 Personal Identity Verification of Contractor Personnel which states in parts contractor shall comply with the requirements of this clause and shall ensure that individuals needing such access shall provide the personal background and biographical information requested by NASA.

If applicable, detailed procedures for the issuance of a PIV credential can be found at the following URL: http://itcd.hq.nasa.gov/PIV.html.

5.14 False Statements

Knowingly and willfully making any false, fictitious, or fraudulent statements or representations may be a felony under the Federal Criminal False Statement Act (18 U.S.C. Sec 1001), punishable by a fine of up to $10,000, up to five years in prison, or both. The Office of the Inspector General has full access to all proposals submitted to NASA.

6. Submission of Proposals

6.1 Submission Requirements

NASA uses electronically supported business processes for the SBIR/STTR programs. An offeror must have Internet access and an e-mail address. Paper submissions are not accepted.

The Electronic Handbook (EHB) for submitting proposals is located at http://sbir.nasa.gov. The Proposal Submission EHB will guide the firms through the steps for submitting an SBIR/STTR proposal. All EHB submissions are through a secure connection. Communication between NASA's SBIR/STTR programs and the firm is primarily through a combination of EHBs and e-mail.

6.2 Submission Process

SBCs must register in the EHB to begin the submission process. It is recommended that the Business Official, or an authorized representative designated by the Business Official, be the first person to register for the SBC. The SBC's Employer Identification Number (EIN)/Taxpayer Identification Number is required during registration.

For successful proposal submission, SBCs must complete all three forms online, upload their technical proposal in an acceptable format, and have the Business Official electronically endorse the proposal. Electronic endorsement of the proposal is handled online with no additional software requirements. The term "technical proposal" refers to the part of the submission as described in Section 3.2.4.

STTR: The Research Institution is required to electronically endorse the Cooperative Agreement prior to the SBC endorsement of the completed proposal submission.

6.2.1 What Needs to Be Submitted

The entire proposal including Forms A, B, C, the briefing chart, and the commercialization metrics survey must be submitted/filled out via the Submissions EHB located on the NASA SBIR/STTR website. (Note: Other forms of submissions such as postal, paper, fax, diskette, or e-mail attachments are not acceptable).

(1) Forms A, B, and C are to be completed online.
(2) The technical proposal is uploaded from your computer via the Internet utilizing secure communication protocol.
(3) Firms must submit a briefing chart online, which is not included in the page count (See Sections 3.2.9).
(4) The commercialization metrics survey is required and to be completed online.

6.2.2 Technical Proposal Submissions

NASA converts all technical proposal files to PDF format for evaluation. Therefore, NASA requests that technical proposals be submitted in PDF format. Other acceptable formats are MS Works, MS Word, and WordPerfect. Note: Due to PDF difficulties with non-standard fonts, Unix and TeX users should output technical proposal files in DVI format.

Graphics
For reasons of space conservation and simplicity the offeror is encouraged, but not required, to embed graphics within the document. For graphics submitted as separate files, the acceptable file formats (and their respective extensions) are: Bit-Mapped (.bmp), Graphics Interchange Format (.gif), JPEG (.jpg), PC Paintbrush (.pcx), WordPerfect Graphic (.wpg), and Tagged-Image Format (.tif). Embedded animation or video will not be considered for evaluation.

Virus Check
The offeror is responsible for performing a virus check on each submitted technical proposal. As a standard part of entering the proposal into the processing system, NASA will scan each submitted electronic technical proposal for viruses. **The detection, by NASA, of a virus on any electronically submitted technical proposal, may cause rejection of the proposal.**

6.2.3 Technical Proposal Uploads

Firms will upload their proposals using the Submissions EHB. Directions will be provided to assist users. All transactions via the EHB are encrypted for security. Firms cannot submit security/password protected technical proposal and/or briefing chart files, as reviewers may not be able to open and read the files. An e-mail will be sent acknowledging each successful upload. An example is provided below:

Sample E-mail for Successful Upload of Technical Proposal

Subject: Successful Upload of Technical Proposal

Upload of Technical Document for your NASA SBIR/STTR Proposal No. __________

This message is to confirm the successful upload of your technical proposal document for:

Proposal No. ____________
(Uploaded File Name/Size/Date)

Please note that any previous uploads are no longer considered as part of your submission.

This e-mail is NOT A RECEIPT OF SUBMISSION of your entire proposal

IMPORTANT! The Business Official or an authorized representative must electronically endorse the proposal in the Electronic Handbook using the "Endorse Proposal" step. Upon endorsement, you will receive an e-mail that will be your official receipt of proposal submission.

Thank you for your participation in NASA's SBIR/STTR Program.

NASA SBIR/STTR Program Support Office

You may upload the technical proposal multiple times, with each new upload replacing the previous version, but only the final uploaded and electronically endorsed version will be considered for review.

6.3 Deadline for Phase I Proposal Receipt

All Phase I proposal submissions must be received no later than 5:00 p.m. EDT on Thursday, September 8, 2011, via the NASA SBIR/STTR Website (http://sbir.nasa.gov). The EHB will not be available for Internet submissions after this deadline. Any proposal received after that date and time shall be considered late and handled according to NASA FAR Supplement 1815.208.

6.4 Acknowledgment of Proposal Receipt

The final proposal submission includes successful completion of Form A (electronically endorsed by the SBC Official), Form B, Form C, the uploaded technical proposal, the and briefing chart. NASA will acknowledge receipt of electronically submitted proposals upon endorsement by the SBC Official to the SBC Official's e-mail address as provided on the proposal cover sheet. If a proposal acknowledgment is not received, the offeror should call NASA SBIR/STTR Program Support Office at 301-937-0888. An example is provided below:

Sample E-mail for Official Confirmation of Receipt of Full Proposal:

Subject: Official Receipt of your NASA SBIR/STTR Proposal No. _______________

Confirmation No. __________________

This message is to acknowledge electronic receipt of your NASA SBIR/STTR Proposal No. _______________.
Your proposal, including the forms and the technical document, has been received at the NASA SBIR/STTR Support Office.

SBIR/STTR 2011 Phase I xx.xx-xxxx (Title)
Form A completed on:
Form B completed on:
Form C completed on:
Technical Proposal Uploaded on:
File Name:
File Type:
File Size:
Briefing Chart completed on:
Proposal endorsed electronically by:

This is your official confirmation of receipt. Please save this email for your records, as no other receipt will be provided. The announcement for negotiation is currently scheduled for November 2011, and will be posted via the SBIR/STTR website (http://sbir.nasa.gov).

Thank you for your participation in the NASA SBIR/STTR program.

NASA SBIR/STTR Program Support Office

6.5 Withdrawal of Proposals

Prior to the close of submissions, proposals may be withdrawn via the Proposal Submission Electronic Handbook hosted on the NASA SBIR/STTR Website (http://sbir.nasa.gov). In order to withdraw a proposal after the deadline, the designated SBC Official must send written notification via email to sbir@reisys.com.

6.6 Service of Protests

Protests, as defined in Section 33.101 of the FAR, that are filed directly with an agency and copies of any protests that are filed with the General Accounting Office (GAO) shall be served on the Contracting Officer by obtaining written and dated acknowledgement of receipt from the NASA SBIR/STTR Program contact listed below:

Cassandra Williams
NASA Shared Services Center
Building 1111, C Road
Stennis Space Center, MS 39529
Cassandra.Williams-1@nasa.gov

The copy of any protest shall be received within one calendar day of filing a protest with the GAO.

7. Scientific and Technical Information Sources

7.1 NASA Websites

General sources relating to scientific and technical information at NASA is available via the following web sites:

NASA Budget Documents, Strategic Plans, and Performance Reports:
http://www.nasa.gov/about/budget/index.html
NASA Organizational Structure: http://www.nasa.gov/centers/hq/organization/index.html
NASA Office of the Chief Technologist (OCT): http://www.nasa.gov/offices/oct/home/index.html
NASA SBIR/STTR Programs: http://sbir.nasa.gov

7.2 United States Small Business Administration (SBA)

The Policy Directives for the SBIR/STTR Programs may be obtained from the following source. SBA information can also be obtained at: http://www.sba.gov.

U.S. Small Business Administration
Office of Technology – Mail Code 6470
409 Third Street, S.W.
Washington, DC 20416
Phone: 202-205-6450

7.3 National Technical Information Service

The National Technical Information Service is an agency of the Department of Commerce and is the Federal Government's largest central resource for Government-funded scientific, technical, engineering, and business related information. For information regarding their various services and fees, call or write:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 703-605-6000
URL: http://www.ntis.gov

8. Submission Forms and Certifications

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Firm Certifications

As defined in Section 2 of the Solicitation, the offeror qualifies as a:

a. Small Business Concern (SBC)	Yes	No
Number of employees: _____		
b. The firm is owned and operated in the United States	Yes	No
c. Socially and Economically Disadvantaged SBC	Yes	No
d. Woman-owned SBC	Yes	No
i) Economically Disadvantaged Women-owned SBC	Yes	No
e. HUBZone-owned SBC	Yes	No
f. Veteran-owned SBC	Yes	No
i) Service Disabled Veteran-owned SBC	Yes	No

Guidelines for Completing Firm Certifications

Firm level certifications that are applicable across all proposal submissions submitted to this Solicitation must be completed via the “Certifications” section of the Proposal Submission Electronic Handbook. The offeror must answer Yes or No as applicable.

Form A – SBIR Cover Sheet

Subtopic No.
Proposal Number: _ _ . _ _ - _ _ _ _
Topic Title:
Subtopic Title:
Proposal Title:

Firm Name:
Mailing Address:
City:
State/Zip:
Phone:
Fax:
EIN/Tax Id:

ACN (Authorized Contract Negotiator) Name:
ACN E-mail:
ACN Phone: Extension:
DUNS + 4:
Cage Code:
Amount Requested: $__________ (auto-populated upon completion of Budge Form C)
Duration: ____ months

OFFEROR CERTIFIES THAT:

As defined in Section 1.5.3 of the Solicitation, the offeror certifies:

a. During performance of the contract, the Principal Investigator is "primarily employed" by the organization as defined in the SBIR Solicitation Note: Co-PI is not acceptable. Yes No

As defined in Section 3.2.4 Part 11 of the Solicitation, indicate if:

b. Essentially equivalent work under this project has been submitted for other Federal funding Yes No

i) If yes, provide information on essentially equivalent proposal submissions below:

Proposal No.	Proposal Title	Date of Submission	Soliciting Agency	(Anticipated) Selection Announcement Date

c. Funding has been received for essentially equivalent work under this project by any other Federal grant, contract, or subcontract Yes No

As described in Section 3 of this solicitation, the offeror meets the following requirements completely:

d. All 11 parts of the technical proposal are included in part order and the page limitation is met	Yes	No
e. Subcontracts/consultants proposed?	Yes	No
i) If yes, does the proposal comply with the subcontractor/consultant limitation? (Section 3.2.4 Part 9)	Yes	No
f. Government equipment or facilities required?	Yes	No
i) If yes, is a signed statement of availability enclosed in Part 8?	Yes	No
ii) If yes, is a non-SBIR funding source identified in Part 8?	Yes	No

In accordance with Section 5.11.9 of the Solicitation as applicable:

g. The offeror understands and shall comply with export control regulations	Yes	No

In accordance with Section 5 of the Solicitation as applicable, indicate if any of the following will be used (must comply with federal regulations):

h. Human Subject	Yes	No
i. Animal Subject	Yes	No
j. Toxic Chemicals	Yes	No
k. Hazardous Materials	Yes	No

As referenced in Section 1.2 of the Solicitation, indicate if the R&D to be performed is related to:

l. Renewable Energy	Yes	No
m. Manufacturing	Yes	No

I understand that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

ENDORSEMENT:

Corporate/Business Official:
Name:
Title:
Phone:
E-mail

Endorsed by:
Date:

PROPRIETARY NOTICE (If Applicable, See Sections 5.5, 5.6)

NOTICE: This data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal, provided that a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages __________ of this proposal.

Note: Do not mark the entire proposal as proprietary. Forms A and B (pages 1 and 2 of your proposal submission) cannot contain proprietary data. (See Section 3.2.3 of the 2011 Solicitation)

Guidelines for Completing SBIR Cover Sheet

Complete Cover Sheet Form A electronically via the Proposal Submission Electronic Handbook.

Proposal Number: This number does not change. The proposal number consists of the four-digit subtopic number and four-digit system-generated number.

Topic Title: Select the topic that this proposal will address. Refer to Section 9 for topic descriptions.

Subtopic Title: Select the subtopic that this proposal will address. Refer to Section 9 for subtopic descriptions.

Proposal Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title. Avoid words like "development" and "study."

Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

Mailing Address: Must match CCR address and should be the address where mail is received.
City, State, Zip: City, 2-letter State designation (i.e. TX for Texas), 9-digit Zip code (i.e. 20705-3106)
Phone, Fax: Number including area code
EIN/Tax ID: Employer Identification Number/Taxpayer ID

ACN Name: Enter the name of the Authorized Contract Negotiator from your firm
ACN E-mail: Email address
ACN Phone, Ext.: Number including area code and extension (if applicable)

DUNS + 4: 9-digit Data Universal Number System; a 4-digit suffix is also required if owned by a parent concern. For information on obtaining a DUNS number go to http://www.dnb.com.

CAGE Code: Commercial Government and Entity Code that is issued by the Central Contractor Registration (CCR). For information on obtaining a CAGE Code, go to http://www.ccr.gov.

Amount Requested: Proposal amount auto-populated from Budget Summary. The amount requested should not exceed $125,000 (see Sections 1.4, 5.1.1).

Duration: Proposed duration in months. The requested duration should not exceed 6 months (see Sections 1.4, 5.1.1).

Certifications: Answer Yes or No as applicable for certifications a – m (see the referenced sections for definitions). Where applicable, SBCs should make sure that their certifications on Form A agree with the content of their technical proposal.

a. The Principal Investigator is required to be “primarily employed” by the organization as defined in Section 1.5.3 of the Solicitation.

b. If essentially equivalent work under this project has been submitted to other Federal Agencies/programs for funding, then the SBC must provide the proposal number, proposal title, date of submission, and soliciting agency. The selection announcement date should also be provided if known.

c. It is unlawful to enter into federally funded agreements requiring essentially equivalent work. By answering “No” the SBC confirms that work under this project has not been funded under any other Federal grant, contract or subcontract.

d. As stated in section 3.2 of the Solicitation, the technical proposal must not exceed the 25-page limitation and must consist of all eleven (11) required parts.

e. By answering “Yes”, the SBC certifies that subcontracts/consultants have been proposed and arrangements have been made to perform on the contract, if awarded.
   i) Proposed subcontractor/consultant business arrangements must not exceed 33 percent of the research and/or analytical work (as determined by the total cost of the proposed subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any). Refer to Section 3.2.4, Part 9 of the Solicitation.

f. By answering “Yes”, the SBC certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities. By answering “No”, the SBC certifies that no such Government Furnished Facilities or Government Furnished Equipment is required to perform the proposed activities. See Section 3.2.4 Part 8 of the Solicitation.
   i) If proposing to use Government Furnished Facilities or Equipment, a signed statement of availability must be included in Part 8 of the Technical Proposal that describes the uniqueness of the facility and its availability to the offeror at specified times, signed by the appropriate Government official.
   ii) If “Yes,” the SBC certifies that it has a confirmed, non-SBIR funding source for whatever charges may be incurred when utilizing the required Government facility. If “No,” a waiver from the SBA is required before a proposer can use SBIR/STTR funds for Government equipment or facilities. Proposals requiring waivers must explain why the waiver is appropriate.

g. Offerors are responsible for ensuring compliance with export control and International Traffic in Arms (ITAR) regulations. All employees who will work on this contract must be eligible under these regulations or the offeror must have in place a valid export license or technical assistance agreement. Violations of these regulations can result in criminal or civil penalties.

h-k. Offeror must indicate by answering “Yes” or “No” as applicable if human subjects, animal subjects, toxic chemicals and/or hazardous materials will be used. SBCs must be in compliance with federal regulations. See Sections 5.13.5, 5.13.6, and 5.13.7 of the Solicitation.

l. Answer “Yes” if this proposal has a connection to energy efficiency or alternative and renewable energy. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to energy efficiency or alternative and renewable energy. See Section 1.2 of the Solicitation.

m. Answer “Yes” if this proposal has a connection to manufacturing. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to manufacturing. See Section 1.2 of the Solicitation.

Electronic Endorsement:

Endorsement of the proposal by the Business Official certifies an understanding that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

Electronic endorsement is performed by the authorized Business Official from the “Endorsement” link located on the Activity Worksheet for each proposal. Electronic endorsement is the final step in the proposal submission process and can only be performed when all required sections of the proposal submission are complete.

Once endorsed, the name and date of endorsement will populate under the Endorsement section of the Cover Sheet Form A.

Form B – SBIR Proposal Summary

Subtopic No.
Proposal Number: __ __.__ __ - __ __ __ __
Subtopic Title:
Proposal Title:

Small Business Concern:
Name:
Address:
City/State/Zip:
Phone:

Principal Investigator/Project Manager:
Name:
Address:
City/State/Zip:
Phone: Extension:
E-mail:

Estimated Technology Readiness Level (TRL) at beginning and end of contract:
Begin: _____
End: _____

Technology Available (TAV) Subtopics: **(Applicable only for proposals submitted under S3.05 and S3.08)**

S3.05 or S3.08 is a Technology Available (TAV) subtopic that includes NASA Intellectual Property (IP).

Do you plan to use the NASA IP under the award? Yes No

If yes, click here to access the NASA Research License Application that must be completed and appended to your technical proposal.

Technical Abstract: (Limit 2,000 characters, approximately 200 words)

Potential NASA Application(s): (Limit 1,500 characters, approximately 150 words)

Potential Non-NASA Application(s): (Limit 1,500 characters, approximately 150 words)

Technology Taxonomy: (Select only the technologies relevant to this specific proposal)
NASA's technology taxonomy has been developed by the SBIR-STTR Program to disseminate awareness of proposed and awarded R/R&D in the agency. It is a listing of over 100 technologies, sorted into broad categories, of interest to NASA.

Guidelines for Completing SBIR Proposal Summary

Complete Proposal Summary Form B electronically via the Proposal Submission Electronic Handbook.

Proposal Number: Auto-populated with proposal number as shown on Cover Sheet.

Subtopic Title: Auto-populated with subtopic title as shown on Cover Sheet.

Proposal Title: Auto-populated with proposal title as shown on Cover Sheet.

Small Business Concern: Auto-populated with firm information as shown on Cover Sheet.

Principal Investigator/Project Manager: Enter the full name of the PI/PM and include all required contact information.

Technology Readiness Level (TRL): Provide the estimated Technology Readiness Level (TRL) at the beginning and end of the contract. See Section 2.23 and Appendix B for TRL definitions.

Technology Available (TAV) Subtopics: TAV subtopics S3.05 and S3.08 may include an offer to license NASA IP on a non-exclusive, royalty-free basis for research use under the SBIR award. When included in a TAV subtopic as an available technology, the use of the NASA IP is strictly voluntary. Refer to section 1.6 of the Solicitation.

Answer “Yes” only if the proposal is being submitted to subtopic S3.05 or S3.08 and includes NASA Intellectual Property (IP) planned for research use under the performance of the contract.

Technical Abstract: Summary of the offeror’s proposed project is limited to 2,000 characters, approximately 200 words, and shall summarize the implications of the approach and the anticipated results of the Phase I. NASA will reject a proposal if the technical abstract is determined to be non-responsive to the subtopic. **The abstract must not contain proprietary information and must describe the NASA need addressed by the proposed R/R&D effort.**

Potential NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Potential Non-NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Technology Taxonomy: Selections for the technology taxonomy are limited to technologies supported or relevant to the specific proposal. The listing of technologies for the taxonomy is provided in Appendix C.

Form C – SBIR Budget Summary

PROPOSAL NUMBER:
SMALL BUSINESS CONCERN:

(1) DIRECT LABOR:

Category	Description	Education	Years of Experience	Hours	Rate	Total
____________	____________________	__________	________	_____	_______	__________
____________	____________________	__________	________	_____	_______	__________
____________	____________________	__________	________	_____	_______	__________

TOTAL DIRECT LABOR:
(1) $ ____________

Are the labor rates fully loaded? Yes No
If yes, explain any costs that apply:

Comments:

Document uploaded for labor rate documentation: (file name)

(2) OVERHEAD COST;

______% of Total Direct Labor or $ ______

OVERHEAD COST:
(2) $ ____________

Comments:

Overhead Cost Sources:
____
____
____

(3) OTHER DIRECT COSTS (ODCs):

Materials:
- Description: ______________________________
- Vendor: __________________________________
- Quantity: __________ Cost: ______________
- Consumable: Yes No
- Competitively Sourced?: Yes No
- Used Exclusively for this Contract?: Yes No
- Supporting Comments: ____________________
- Supporting Documents: (file name)

Supplies:

Description: ______________________________

Vendor: _________________________________

Quantity: ___________ Cost: _______________

Consumable: Yes No

Competitively Sourced?: Yes No

Used Exclusively for this Contract?: Yes No

Supporting Comments: _____________________

Supporting Documents: (file name)

Equipment:

Description: ______________________________

Vendor: _________________________________

Quantity: ___________ Cost: _______________

Competitively Sourced?: Yes No

Used Exclusively for this Contract?: Yes No

Supporting Comments: _____________________

Supporting Documents: (file name)

Other:

Travel:

Location From: _______________ Location To: _______________

Number of People: _____________ Number of Days: ___________

Purpose of Trip: ____

Airfare: ____________________ Car Rental: ________________

Per Diem: __________________ Other Costs: _______________

Total Costs: _________________

Sources of Estimates: ____________________________________

Explanation/Justification: _________________________________

Explanation of ODCs:

Provide any additional information on the Other Direct Costs listed above, including the basis used for estimating the costs.

Subcontractor/Consultants:	Total Cost:
______________________________	_________________
______________________________	_________________
______________________________	_________________

(Note: Separate Budget Summaries completed for all proposed Subcontractors/Consultants via the Subcontractors/Consultants section of Form C)

TOTAL OTHER DIRECT COSTS:
(3) $ ____________

(1)+(2)+(3)=(4)

SUBTOTAL:
(4) $ ____________

(5) GENERAL & ADMINISTRATIVE (G&A) COSTS
______% of Subtotal or $ ______ G&A COSTS:

	(5)	$	____________

Comments:
If an audit rate is not available, provide a detailed explanation of the cost base used to develop the G&A rate and if possible, a historical actual G&A rate for the past three years.

G&A Cost Elements:
____
____
____

(4)+(5)=(6)	TOTAL COSTS (6)	$	____________
(7) ADD PROFIT or SUBTRACT COST SHARING (As applicable)	PROFIT/COST SHARING: (7)	$	____________

Comments:

(6)+(7)=(8)	AMOUNT REQUESTED: (8)	$	____________

GOVERNMENT FACILITIES OR EQUIPMENT:

If you require the use of a Government Facility or Equipment, identify it below as well as in Part 8 of your technical proposal. (See certification l on Form A)

AUDIT AGENCY:

If your company's accounting system has been audited, are the rates from that audit agreement used for this proposal?

__ The rates listed in the negotiated rate agreement were used to prepare the budget summary
__ Other rates were used to prepare the budget summary
__ My company’s accounting system has not been audited

If the listed rates are not being used to prepare the budget summary, please provide an explanation:

Guidelines for Preparing SBIR Budget Summary

Complete Budget Summary Form C electronically.

The offeror shall electronically submit a price proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting and estimating system.

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, in the text boxes or via uploads as indicated in the electronic form.

Offerors with questions about the appropriate classification of costs are advised to consult with an experienced accountant that has experience in government contracting and cost accounting principals. Information provided by the Defense Contract Audit Administration in their publication "Information for Contractors" may also be useful. This publication is available on-line at http://www.dcaa.mil/dcaap7641.90.pdf.

Firm: Same as Cover Sheet.

Proposal Number: Same as Cover Sheet.

Direct Labor: Select the appropriate labor category for each person who will be working directly on the proposed research effort and provide the labor description, level of education, years of experience, total number of hours, and labor rate. Detail the labor hours used for each year of the proposed research effort separately.

Indicate if the direct labor rates are fully loaded and, if yes, explain any costs that are included in the rate such as fringe benefits, etc. Provide the breakout rate such as the labor hour rate, health benefits, life insurance etc. Some examples of direct labor include Principal Investigator, Engineer, Scientist, Analyst or Research Assistant/Laboratory Assistant. All listed categories shall be directly related to proposed work to be performed under contract with NASA. Any contributions from non-technical personnel proposed under direct labor shall be explicitly explained. Labor rates that do not compare favorably to comparable state average rates at http://www.bls.gov require additional documentation, supporting the proposed rate or salary.

Note: Costs associated with company executives, accountants or administrative support are typically included in a company's general and administrative costs. If these costs are being proposed as direct labor then provide the details of how the proposed hours were allocated to this effort and verify that these costs are not also covered in your overhead or G&A rate.

Overhead Cost: Specify current rate and base. Use current rate(s) negotiated with your firm's cognizant Federal-auditing agency, if available. A rate that has not been audited requires a detailed explanation of the cost base used to develop the rate and if possible, historical actual overhead rates for the past three years.

Specify the cost elements of the company's overhead costs in the text boxes provided. Possible overhead cost elements include insurance, sick leave, and vacation.

Note: If no labor overhead rate is proposed and the proposed direct labor includes all fringe benefits, you may enter "0" for the overhead cost line.

Other Direct Costs (ODCs):
Refer to FAR 31.205 – Selected Costs for determination of cost allowability.

<u>Materials and Supplies:</u> Under the Materials and Supplies sections, indicate type, vendor, quantity required, and cost. Identify whether each item is consumable, which year it will be purchased, if it was competitively sourced, and

if it will be used exclusively for this contract. Your proposed cost shall be justified and supporting documents should be uploaded. General materials or supplies without adequate explanation of the components, quantity and use of said items are not an acceptable breakdown. In the supporting comments block, provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc…). The Contracting Officer will make the final determination.

Special Tooling, Testing, and Test Equipment: The need for these items, if proposed, will be carefully reviewed. Equipment must be made in the USA to the maximum extent practical. The offeror should provide competitive quotes to support the proposed costs or should justify why only one source is available. Competitive quotes may be signed quotes from vendors or copies of catalogue pages. Normally the costs of any equipment should be quoted on a purchase basis, unless the offeror can demonstrate that lease or rent of the equipment is clearly advantageous to the government. The Contracting Officer will make the final determination. Upload supporting documentation as necessary. In the supporting comments block provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc.). The Contracting Officer will make the final determination.

Travel: All proposed travel must be necessary for the success of the research. Include a detailed accounting of all proposed expenses to include the purpose of proposed trips, number of trips, travelers per trip, as well as meals, hotel, and rental car estimated costs. Sources of estimate should be identified when travel is proposed along with a justification for each trip. Proposed travel costs shall be in accordance with the Federal Travel Regulation http://www.gsa.gov/federaltravelregulation.

Subcontracts/Consultants: Subcontracts/Consultants costs are included in the Other Direct Costs total. A separate budget summary must be completed for each subcontract/consultant proposed. Further instructions are provided in the Subcontracts/Consultants section below.

Note: Do not add subcontractors or consultants as a line item under the ODCs section of Form C. It will automatically be added to the ODCs upon completion of the separate Subcontractor/Consultant budget summary form.

Other: List all other direct costs that are not otherwise included in the categories described above such as rental of facilities, etc…

Note: The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Firms should be prepared to justify all material, supplies, and equipment costs during negotiations. See section 3.2.4 Part 8 for further guidance.

Explanation of ODCs: Provide any additional information for the proposed ODCs, including basis for cost estimation, in the text box provided.

Subcontracts/Consultants: List consultants by name and specify, for each, the number of hours and hourly costs. Detailed quotes from subcontractors should be provided in the same format. Note that a subcontract entered into for performance of research or research and development differs from an arrangement with a vendor to provide a service such as machining, analysis with test equipment or use of computer time. The costs of such arrangements with vendors should be covered under Special Tooling, Testing, Test Equipment and Material or under Other Direct Costs. Upon request of the contracting officer, the subcontractor's cost proposals may be sealed or mailed directly for government eyes only.

A letter of commitment shall be uploaded for each proposed subcontractor/consultant from the Subcontractor/Consultant Letter of Commitment section of the subcontractor/consultant budget summary form. If a commitment letter is not available, you shall provide an explanation in the text box to include a point of contact and contact information in order for NASA to obtain the required document to confirm availability to perform the proposed work during the proposed timeframe. Note that not providing the information now may delay award and contract negotiations.

General and Administrative (G&A) Costs: Specify a current rate and base to which G&A costs will be applied. If available, use the current rate recommendations from the cognizant Federal-auditing agency. If an audit rate is not available, provide a detailed explanation of the cost base used to develop the rate and if possible, a historical actual G&A rate for the past three years.

Specify the elements of the company's G&A costs in the text boxes provided. Possible G&A cost elements include Rent, Utilities, and Management.

Profit/Cost Sharing: See Section 5.8. Profit is to be added to total cost, while shared costs are to be subtracted from total cost, as applicable.

Amount Requested: The amount requested is equal to the sum of the Direct Labor, Overhead, ODCs, G&A and any profit, less any cost sharing. The amount requested cannot exceed $125,000 for Phase I.

Government Facilities and Equipment: If you require the use of Government Facilities or Equipment, identify the Government facilities or equipment in the text box provided, as well as in Part 8 of your technical proposal. Please note that this section SHALL be completed if you certified in Form A that you will require the use of Government Facilities. Leave this section BLANK if you DO NOT require the use of Government facilities or equipment.

Audit Information: Complete the Audit Information section of Form C to indicate if your company's accounting system has been audited and if the rates from that audit agreement are used for this proposal.

Note: There is a separate "Audit Information" section linked from your Activity Worksheet that must also be completed.

SBIR Check List

For assistance in completing your Phase I proposal, use the following checklist to ensure your submission is complete.

1. **The entire proposal including any supplemental material shall not exceed a total of 25 8.5 x 11 inch pages** (Section 3.2.2).
2. The proposal and innovation is submitted for one subtopic only (Section 3.1).
3. The entire proposal is submitted consistent with the requirements and in the order outlined in Section 3.2.
4. The technical proposal contains all eleven parts in order (Section 3.2.4).
5. The 1-page briefing chart does not include any proprietary data (Section 3.2.9).
6. Certifications in Form A are completed, and agree with the content of the technical proposal.
7. Proposed funding does not exceed $125,000 (Sections 1.4, 5.1.1).
8. Proposed project duration does not exceed 6 months (Sections 1.4, 5.1.1).
9. Entire proposal including Forms A, B, and C submitted via the Internet.
10. Form A electronically endorsed by the SBC Official.
11. **Proposals must be received no later than 5:00 p.m. EDT on Thursday, September 8, 2011** (Section 6.3).

Form A – STTR Cover Sheet

Subtopic No.
Proposal Number: _ _ . _ _ - _ _ _ _
Topic Title:
Subtopic Title:
Proposal Title:

Firm Name:
Mailing Address:
City:
State/Zip:
Phone:
Fax:
EIN/Tax Id:

Research Institution Name:
Mailing Address:
City:
State/Zip:
Phone:
Fax:
EIN/Tax Id:

ACN (Authorized Contract Negotiator) Name:
ACN E-mail:
ACN Phone: Extension:
DUNS + 4:
Cage Code:
Amount Requested: $__________ (auto-populated upon completion of Budge Form C)
Duration: ____ months

OFFEROR CERTIFIES THAT:

As described in section 2.14 of the Solicitation, the partnering Research Institution qualifies as a:

a. FFRDC Yes No
b. Nonprofit Research Institute Yes No
c. Nonprofit College or University Yes No

As defined in Section 3.2.4 Part 11 of the Solicitation, indicate if

d. Essentially equivalent work under this project has been submitted for other Federal funding Yes No

i) If yes, provide information on essentially equivalent proposal submissions below:

Proposal No.	Proposal Title	Date of Submission	Soliciting Agency	(Anticipated) Selection Announcement Date

e. Funding has been received for essentially equivalent work under this project by any other Federal grant, contract, or subcontract Yes No

As described in Section 3 of this solicitation, the offeror meets the following requirements completely:

f. Cooperative Agreement electronically endorsed by the SBC and RI	Yes	No
g. A Signed Allocation of Rights Agreement will be available for the Contracting Officer at time of selection	Yes	No
h. All 11 parts of the technical proposal are included in part order and the page limitation is met	Yes	No
i. Subcontracts/consultants proposed? (Other than RI)	Yes	No
i) If yes, does the proposal comply with the subcontractor/consultant limitation? (Section 3.2.4 Part 9)	Yes	No
j. Government equipment or facilities required?	Yes	No
i) If yes, is a signed statement of availability enclosed in Part 8?	Yes	No
ii) If yes, is a non-STTR funding source identified in Part 8?	Yes	No

In accordance with Section 5.11.9 of the Solicitation as applicable:

k. The offeror understands and shall comply with export control regulations	Yes	No

In accordance with Section 5 of the Solicitation as applicable, indicate if any of the following will be used (must comply with federal regulations):

l. Human Subject	Yes	No
m. Animal Subject	Yes	No
n. Toxic Chemicals	Yes	No
o. Hazardous Materials	Yes	No

As referenced in Section 1.2 of the Solicitation, indicate if the R&D to be performed is related to:

p. Renewable Energy	Yes	No
q. Manufacturing	Yes	No

The SBC will perform ___ % of the work and the RI will perform ___% of the work on this project.

I understand that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

ENDORSEMENT:

Corporate/Business Official:
Name:
Title:
Phone:
E-mail

Endorsed by:
Date:

PROPRIETARY NOTICE (If Applicable, See Sections 5.5, 5.6)

NOTICE: This data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal, provided that a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages __________ of this proposal.

Note: Do not mark the entire proposal as proprietary. Forms A and B (pages 1 and 2 of your proposal submission) cannot contain proprietary data. (See Section 3.2.3 of the 2011 Solicitation)

Guidelines for Completing STTR Cover Sheet

Complete Cover Sheet Form A electronically via the Proposal Submission Electronic Handbook.

Proposal Number: This number does not change. The proposal number consists of the four-digit subtopic number and four-digit system-generated number.

Topic Title: Select the topic that this proposal will address. Refer to Section 9 for topic descriptions.

Subtopic Title: Select the subtopic that this proposal will address. Refer to Section 9 for subtopic descriptions.

Proposal Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title. Avoid words like "development" and "study."

Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

Research Institution Name: Enter the full name of the partnering Research Institution.

Mailing Address: Must match CCR address and should be the address where mail is received.
City, State, Zip: City, 2-letter State designation (i.e. TX for Texas), 9-digit Zip code (i.e. 20705-3106)
Phone, Fax: Number including area code
EIN/Tax ID: Employer Identification Number/Taxpayer ID

ACN Name: Enter the name of the Authorized Contract Negotiator from your firm
ACN E-mail: Email address
ACN Phone, Ext.: Number including area code and extension (if applicable)

DUNS + 4: 9-digit Data Universal Number System; a 4-digit suffix is also required if owned by a parent concern. For information on obtaining a DUNS number go to http://www.dnb.com.

CAGE Code: Commercial Government and Entity Code that is issued by the Central Contractor Registration (CCR). For information on obtaining a CAGE Code, go to http://www.ccr.gov.

Amount Requested: Proposal amount auto-populated from Budget Summary. The amount requested should not exceed $125,000 (see Sections 1.4, 5.1.1).

Duration: Proposed duration in months. The requested duration should not exceed 12 months (see Sections 1.4, 5.1.1).

Certifications: Answer Yes or No as applicable for certifications a – m (see the referenced sections for definitions). Where applicable, SBCs should make sure that their certifications on Form A agree with the content of their technical proposal.

a-c. Indicate whether the Research Institution (RI) qualifies as a FFRDC, Nonprofit Research Institution, or a Nonprofit College/University. (Only one of these should be marked as “Yes”).

d. If essentially equivalent work under this project has been submitted to other Federal Agencies/programs for funding, then the SBC must provide the proposal number, proposal title, date of submission, and soliciting agency. The selection announcement date should also be provided if known.

e. It is unlawful to enter into federally funded agreements requiring essentially equivalent work. By answering “No” the SBC confirms that work under this project has not been funded under any other Federal grant, contract or subcontract.

f. The Cooperative Agreement electronically endorsed by the authorized SBC Official and RI Official. Refer to Section 3.2.5 of the Solicitation. Note: Endorsement is performed via the “Endorsement” link located in the Activity Worksheet for each proposal.

g. Following the Selection Announcement for negotiation, the offeror must provide to the Contracting Officer, a completed Allocation of Rights Agreement (ARA). The ARA shall state the allocation of intellectual property rights with respect to the proposed STTR activity and planned follow-on research, development and/or commercialization. See Section 3.2.11 of the Solicitation.

h. As stated in section 3.2 of the Solicitation, the technical proposal must not exceed the 25-page limitation and must consist of all eleven (11) required parts.

i. By answering "Yes", the SBC certifies that subcontracts/consultants have been proposed and arrangements have been made to perform on the contract, if awarded.
   i) Proposed subcontractor/consultant business arrangements must not exceed 30 percent of the research and/or analytical work (as determined by the total cost of the proposed subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any). Refer to Section 3.2.4, Part 9 of the Solicitation.

j. By answering "Yes", the SBC certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities. By answering "No", the SBC certifies that no such Government Furnished Facilities or Government Furnished Equipment is required to perform the proposed activities. See Section 3.2.4 Part 8 of the Solicitation.
   i) If proposing to use Government Furnished Facilities or Equipment, a signed statement of availability must be included in Part 8 of the Technical Proposal that describes the uniqueness of the facility and its availability to the offeror at specified times, signed by the appropriate Government official.
   ii) If "Yes," the SBC certifies that it has a confirmed, non-SBIR funding source for whatever charges may be incurred when utilizing the required Government facility. If "No," a waiver from the SBA is required before a proposer can use SBIR/STTR funds for Government equipment or facilities. Proposals requiring waivers must explain why the waiver is appropriate.

k. Offerors are responsible for ensuring compliance with export control and International Traffic in Arms (ITAR) regulations. All employees who will work on this contract must be eligible under these regulations or the offeror must have in place a valid export license or technical assistance agreement. Violations of these regulations can result in criminal or civil penalties.

l-o. Offeror must indicate by answering "Yes" or "No" as applicable if human subjects, animal subjects, toxic chemicals and/or hazardous materials will be used. SBCs must be in compliance with federal regulations. See Sections 5.13.5 5.13.6, and 5.13.7 of the Solicitation.

p. Answer "Yes" if this proposal has a connection to energy efficiency or alternative and renewable energy. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to energy efficiency or alternative and renewable energy. See Section 1.2 of the Solicitation.

q. Answer "Yes" if this proposal has a connection to manufacturing. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to manufacturing. See Section 1.2 of the Solicitation.

Electronic Endorsement:
Endorsement of the proposal by the Business Official certifies an understanding that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

Electronic endorsement is performed by the authorized Business Official from the "Endorsement" link located on the Activity Worksheet for each proposal. Electronic endorsement is the final step in the proposal submission process and can only be performed when all required sections of the proposal submission are complete.
Once endorsed, the name and date of endorsement will populate under the Endorsement section of the Cover Sheet Form A.

Form B – STTR Proposal Summary

Subtopic No.
Proposal Number: __ __.__ __ - __ __ __ __
Subtopic Title:
Proposal Title:

<u>Small Business Concern</u>:
Name:
Address:
City/State/Zip:
Phone:

<u>Research Institution</u>:
Name:
Address:
City/State/Zip:
Phone:

<u>Principal Investigator/Project Manager</u>:
Name:
Address:
City/State/Zip:
Phone: Extension:
E-mail:

<u>Estimated Technology Readiness Level (TRL) at beginning and end of contract</u>:
Begin: _____
End: _____

<u>Technical Abstract</u>: (Limit 2,000 characters, approximately 200 words)

<u>Potential NASA Application(s)</u>: (Limit 1,500 characters, approximately 150 words)

<u>Potential Non-NASA Application(s)</u>: (Limit 1,500 characters, approximately 150 words)

<u>Technology Taxonomy</u>: (Select only the technologies relevant to this specific proposal)
NASA's technology taxonomy has been developed by the SBIR-STTR program to disseminate awareness of proposed and awarded R/R&D in the agency. It is a listing of over 100 technologies, sorted into broad categories, of interest to NASA.

Guidelines for Completing STTR Proposal Summary

Complete Proposal Summary Form B electronically via the Proposal Submission Electronic Handbook.

Proposal Number: Auto-populated with proposal number as shown on Cover Sheet.

Subtopic Title: Auto-populated with subtopic title as shown on Cover Sheet.

Proposal Title: Auto-populated with proposal title as shown on Cover Sheet.

Small Business Concern: Auto-populated with firm information as shown on Cover Sheet.

Research Institution: Auto-populated with RI information as shown on Cover Sheet.

Principal Investigator/Project Manager: Enter the full name of the PI/PM and include all required contact information.

Technology Readiness Level (TRL): Provide the estimated Technology Readiness Level (TRL) at the beginning and end of the contract. See Section 2.23 and Appendix B for TRL definitions.

Technical Abstract: Summary of the offeror's proposed project is limited to 2,000 characters, approximately 200 words, and shall summarize the implications of the approach and the anticipated results of the Phase I. NASA will reject a proposal if the technical abstract is determined to be non-responsive to the subtopic. **The abstract must not contain proprietary information and must describe the NASA need addressed by the proposed R/R&D effort.**

Potential NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Potential Non-NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Technology Taxonomy: Selections for the technology taxonomy are limited to technologies supported or relevant to the specific proposal. The listing of technologies for the taxonomy is provided in Appendix C.

Form C – STTR Budget Summary

PROPOSAL NUMBER:
SMALL BUSINESS CONCERN:

(1) DIRECT LABOR:

Category	Description	Education	Years of Experience	Hours	Rate	Total
____________	____________________	_____________	________	_____	_______	_____________
____________	____________________	_____________	________	_____	_______	_____________
____________	____________________	_____________	________	_____	_______	_____________

TOTAL DIRECT LABOR:
(1) $ ____________

Are the labor rates fully loaded? Yes No
If yes, explain any costs that apply:

Comments:

Document uploaded for labor rate documentation: (file name)

(2) OVERHEAD COST;

______% of Total Direct Labor or $ ______

OVERHEAD COST:
(2) $ ____________

Comments:

Overhead Cost Sources:
____
____
____

(3) OTHER DIRECT COSTS (ODCs):

Materials:
- Description: _______________________________
- Vendor: __________________________________
- Quantity: ___________ Cost: ________________
- Consumable: Yes No
- Competitively Sourced?: Yes No
- Used Exclusively for this Contract?: Yes No
- Supporting Comments: ______________________
- Supporting Documents: (file name)

Supplies:

Description: ________________________________
Vendor: ___________________________________
Quantity: ___________ Cost: ________________
Consumable: Yes No
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Equipment:

Description: ________________________________
Vendor: ___________________________________
Quantity: ___________ Cost: ________________
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Other:

Travel:

Location From: _______________ Location To: _______________
Number of People: _____________ Number of Days: ___________
Purpose of Trip: ____
Airfare: _____________________ Car Rental: ________________
Per Diem: ___________________ Other Costs: _______________
Total Costs: _________________
Sources of Estimates: ______________________________________
Explanation/Justification: ___________________________________

Explanation of ODCs:
Provide any additional information on the Other Direct Costs listed above, including the basis used for estimating the costs.

Subcontractor/Consultants: Total Cost:

___________________________________ _________________
___________________________________ _________________

(Note: Separate Budget Summaries completed for all proposed Subcontractors/Consultants via the Subcontractors/Consultants section of Form C)

Research Institution: Total Cost:

___________________________________ _________________

(Note: Separate Budget Summary completed for the Research Institution via the Research Institution section of Form C)

TOTAL OTHER DIRECT COSTS:
(3) $ _____________

(1)+(2)+(3)=(4) SUBTOTAL:
(4) $ ____________

(5) GENERAL & ADMINISTRATIVE (G&A) COSTS
______% of Subtotal or $ ______ G&A COSTS:
(5) $ ____________

Comments:
If an audit rate is not available, provide a detailed explanation of the cost base used to develop the G&A rate and if possible, a historical actual G&A rate for the past three years.

G&A Cost Elements:
____
____
____

(4)+(5)=(6) TOTAL COSTS
(6) $ ____________

(7) ADD PROFIT or SUBTRACT COST SHARING PROFIT/COST SHARING:
(As applicable) (7) $ ____________

Comments:

(6)+(7)=(8) AMOUNT REQUESTED:
(8) $ ____________

GOVERNMENT FACILITIES OR EQUIPMENT:

If you require the use of a Government Facility or Equipment, identify it below as well as in Part 8 of your technical proposal. (See certification l on Form A)

AUDIT AGENCY:

If your company's accounting system has been audited, are the rates from that audit agreement used for this proposal?

__ The rates listed in the negotiated rate agreement were used to prepare the budget summary
__ Other rates were used to prepare the budget summary
__ My company's accounting system has not been audited

If the listed rates are not being used to prepare the budget summary, please provide an explanation:

Guidelines for Preparing STTR Budget Summary

Complete Budget Summary Form C electronically.

The offeror shall electronically submit a price proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting and estimating system.

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, in the text boxes or via uploads as indicated in the electronic form.

Offerors with questions about the appropriate classification of costs are advised to consult with an experienced accountant that has experience in government contracting and cost accounting principals. Information provided by the Defense Contract Audit Administration in their publication "Information for Contractors" may also be useful. This publication is available on-line at http://www.dcaa.mil/dcaap7641.90.pdf.

Firm: Same as Cover Sheet.

Proposal Number: Same as Cover Sheet.

Direct Labor: Select the appropriate labor category for each person who will be working directly on the proposed research effort and provide the labor description, level of education, years of experience, total number of hours, and labor rate. Detail the labor hours used for each year of the proposed research effort separately.

Indicate if the direct labor rates are fully loaded and, if yes, explain any costs that are included in the rate such as fringe benefits, etc. Provide the breakout rate such as the labor hour rate, health benefits, life insurance etc. Some examples of direct labor include Principal Investigator, Engineer, Scientist, Analyst or Research Assistant/Laboratory Assistant. All listed categories shall be directly related to proposed work to be performed under contract with NASA. Any contributions from non-technical personnel proposed under direct labor shall be explicitly explained. Labor rates that do not compare favorably to comparable state average rates at http://www.bls.gov require additional documentation, supporting the proposed rate or salary.

Note: Costs associated with company executives, accountants or administrative support are typically included in a company's general and administrative costs. If these costs are being proposed as direct labor then provide the details of how the proposed hours were allocated to this effort and verify that these costs are not also covered in your overhead or G&A rate.

Overhead Cost: Specify current rate and base. Use current rate(s) negotiated with your firm's cognizant Federal-auditing agency, if available. A rate that has not been audited requires a detailed explanation of the cost base used to develop the rate and if possible, historical actual overhead rates for the past three years.

Specify the cost elements of the company's overhead costs in the text boxes provided. Possible overhead cost elements include insurance, sick leave, and vacation.

Note: If no labor overhead rate is proposed and the proposed direct labor includes all fringe benefits, you may enter "0" for the overhead cost line.

Other Direct Costs (ODCs):
Refer to FAR 31.205 – Selected Costs for determination of cost allowability.

<u>Materials and Supplies:</u> Under the Materials and Supplies sections, indicate type, vendor, quantity required, and cost. Identify whether each item is consumable, which year it will be purchased, if it was competitively sourced, and

if it will be used exclusively for this contract. Your proposed cost shall be justified and supporting documents should be uploaded. General materials or supplies without adequate explanation of the components, quantity and use of said items are not an acceptable breakdown. In the supporting comments block, provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc…). The Contracting Officer will make the final determination.

Special Tooling, Testing, and Test Equipment: The need for these items, if proposed, will be carefully reviewed. Equipment must be made in the USA to the maximum extent practical. The offeror should provide competitive quotes to support the proposed costs or should justify why only one source is available. Competitive quotes may be signed quotes from vendors or copies of catalogue pages. Normally the costs of any equipment should be quoted on a purchase basis, unless the offeror can demonstrate that lease or rent of the equipment is clearly advantageous to the government. The Contracting Officer will make the final determination. Upload supporting documentation as necessary. In the supporting comments block provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc.). The Contracting Officer will make the final determination.

Travel: All proposed travel must be necessary for the success of the research. Include a detailed accounting of all proposed expenses to include the purpose of proposed trips, number of trips, travelers per trip, as well as meals, hotel, and rental car estimated costs. Sources of estimate should be identified when travel is proposed along with a justification for each trip. Proposed travel costs shall be in accordance with the Federal Travel Regulation http://www.gsa.gov/federaltravelregulation.

Subcontracts/Consultants: Subcontracts/Consultants costs are included in the Other Direct Costs total. A separate budget summary must be completed for each subcontract/consultant proposed. Further instructions are provided in the Subcontracts/Consultants section below.

Note: Do not add subcontractors or consultants as a line item under the ODCs section of Form C. It will automatically be added to the ODCs upon completion of the separate Subcontractor/Consultant budget summary form.

Research Institution: Research Institution costs are included in the Other Direct Costs total. A separate budget summary must be completed for the Research Institution. Further instructions are provided in the Research Institution section below.

Note: Do not add the Research Institution as a line item under the ODCs section of Form C. It will automatically be added to the ODCs upon completion of the separate Research Institution budget summary form.

Other: List all other direct costs that are not otherwise included in the categories described above such as rental of facilities, etc.

Note: The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Firms should be prepared to justify all material, supplies, and equipment costs during negotiations. See section 3.2.4 Part 8 for further guidance.

Explanation of ODCs: Provide any additional information for the proposed ODCs, including basis for cost estimation, in the text box provided.

Subcontracts/Consultants: List consultants by name and specify, for each, the number of hours and hourly costs. Detailed quotes from subcontractors should be provided in the same format. Note that a subcontract entered into for performance of research or research and development differs from an arrangement with a vendor to provide a service such as machining, analysis with test equipment or use of computer time. The costs of such arrangements with vendors should be covered under Special Tooling, Testing, Test Equipment and Material or under Other Direct

Costs. Upon request of the contracting officer, the subcontractor's cost proposals may be sealed or mailed directly for government eyes only.

A letter of commitment shall be uploaded for each proposed subcontractor/consultant from the Subcontractor/Consultant Letter of Commitment section of the subcontractor/consultant budget summary form. If a commitment letter is not available, you shall provide an explanation in the text box to include a point of contact and contact information in order for NASA to obtain the required document to confirm availability to perform the proposed work during the proposed timeframe. Note that not providing the information now may delay award and contract negotiations.

Research Institution: Provide detailed budget information for the costs associated with the Research Institution.

General and Administrative (G&A) Costs: Specify a current rate and base to which G&A costs will be applied. If available, use the current rate recommendations from the cognizant Federal-auditing agency. If an audit rate is not available, provide a detailed explanation of the cost base used to develop the rate and if possible, a historical actual G&A rate for the past three years.

Specify the elements of the company's G&A costs in the text boxes provided. Possible G&A cost elements include Rent, Utilities, and Management.

Profit/Cost Sharing: See Section 5.8. Profit is to be added to total cost, while shared costs are to be subtracted from total cost, as applicable.

Amount Requested: The amount requested is equal to the sum of the Direct Labor, Overhead, ODCs, G&A and any profit, less any cost sharing. The amount requested cannot exceed $125,000 for Phase I.

Government Facilities and Equipment: If you require the use of Government Facilities or Equipment, identify the Government facilities or equipment in the text box provided, as well as in Part 8 of your technical proposal. Please note that this section SHALL be completed if you certified in Form A that you will require the use of Government Facilities. Leave this section BLANK if you DO NOT require the use of Government facilities or equipment.

Audit Information: Complete the Audit Information section of Form C to indicate if your company's accounting system has been audited and if the rates from that audit agreement are used for this proposal.

Note: There is a separate "Audit Information" section linked from your Activity Worksheet that must also be completed.

Model Cooperative R/R&D Agreement

By virtue of the signatures of our authorized representatives, ________(Small Business Concern)__________, and ____________________________(Research Institution)________________________ have agreed to cooperate on the ________(Proposal Title)________ Project, in accordance with the proposal being submitted with this agreement.

This agreement shall be binding until the completion of all Phase I activities, at a minimum. If the________ ________(Proposal Title)________ Project is selected to continue into Phase II, the agreement may also be binding in Phase II activities that are funded by NASA, then this agreement shall be binding until those activities are completed. The agreement may also be binding in Phase III activities that are funded by NASA.

After notification of Phase I selection and prior to contract release, we shall prepare and submit, if requested by NASA, an **Allocation of Rights Agreement**, which shall state our rights to the intellectual property and technology to be developed and commercialized by the ______________(Proposal Title)________ Project. We understand that our contract cannot be approved and project activities may not commence until the **Allocation of Rights Agreement** has been signed and certified to NASA.

Please direct all questions and comments to _____(Small Business Concern representative) at (Phone Number)____.

________Signature____________________

________Name/title____________________

________Small Business Concern__________

________Signature____________________

________Name/title____________________

________Research Institution_____________

Small Business Technology Transfer (STTR) Program Model Allocation of Rights Agreement

This Agreement between ____, a small business concern organized as a __________________________ under the laws of _________________ and having a principal place of business at ____ ____________________, ("SBC") and ____, a research institution having a principal place of business at __________________________ _________________,("RI") is entered into for the purpose of allocating between the parties certain rights relating to an STTR project to be carried out by SBC and RI (hereinafter referred to as the "PARTIES") under an STTR funding agreement that may be awarded by ____NASA_____ to SBC to fund a proposal entitled "__________________________________ ____" submitted, or to be submitted, to by SBC on or about ___________________________, 20___.

1. Applicability of this Agreement.

(a) This Agreement shall be applicable only to matters relating to the STTR project referred to in the preamble above.

(b) If a funding agreement for STTR project is awarded to SBC based upon the STTR proposal referred to in the preamble above, SBC will promptly provide a copy of such funding agreement to RI, and SBC will make a sub-award to RI in accordance with the funding agreement, the proposal, and this Agreement. If the terms of such funding agreement appear to be inconsistent with the provisions of this Agreement, the Parties will attempt in good faith to resolve any such inconsistencies.

However, if such resolution is not achieved within a reasonable period, SBC shall not be obligated to award nor RI to accept the sub-award. If a sub-award is made by SBC and accepted by RI, this Agreement shall not be applicable to contradict the terms of such sub-award or of the funding agreement awarded by NASA to SBC except on the grounds of fraud, misrepresentation, or mistake, but shall be considered to resolve ambiguities in the terms of the sub-award.

(c) The provisions of this Agreement shall apply to any and all consultants, subcontractors, independent contractors, or other individuals employed by SBC or RI for the purposes of this STTR project.

2. Background Intellectual Property.

(a) "Background Intellectual Property" means property and the legal right therein of either or both parties developed before or independent of this Agreement including inventions, patent applications, patents, copyrights, trademarks, mask works, trade secrets and any information embodying proprietary data such as technical data and computer software.

(b) This Agreement shall not be construed as implying that either party hereto shall have the right to use Background Intellectual Property of the other in connection with this STTR project except as otherwise provided hereunder.

(1) The following Background Intellectual Property of SBC may be used nonexclusively and except as noted, without compensation by RI in connection with research or development activities for this STTR project (if "none" so state): ______________________________________ ____ ____;

(2) The following Background Intellectual Property of RI may be used nonexclusively and, except as noted, without compensation by SBC in connection with research or development activities for this STTR project (if "none" so state): ____
____
____;

(3) The following Background Intellectual Property of RI may be used by SBC nonexclusively in connection with commercialization of the results of this STTR project, to the extent that such use is reasonably necessary for practical, efficient and competitive commercialization of such results but not for commercialization independent of the commercialization of such results, subject to any rights of the Government therein and upon the condition that SBC pay to RI, in addition to any other royalty including any royalty specified in the following list, a royalty of _____% of net sales or leases made by or under the authority of SBC of any product or service that embodies, or the manufacture or normal use of which entails the use of, all or any part of such Background Intellectual Property (if "none" so state): ____
____
____.

3. Project Intellectual Property.

(a) "Project Intellectual Property" means the legal rights relating to inventions (including Subject Inventions as defined in 37 CFR § 401), patent applications, patents, copyrights, trademarks, mask works, trade secrets and any other legally protectable information, including computer software, first made or generated during the performance of this STTR Agreement.

(b) Except as otherwise provided herein, ownership of Project Intellectual Property shall vest in the party whose personnel conceived the subject matter, and such party may perfect legal protection in its own name and at its own expense. Jointly made or generated Project Intellectual Property shall be jointly owned by the Parties unless otherwise agreed in writing. The SBC shall have the first option to perfect the rights in jointly made or generated Project Intellectual Property unless otherwise agreed in writing.

(1) The rights to any revenues and profits, resulting from any product, process, or other innovation or invention based on the cooperative shall be allocated between the SBC and the RI as follows:

SBC Percent: ________ RI Percent: ________

(2) Expenses and other liabilities associated with the development and marketing of any product, process, or other innovation or invention shall be allocated as follows: the SBC will be responsible for ______ percent and the RI will be responsible for ______ percent.

(c) The Parties agree to disclose to each other, in writing, each and every Subject Invention, which may be patentable or otherwise protectable under the United States patent laws in Title 35, United States Code. The Parties acknowledge that they will disclose Subject Inventions to each other and the Agency within two months after their respective inventor(s) first disclose the invention in writing to the person(s) responsible for patent matters of the disclosing Party. All written disclosures of such inventions shall contain sufficient detail of the invention, identification of any statutory bars, and shall be marked confidential, in accordance with 35 U.S.C. § 205.

(d) Each party hereto may use Project Intellectual Property of the other nonexclusively and without compensation in connection with research or development activities for this STTR project, including inclusion in STTR project reports to the AGENCY and proposals to the AGENCY for continued funding of this STTR project through additional phases.

(e) In addition to the Government's rights under the Patent Rights clause of 37 CFR § 401.14, the Parties agree that the Government shall have an irrevocable, royalty free, nonexclusive license for any Governmental purpose in any Project Intellectual Property.

(f) SBC will have an option to commercialize the Project Intellectual Property of RI, <u>subject to any rights of the Government therein</u>, as follows—

(1) Where Project Intellectual Property of RI is a potentially patentable invention, SBC will have an exclusive option for a license to such invention, for an initial option period of _______ months after such invention has been reported to SBC. SBC may, at its election and subject to the patent expense reimbursement provisions of this section, extend such option for an additional _______ months by giving written notice of such election to RI prior to the expiration of the initial option period. During the period of such option following notice by SBC of election to extend, RI will pursue and maintain any patent protection for the invention requested in writing by SBC and, except with the written consent of SBC or upon the failure of SBC to reimburse patenting expenses as required under this section, will not voluntarily discontinue the pursuit and maintenance of any United States patent protection for the invention initiated by RI or of any patent protection requested by SBC. For any invention for which SBC gives notice of its election to extend the option, SBC will, within ______ days after invoice, reimburse RI for the expenses incurred by RI prior to expiration or termination of the option period in pursuing and maintaining (i) any United States patent protection initiated by RI and (ii) any patent protection requested by SBC. SBC may terminate such option at will by giving written notice to RI, in which case further accrual of reimbursable patenting expenses hereunder, other than prior commitments not practically revocable, will cease upon RI's receipt of such notice. At any time prior to the expiration or termination of an option, SBC may exercise such option by giving written notice to RI, whereupon the parties will promptly and in good faith enter into negotiations for a license under RI's patent rights in the invention for SBC to make, use and/or sell products and/or services that embody, or the development, manufacture and/or use of which involves employment of, the invention. The terms of such license will include: (i) payment of reasonable royalties to RI on sales of products or services which embody, or the development, manufacture or use of which involves employment of, the invention; (ii) reimbursement by SBC of expenses incurred by RI in seeking and maintaining patent protection for the invention in countries covered by the license (which reimbursement, as well as any such patent expenses incurred directly by SBC with RI's authorization, insofar as deriving from RI's interest in such invention, may be offset in full against up to _______ of accrued royalties in excess of any minimum royalties due RI); and, in the case of an exclusive license, (3) reasonable commercialization milestones and/or minimum royalties.

(2) Where Project Intellectual Property of RI is other than a potentially patentable invention, SBC will have an exclusive option for a license, for an option period extending until ______ months following completion of RI's performance of that phase of this STTR project in which such Project Intellectual Property of RI was developed by RI. SBC may exercise such option by giving written notice to RI, whereupon the parties will promptly and in good faith enter into negotiations for a license under RI's interest in the subject matter for SBC to make, use and/or sell products or services which embody, or the development, manufacture and/or use of which involve employment of, such Project Intellectual Property of RI. The terms of such license will include: (i) payment of reasonable royalties to RI on sales of products or services that embody, or the development, manufacture or use of which involves employment of, the Project Intellectual Property of RI and, in the case of an exclusive license, (ii) reasonable commercialization milestones and/or minimum royalties.

(3) Where more than one royalty might otherwise be due in respect of any unit of product or service under a license pursuant to this Agreement, the parties shall in good faith negotiate to ameliorate any effect thereof that would threaten the commercial viability of the affected products or services by providing in such license(s) for a reasonable discount or cap on total royalties due in respect of any such unit.

4. Follow-on Research or Development.

All follow-on work, including any licenses, contracts, subcontracts, sublicenses or arrangements of any type, shall contain appropriate provisions to implement the Project Intellectual Property rights provisions of this agreement and insure that the Parties and the Government obtain and retain such rights granted herein in all future resulting research, development, or commercialization work.

5. Confidentiality/Publication.

(a) Background Intellectual Property and Project Intellectual Property of a party, as well as other proprietary or confidential information of a party, disclosed by that party to the other in connection with this STTR project shall be received and held in confidence by the receiving party and, except with the consent of the disclosing party or as permitted under this Agreement, neither used by the receiving party nor disclosed by the receiving party to others, provided that the receiving party has notice that such information is regarded by the disclosing party as proprietary or confidential. However, these confidentiality obligations shall not apply to use or disclosure by the receiving party after such information is or becomes known to the public without breach of this provision or is or becomes known to the receiving party from a source reasonably believed to be independent of the disclosing party or is developed by or for the receiving party independently of its disclosure by the disclosing party.

(b) Subject to the terms of paragraph (a) above, either party may publish its results from this STTR project. However, the publishing party will give a right of refusal to the other party with respect to a proposed publication, as well as a _____ day period in which to review proposed publications and submit comments, which will be given full consideration before publication. Furthermore, upon request of the reviewing party, publication will be deferred for up to ______ additional days for preparation and filing of a patent application which the reviewing party has the right to file or to have filed at its request by the publishing party.

6. Liability.

(a) Each party disclaims all warranties running to the other or through the other to third parties, whether express or implied, including without limitation warranties of merchantability, fitness for a particular purpose, and freedom from infringement, as to any information, result, design, prototype, product or process deriving directly or indirectly and in whole or part from such party in connection with this STTR project.

(b) SBC will indemnify and hold harmless RI with regard to any claims arising in connection with commercialization of the results of this STTR project by or under the authority of SBC. The PARTIES will indemnify and hold harmless the Government with regard to any claims arising in connection with commercialization of the results of this STTR project.

7. Termination.

(a) This agreement may be terminated by either Party upon __ days written notice to the other Party. This agreement may also be terminated by either Party in the event of the failure of the other Party to comply with the terms of this agreement.

(b) In the event of termination by either Party, each Party shall be responsible for its share of the costs incurred through the effective date of termination, as well as its share of the costs incurred after the effective date of termination, and which are related to the termination. The confidentiality, use, and/or nondisclosure obligations of this agreement shall survive any termination of this agreement.

AGREED TO AND ACCEPTED--

Small Business Concern

By:____________________________________ Date:____________
Print Name:____
Title:____

Research Institution

By:____________________________________ Date:_____________
Print Name:____
Title:____

STTR Check List

For assistance in completing your Phase I proposal, use the following checklist to ensure your submission is complete.

For assistance in completing your Phase I proposal, use the following checklist to ensure your submission is complete.

1. **The entire proposal including any supplemental material shall not exceed a total of 25 8.5 x 11 inch pages, including Cooperative Agreement** (Sections 3.2.2, 3.2.5).

2. The proposal and innovation is submitted for one subtopic only (Section 3.1).

3. The entire proposal is submitted consistent with the requirements and in the order outlined in Section 3.2.

4. The technical proposal contains all eleven parts in order (Section 3.2.4).

5. The 1-page briefing chart does not include any proprietary data (Section 3.2.9).

6. Certifications in Form A are completed, and agree with the content of the technical proposal.

7. Proposed funding does not exceed $125,000 (Sections 1.4).

8. Proposed project duration does not exceed 12 months (Sections 1.4).

9. Cooperative Agreement has been electronically endorsed by both the SBC Official and RI (Sections 3.2.5, 6.2).

10. Entire proposal including Forms A, B, C, and Cooperative Agreement submitted via the Internet.

11. Form A electronically endorsed by the SBC Official.

12. **Proposals must be received no later than 5:00 p.m. EDT on Thursday, September 8, 2011 (Section 6.3).**

13. Signed Allocation of Rights Agreement available for Contracting Officer at time of selection.

Part 2: Phase II Proposal Instructions for the NASA 2011 SBIR/STTR Solicitation

National Aeronautics and Space Administration

SMALL BUSINESS
INNOVATION RESEARCH (SBIR)
&
SMALL BUSINESS
TECHNOLOGY TRANSFER (STTR)

Part 2: Phase II Proposal Instructions

The electronic version of this document is at: http://sbir.nasa.gov

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2011 NASA SBIR/STTR Program Solicitations

1. Program Description

1.1 Introduction

This document provides a general description of the NASA SBIR/STTR Phase II proposal submission requirements and the Phase II program. All small business concerns (SBCs) that are awarded and have successfully completed their Phase I contracts are invited to submit Phase II proposals. Receipt of Phase II proposals are due on the last day of performance under SBIR/STTR Phase I contracts, the submission period will be available approximately 6 weeks prior to the completion date. **Note: The information in this document is subject to revision and if necessary, updated Phase II proposal instructions will be provided to the SBCs 6 weeks prior to the due date of the Phase II proposal.**

The NASA SBIR/STTR programs do not accept proposals solely directed towards system studies, market research, routine engineering development of existing products or proven concepts and modifications of existing products without substantive innovation.

Approximately 45% of the selected Phase I contracts are selected for Phase II follow-on efforts. All awards are subject to the availability of funds.

Proposals must be submitted online via the Proposal Submissions Electronic Handbook at http://sbir.nasa.gov and include all relevant documentation. Unsolicited proposals will not be accepted.

1.2 Program Authority and Executive Order

SBIR and STTR opportunities are solicited annually pursuant to the Small Business Innovation Development Act of 1982 (Public Law 97-219), Small Business Innovation Research Program Reauthorization Act of 2000 (Public Law 106-554), the Small Business Research and Development Act of 1992 (Public Law 102-564), the Small Business Technology Transfer Program Reauthorization Act of 2001 (Public Law 107-50), and as most recently amended by Congress has extended the SBIR and STTR programs through September 30, 2011 (P.L. 112-17). A new authorization or extension is anticipated prior to this end date.

Executive Order: This Solicitation complies with Executive Order 13329 (issued February 26, 2004) directing Federal agencies that administer the SBIR and STTR programs to encourage innovation in manufacturing related research and development consistent with the objectives of each agency and to the extent permitted by law.

On February 26, 2004, the President issued Executive Order 13329 (69 FR 9181) entitled “Encouraging Innovation in Manufacturing.” In response to this Executive Order, NASA encourages the submission of applications that deal with some aspect of innovative manufacturing technology. If a proposal has a connection to manufacturing this should be indicated in the Part 5 (Related R/R&D) of the proposal and a brief explanation of how it is related to manufacturing should be provided.

Energy Independence and Security Act of 2007, section 1203, stated that federal agencies shall give high priority to small business concerns that participate in or conduct energy efficiency or renewable energy system research and development projects. If a proposal has a connection to energy efficiency or alternative and renewable energy this should be indicated in Part 5 (Related R/R&D) of the proposal and a brief explanation of how it is related to energy efficiency and alternative and renewable energy should be provided.

1.3 Program Management

The Office of the Chief Technologist under the Office of the NASA Associate Administrator provides overall policy direction for implementation of the NASA SBIR/STTR programs. The NASA SBIR/STTR Program Management Office, which operates the programs in conjunction with NASA Mission Directorates and Centers, is hosted at the NASA Ames Research Center. NASA Shared Services Center (NSSC) provides the overall procurement management for the programs. All of the NASA Centers actively participate in the SBIR/STTR programs; and to reinforce NASA's objective of infusion of SBIR/STTR developed technologies into its programs and projects, each Center has personnel focused on that activity.

NASA research and technology areas to be solicited are identified annually by Mission Directorates. The Directorates identify high priority research and technology needs for their respective programs and projects. The needs are explicitly described in the topics and subtopics descriptions developed by technical experts at NASA's Centers. The range of technologies is broad, and the list of topics and subtopics may vary in content from year to year. See section 9.1 for details on the Mission Directorate research topic descriptions.

The STTR Program Solicitation is aligned with needs and associated core competencies of the NASA Centers as described in Section 9.2.

Information regarding the Mission Directorates and the NASA Centers can be obtained at the following web sites:

NASA Mission Directorates	
Aeronautics Research	http://www.aeronautics.nasa.gov/
Exploration Systems	http://www.nasa.gov/exploration/home/index.html
Science	http://nasascience.nasa.gov
Space Operations	http://www.nasa.gov/directorates/somd/home/

NASA Centers	
Ames Research Center (ARC)	http://www.nasa.gov/centers/ames/home/index.html
Dryden Flight Research Center (DFRC)	http://www.nasa.gov/centers/dryden/home/index.html
Glenn Research Center (GRC)	http://www.nasa.gov/centers/glenn/home/index.html
Goddard Space Flight Center (GSFC)	http://www.nasa.gov/centers/goddard/home/index.html
Jet Propulsion Laboratory (JPL)	http://www.nasa.gov/centers/jpl/home/index.html
Johnson Space Center (JSC)	http://www.nasa.gov/centers/johnson/home/index.html
Kennedy Space Center (KSC)	http://www.nasa.gov/centers/kennedy/home/index.html
Langley Research Center (LaRC)	http://www.nasa.gov/centers/langley/home/index.html
Marshall Space Flight Center (MSFC)	http://www.nasa.gov/centers/marshall/home/index.html
Stennis Space Center (SSC)	http://www.nasa.gov/centers/stennis/home/index.html

1.4 Three-Phase Program

Both the SBIR and STTR programs are divided into three funding and development stages.

Phase I: The purpose of Phase I is to determine the scientific, technical, commercial merit and feasibility of the proposed innovation, and the quality of the SBC's performance. Phase I work and results should provide a sound basis for the continued development, demonstration and delivery of the proposed innovation in Phase II and follow-on efforts. Successful completion of Phase I objectives is a prerequisite to consideration for a Phase II award.

Phase II: The purpose of Phase II is the development, demonstration and delivery of the innovation. Only SBCs awarded Phase I contracts are eligible for Phase II funding agreements. Phase II projects are chosen as a result of competitive evaluations and based on selection criteria provided in the Phase II instructions.

Maximum value and period of performance for Phase I and Phase II contracts:

Phase I Contracts	**SBIR**	**STTR**
Maximum Contract Value	$ 125,000	$ 125,000
Period of Performance	6 months	12 months
Phase II Contracts	**SBIR**	**STTR**
Maximum Contract Value	$ 700,000	$ 700,000
Period of Performance	24 months	24 months

* Nominal period of performance for a Phase II is 24 months. If your period of performance is less than 18 months, you may not be eligible for a Phase II Enhancement as described below.

Phase II Enhancement (PII-E): The objective of the Phase II-E Option is to further encourage the transition of Phase II contracts into Phase III awards by providing a cost share extension of R/R&D efforts to the current Phase II contract with new Phase III contracts. Eligible firms must secure a 3rd party investor to partner and invest in enhancing their technology for further research, infusion, and/or commercialization. Under this option, NASA will match with SBIR/STTR funds up to $250,000 of non-SBIR/non-STTR investment from a NASA project, NASA contractor, or 3rd party commercial investor to extend an existing Phase II project for up to a minimum of 4 months to perform additional R/R&D. The total cumulative award for the Phase II contract plus the Phase II-E match is not expected to exceed $1,000,000.00 of SBIR/STTR funding. The non-SBIR or non-STTR contribution is not limited since it is regulated under the guidelines for Phase III awards.

Additional details, including specific submission dates and how to apply for the Phase II-E, will be provided no later than the 15th month of the performance of the Phase II contract. Select applicants will also be notified on when they can submit their application packages and will have a period of 2 weeks to get them submitted. Application packages will not be accepted before or after the notified 2-week submission period.

Phase III: NASA may award Phase III contracts for products or services with non-SBIR/STTR funds. The competition for SBIR/STTR Phase I and Phase II awards satisfies any competition requirement of the Armed Services Procurement Act, the Federal Property and Administrative Services Act, and the Competition in Contracting Act. Therefore, an agency that wishes to fund a Phase III project is not required to conduct another competition in order to satisfy those statutory provisions. Phase III work may be for products, production, services, R/R&D, or any combination thereof that is derived from, extends, or logically concludes efforts performed under prior SBIR/STTR funding agreements. A Federal agency may enter into a Phase III agreement at any time with a Phase I or Phase II awardee.

There is no limit on the number, duration, type, or dollar value of Phase III awards made to a business concern. There is no limit on the time that may elapse between a Phase I or Phase II and a Phase III award. The small business size limits for Phase I and Phase II awards do not apply to Phase III awards.

1.5 Eligibility Requirements

1.5.1 Small Business Concern

Only firms qualifying as SBCs, as defined in Section 2.19, are eligible to participate in these programs. Socially and economically disadvantaged and women-owned SBCs are particularly encouraged to propose.

1.5.2 Place of Performance

R/R&D must be performed in the United States (Section 2.24). However, based on a rare and unique circumstance (for example, if a supply or material or other item or project requirement is not available in the United States), NASA may allow a particular portion of the research or R&D work to be performed or obtained in a country outside of the United States. Proposals must clearly indicate if any work will be performed outside the United States. Prior to award, approval by the Contracting Officer for such specific condition(s) must be in writing.

Note: Offerors are responsible for ensuring that all employees who will work on this contract are eligible under export control and International Traffic in Arms (ITAR) regulations. Any employee who is not a U.S. citizen or a permanent resident may be restricted from working on this contract if the technology is restricted under export control and ITAR regulations unless the prior approval of the Department of State or the Department of Commerce is obtained via a technical assistance agreement or an export license. Violations of these regulations can result in criminal or civil penalties.

1.5.3 Principal Investigator (PI)

The primary employment of the Principal Investigator (PI) shall be with the SBC under the SBIR Program, while under the STTR Program, either the SBC or RI shall employ the PI. Primary employment means that more than 50% of the PI's total employed time (including all concurrent employers, consulting, and self-employed time) is spent with the SBC or RI at time of award and during the entire period of performance. Primary employment with a small business concern precludes full-time employment at another organization. If the PI does not currently meet these primary employment requirements, then the offeror must explain how these requirements will be met if the proposal is selected for contract negotiations that may lead to an award. Co-PI's are not allowed.

Note: NASA considers a fulltime workweek to be nominally 40 hours and we consider 19.9-hour workweek elsewhere to be in conflict with this rule.

REQUIREMENTS	SBIR	STTR
Primary Employment	PI must be with the SBC	PI must be employed with the RI or SBC
Employment Certification	The offeror must certify in the proposal that the primary employment of the PI will be with the SBC at the time of award and during the conduct of the project.	The offeror must certify in the proposal that the primary employment of the PI will be with the SBC or the RI at the time of award and during the conduct of the project.
Co-Principal Investigators	Not Allowed	Not Allowed
Misrepresentation of Qualifications	Shall result in rejection of the proposal or termination of the contract	Shall result in rejection of the proposal or termination of the contract
Substitution of PIs	Shall receive advanced written approval from NASA	Shall receive advanced written approval from NASA

1.6 NASA SBIR"TAV" Subtopics

Subtopics listed in Section 9. (S3.05 and S3.08) of this solicitation have Technology Available (TAV) with NASA IP. Subtopics with the "TAV" designation address the objective of increasing the commercial application of innovations derived from Federal R&D. While NASA scientists and engineers conduct breakthrough research that leads to innovations, the range of NASA's effort does not extend to product development in any of its intramural research areas. Additional work is necessary to exploit these NASA technologies for either infusion or commercial viability and likely requires innovation on behalf of the private sector. However, NASA provides these technologies "as is" and makes no representation or guarantee that additional effort will result in infusion or commercial viability. As with all SBIR awards, these TAV subtopics are intended to cultivate innovation in the private sector and to identify a commercially promising NASA technology and the technological gaps that must be filled in order to transition it to the marketplace.

The NASA technologies identified in "TAV" subtopics are either protected by NASA-owned patents (NASA IP) or if not patented, are dedicated to the public domain. If a TAV subtopic cites a patent, a non-exclusive, royalty-free research license will be required to use the NASA IP during the SBIR performance period. If there is no patent cited, the technology is freely available for use without the need for any license.

> **Disclaimer**: TAV subtopics may include an offer to license NASA IP on a non-exclusive, royalty-free basis, for research use under the SBIR contract. When included in a TAV subtopic as an available technology, use of the NASA IP is strictly voluntary. Whether or not a firm uses NASA IP within their proposed effort will not in any way be a factor in the selection for award.

All offerors submitting proposals addressing TAV subtopics, citing NASA IP must submit a non-exclusive, royalty-free license application if the use of the NASA IP is desired. The NASA license application is available on the NASA SBIR website: http://sbir.gsfc.nasa.gov/SBIR/research_license_app.doc. Only those research license applications accompanying proposals that result in an SBIR award under this solicitation will be granted.

SBIR awards resulting from TAV subtopics that list NASA IP will include, as necessary, the grant of a non-exclusive research license to use the NASA IP under the SBIR contract awarded. SBIR offerors are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NASA IP will be granted unless an SBIR awardee applies for and receives such a license in accordance with the Federal patent licensing regulations at 37 CFR Part 404. Awardees with contracts for subtopics that identify specific NASA IP will be given the opportunity to negotiate a non-exclusive commercialization license or if available, an exclusive commercialization license to the NASA IP.

An SBIR awardee that has been granted a non-exclusive, royalty-free research license to use NASA IP under the SBIR award may, if available and on a non-interference basis, also have to access NASA personnel knowledgeable about the NASA IP. For further information, see Section 5.7.6.

1.7 General Information

1.7.1 Solicitation Distribution

This 2011 SBIR/STTR Program Solicitation is available via the NASA SBIR/STTR Website (http://sbir.nasa.gov), SBCs are encouraged to check the website for program updates and information. Any updates or corrections to the Solicitation will be posted there. If the SBC has difficulty accessing the Solicitation, please contact the Help Desk (Section 1.7.2).

1.7.2 Means of Contacting NASA SBIR/STTR Program

(1) NASA SBIR/STTR Website: **http://sbir.nasa.gov**

(2) Help Desk: The NASA SBIR/STTR Help Desk can answer any questions regarding clarification of proposal instructions and any administrative matters. The Help Desk may be contacted by:

E-mail:	sbir@reisys.com
Telephone:	301-937-0888 between 9:00 a.m.-5:00 p.m. (Mon.-Fri., Eastern Time)
Facsimile:	301-937-0204

The requestor must provide the name and telephone number of the person to contact, the organization name and address, and the specific questions or requests.

(3) NASA SBIR/STTR Program Manager: Specific information requests that could not be answered by the Help Desk should be mailed or e-mailed to:

Dr. Gary C. Jahns, Program Manager
NASA SBIR/STTR Program Management Office
MS 202A-3, Ames Research Center
Moffett Field, CA 94035-1000
Gary.C.Jahns@nasa.gov

2. Definitions

2.1 Allocation of Rights Agreement

A written agreement negotiated between the Small Business Concern and the single, partnering Research Institution, allocating intellectual property rights and rights, if any, to carry out follow-on research, development, or commercialization.

2.2 Commercialization

Commercialization is a process of developing markets, producing and delivering products or services for sale (whether by the originating party or by others). As used here, commercialization includes both Government and non-Government markets.

2.3 Cooperative Research or Research and Development (R/R&D) Agreement

A financial assistance mechanism used when substantial Federal programmatic involvement with the awardee during performance is anticipated by the issuing agency. The Cooperative R/R&D Agreement contains the responsibilities and respective obligations of the parties.

2.4 Cooperative Research or Research and Development (R/R&D)

For purposes of the NASA STTR Program, cooperative R/R&D is that which is to be conducted jointly by the SBC and the RI in which a minimum of 40 percent of the work (before any cost sharing or fee/profit proposed by the firm) is performed by the SBC and a minimum of 30 percent of the work is performed by the RI.

2.5 Economically Disadvantaged Women-Owned Small Businesses (EDWOSBs)

To be an eligible EDWOSB, a company must:

(1) Be a WOSB that is at least 51% owned by one or more women who are "economically disadvantaged". (2) Have one or more economically disadvantaged women manage the day-to-day operations, make long-term decisions for the business, hold the highest officer position in the business and work at the business full-time during normal working hours. A woman is presumed economically disadvantaged if she has a personal net worth of less than $700,000 (with some exclusions), her adjusted gross yearly income averaged over the three years preceding the certification less than $350,000, and the fair market value of all her assets is less than $6 million.

Please note that for both WOSB and EDWOSB, the 51% ownership must be unconditional and direct. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.6 Essentially Equivalent Work

The "scientific overlap," which occurs when (1) substantially the same research is proposed for funding in more than one contract proposal or grant application submitted to the same Federal agency; (2) substantially the same research is submitted to two or more different Federal agencies for review and funding consideration; or (3) a specific research objective and the research design for accomplishing an objective are the same or closely related in two or more proposals or awards, regardless of the funding source.

2.7 Funding Agreement

Any contract, grant, cooperative agreement, or other funding transaction entered into between any Federal agency and any entity for the performance of experimental, developmental, research and development, services, or research work funded in whole or in part by the Federal Government.

2.8 Historically Underutilized Business Zone (HUBZone) Small Business Concern

A HUBZone small business concern means a small business concern that appears on the List of Qualified HUBZone Small Business Concerns maintained by the Small Business Administration. To see the full definition of a HUBzone see the FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html) or go to the SBA HUBzone site (www.sba.gov/hubzone) for more details.

2.9 Infusion

The integration of SBIR/STTR developed knowledge or technologies within NASA programs and projects, other Government agencies and/or commercial entities. This includes integration with NASA program and project funding, development and flight and ground demonstrations.

2.10 Innovation

An innovation is something new or improved, having marketable potential, including: (1) development of new technologies, (2) refinement of existing technologies, or (3) development of new applications for existing technologies.

2.11 Intellectual Property (IP)

The separate and distinct types of intangible property that are referred to collectively as “intellectual property,” including but not limited to: patents, trademarks, copyrights, trade secrets, SBIR/STTR technical data (as defined in Section 2.16), ideas, designs, know-how, business, technical and research methods, other types of intangible business assets, and including all types of intangible assets either proposed or generated by the SBC as a result of its participation in the SBIR/STTR Program.

2.12 NASA Intellectual Property (NASA IP)

NASA IP is NASA-owned, patented technologies that NASA is offering under a non-exclusive, royalty-free research license for use under the SBIR award.

2.13 Principal Investigator (PI)

The one individual designated by the applicant to provide the scientific and technical direction to a project supported by the funding agreement.

2.14 Research Institution (RI)

A U.S. research institution is one that is: (1) a contractor-operated Federally funded research and development center, as identified by the National Science Foundation in accordance with the Government-wide Federal Acquisition Regulation issued in Section 35(c)(1) of the Office of Federal Procurement Policy Act (or any successor legislation thereto), or (2) a nonprofit research institution as defined in Section 4(5) of the Stevenson-Wydler Technology Innovation Act of 1980, or (3) a nonprofit college or university.

2.15 Research or Research and Development (R/R&D)

Creative work that is undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture, and society, and the use of this stock of knowledge to devise new applications. It includes administrative expenses for R&D. It excludes physical assets for R&D, such as R&D equipment and facilities. It also excludes routine product testing, quality control, mapping, collection of general-purpose statistics, experimental production, routine monitoring and evaluation of an operational program, and training of scientific and technical personnel.

> **Basic Research:** systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind. Basic research, however, may include activities with broad applications in mind.
>
> **Applied Research:** systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
>
> **Development:** systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

Note: NASA SBIR/STTR programs do not accept proposals solely directed towards system studies, market research, routine engineering development of existing products or proven concepts and modifications of existing products without substantive innovation (See Section 1.1).

2.16 SBIR/STTR Technical Data

Technical data includes all data generated in the performance of any SBIR/STTR funding agreement.

2.17 SBIR/STTR Technical Data Rights

The rights an SBC obtains for data generated in the performance of any SBIR/STTR funding agreement that an awardee delivers to the Government during or upon completion of a federally funded project, and to which the Government receives a license.

2.18 Service Disabled Veteran-Owned Small Business

A Service-Disabled Veteran-Owned Small Business is one that is: (1) not less than 51% of which is owned by one or more service-disabled veterans or, in the case of any publicly owned business, not less than 51% of the stock of which is owned by one or more service-disabled veterans; (2) management and daily business operations, which are controlled by one or more service-disabled veterans or, in the case of a service-disabled veteran with permanent and severe disability, the spouse or permanent caregiver of such veteran; and (3) is small as defined by e-CFR §125.11.

Service-disabled veteran means a veteran, as defined in 38 U.S.C. 101(2), with a disability that is service connected, as defined in 38 U.S.C. 101(16). For a general definition, see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.19 Small Business Concern (SBC)

An SBC is one that, at the time of award of Phase I and Phase II funding agreements, meets the following criteria:

(1) Is organized for profit, with a place of business located in the United States, which operates primarily within the United States or which makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor;

(2) is in the legal form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust or cooperative; except that where the form is a joint venture, there can be no more than 49 percent participation by business entities in the joint venture;
(3) is at least 51 percent owned and controlled by one or more individuals who are citizens of, or permanent resident aliens in, the United States: except in the case of a joint venture, where each entity to the venture must be 51 percent owned and controlled by one or more individuals who are citizens of, or permanent resident aliens in, the United States; and
(4) has, including its affiliates, not more than 500 employees.

The terms “affiliates” and “number of employees” are defined in greater detail in 13 CFR Part 121. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.20 Socially and Economically Disadvantaged Individual

A socially and economically disadvantaged individual is defined as a member of any of the following groups: Black Americans, Hispanic Americans, Hawaiian Natives, Alaskan Natives, Native Americans, Asian- Pacific Americans, Subcontinent Asian Americans, or any other individual found to be socially and economically disadvantaged by the Small Business Administration (SBA) pursuant to Section 8(a) of the Small Business Act, 15 U.S. Code (U.S.C.) 637(a).

Economically disadvantaged individuals are socially disadvantaged and their ability to compete in the free enterprise system has been impaired due to diminished capital and credit opportunities, as compared to others in the same or similar line of business who are not socially disadvantaged.

2.21 Socially and Economically Disadvantaged Small Business Concern

A socially and economically disadvantaged small business concern is one that is at least 51% owned and controlled by one or more socially and economically disadvantaged individuals, or an Indian tribe, including Alaska Native Corporations (ANCs), a Native Hawaiian Organization (NHO), or a Community Development Corporation (CDC). Control includes both the strategic planning (as that exercised by boards of directors) and the day-to-day management and administration of business operations. See 13 CFR 124.109, 124.110, and 124.111 for special rules pertaining to concerns owned by Indian tribes (including ANCs), NHOs, or CDCs, respectively. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.22 Subcontract

Any agreement, other than one involving an employer-employee relationship, entered into by an awardee of a funding agreement calling for supplies or services for the performance of the original funding agreement.

2.23 Technology Readiness Level (TRLs)

Technology Readiness Level (TRLs) is a uni-dimensional scale used to provide a measure of technology maturity.

Level 1: Basic principles observed and reported.
Level 2: Technology concept and/or application formulated.
Level 3: Analytical and experimental critical function and/or characteristic proof of concept.
Level 4: Component and/or breadboard validation in laboratory environment.
Level 5: Component and/or breadboard validation in relevant environment.
Level 6: System/subsystem model or prototype demonstration in a relevant environment (Ground or Space).
Level 7: System prototype demonstration in an operational (space) environment.
Level 8: Actual system completed and (flight) qualified through test and demonstration (Ground and Space).
Level 9: Actual system (flight) proven through successful mission operations.

Additional information on TRLs is available in Appendix B.

2.24 United States

Includes the 50 States, the territories and possessions of the Federal Government, the Commonwealth of Puerto Rico, the District of Columbia, the Republic of the Marshall Islands, the Federated States of Micronesia, and the Republic of Palau.

2.25 Veteran-Owned Small Business

A veteran-owned SBC is a small business that: (1) is at least 51% unconditionally owned by one or more veterans, as defined at 38 U.S.C. 101(2); or in the case of any publicly owned business, at least 51% of the stock of which is unconditionally owned by one or more veterans; and (2) whose management and daily business operations are controlled by one or more veterans. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

2.26 Women-Owned Small Business

To be an eligible WOSB, a company must: (1) be a small business that is at least 51% percent unconditionally and directly owned and controlled by one or more women who are United States citizens. (2) have one or more women who manage the day-to-day operations, make long-term decisions for the business, hold the highest officer position in the business and work at the business full-time during normal working hours.

Please note that for a WOSB the 51% ownership must be unconditional and direct. For a general definition please see FAR 2.101 (https://www.acquisition.gov/far/current/html/Subpart 2_1.html).

3. Proposal Preparation Instructions and Requirements

3.1 Fundamental Considerations

The object of Phase II is to continue the R/R&D effort from the completed Phase I. Only SBIR/STTR awardees in Phase Is are eligible to participate in Phases II and III.

Contract Deliverables
Phase II contracts shall require the delivery of reports that present (1) the work and results accomplished, (2) the scientific, technical and commercial merit and feasibility of the proposed innovation and Phase II results, (3) its relevance and significance to one or more NASA needs (Section 9), and (4) the progress towards transitioning the proposed innovation and Phase II results into follow-on investment, development, testing and utilization for NASA mission programs and other potential customers. The delivery of a prototype unit, software package, or a complete product or service, for NASA testing and utilization is desirable and, if proposed, must be described and listed as a deliverable in the proposal.

Report deliverables shall be submitted electronically via the EHB. NASA requests the submission of report deliverables in PDF format. Other acceptable formats are MS Word, MS Works, and WordPerfect.

3.2 Phase II Proposal Requirements

3.2.1 General Requirements

The Phase I contract will serve as a request for proposal (RFP) for the Phase II follow-on project. Phase II proposals are more comprehensive than those required for Phase I. Submission of a Phase II proposal is in accordance with Phase I contract requirements and is voluntary. NASA assumes no responsibility for any proposal preparation expenses.

A competitive Phase II proposal will clearly and concisely (1) describe the proposed innovation relative to the state of the art and the market, (2) address Phase I results relative to the scientific, technical merit and feasibility of the proposed innovation and its relevance and significance to the NASA needs as described in Section 9, and (3) provide the planning for a focused project that builds upon Phase I results and encompasses technical, market, financial and business factors relating to the development and demonstration of the proposed innovation, and its transition into products and services for NASA mission programs and other potential customers.

3.2.2 Format Requirements

<u>Proposals that do not follow the formatting requirement are subject to rejection during administrative screening.</u>

Page Limitations and Margins
Any page(s) going over the required page limited will be deleted and omitted from the proposal review. A Phase II proposal shall not exceed a total of 50 standard 8 1/2 x 11 inch (21.6 x 27.9 cm) pages. Forms A, B, and C count as one page each regardless of whether the completed forms print as more than one page. Each page shall be numbered consecutively at the bottom. Margins shall be 1.0 inch (2.5 cm). All required items of information must be covered in the proposal and will be included in the page total. The space allocated to each part of the technical content will depend on the project and the offeror's approach.

Each proposal submitted must contain the following items in the order presented:

(1) Cover Sheet (Form A), electronically endorsed, counts as 1 page towards the 50-page limit;
(2) Proposal Summary (Form B), counts as 1 page towards the 50-page limit;

(3) Budget Summary (Form C), counts as 1 page towards the 50-page limit;
(4) Cooperative R/R&D Agreement between the SBC and RI **(STTR only)**, counts as 1 page towards the 50-page limit;
(5) Technical Content (11 Parts in order as specified in Section 3.2.4, **not to exceed 47 pages for SBIR and 46 pages for STTR**), including all graphics, and starting with a table of contents,
(6) Briefing Chart (Not included in the 50-page limit and must not contain proprietary data).

Type Size
No type size smaller than 10 point shall be used for text or tables, except as legends on reduced drawings. Proposals prepared with smaller font sizes will be rejected without consideration.

Header/Footer Requirements
Header must include firm name, proposal number, and project title. Footer must include the page number and proprietary markings if applicable. Margins can be used for header/footer information.

Classified Information
NASA does not accept proposals that contain classified information.

3.2.3 Forms
This part of the submission is all done electronically, with each form counting as 1 page towards the 50-page limit and accounting for pages 1-3 of the proposal regardless of the length.

3.2.3.1 Cover Sheet (Form A)

A sample Cover Sheet form is provided in Section 8. The offeror shall provide complete information for each item and submit the form as required in Section 6. The proposal project title shall be concise and descriptive of the proposed effort. The title should not use acronyms or words like "Development of" or "Study of." The NASA research topic title must not be used as the proposal title. Form A counts as one page towards the 50-page limit.

Note: The Cover Sheet (Form A) is public information and may be disclosed. Do not include proprietary information on Form A.

3.2.3.2 Proposal Summary (Form B)

A sample Proposal Summary form is provided in Section 8. The offeror shall provide complete information for each item and submit Form B as required in Section 6. Form B counts as one page towards the 50-page limit.

Note: Proposal Summary (Form B), including the Technical Abstract, is public information and may be disclosed. Do not include proprietary information on Form B.

3.2.3.3. Budget Summary (Form C)

A sample of the Budget Summary form is provided in Section 8. The offeror shall complete the Budget Summary following the instructions provided with the sample form. The total requested funding for the Phase II effort shall not exceed $700,000. A text box is provided on the electronic budget form for additional explanation. Information shall be submitted to explain the offeror’s plans for use of the requested funds to enable NASA to determine whether the proposed price is fair and reasonable. Form C counts as one page towards the 50-page limit.

Note: The Government is not responsible for any monies expended by the applicant before award of any contract.

3.2.4 Technical Proposal

This part of the submission shall not contain any budget data and must consist of all eleven (11) parts listed below in the given order. All eleven parts of the technical proposal must be numbered and titled. Parts that are not applicable must be included and marked "Not Applicable." A proposal omitting any part will be considered non-responsive to this Solicitation and will be rejected during administrative screening. The required table of contents is provided below:

Phase II Table of Contents

Part 1: Table of Contents……………………………………………………………………………Page 4
Part 2: Identification and Significance of the Innovation and Results of the Phase I Proposal
Part 3: Technical Objectives
Part 4: Work Plan
Part 5: Related R/R&D
Part 6: Key Personnel
Part 7: Phase III Efforts, Commercialization and Business Planning
Part 8: Facilities/Equipment
Part 9: Subcontracts and Consultants
Part 10: Potential Post Applications
Part 11: Essentially Equivalent and Duplicate Proposals and Awards

Part 1: Table of Contents
The technical content shall begin with a brief table of contents indicating the page numbers of each of the parts of the proposal and should start on page 4 because Forms A, B, and C account for pages 1-3.

Part 2: Identification and Significance of the Innovation and Results of the Phase I Proposal
Drawing upon Phase I results, succinctly describe:

(1) The proposed innovation;
(2) the relevance and significance of the proposed innovation to a need or needs, within a subtopic described in Section 9;
(3) the proposed innovation relative to the state of the market, the state of the art, and its feasibility; and
(4) the capability of the offeror to conduct the proposed R/R&D and to fulfill the commercialization of the proposed innovation.

Part 3: Technical Objectives
Define the specific objectives of the Phase II research and technical approach.

Note: All offerors submitting proposals addressing TAV subtopics that are planning to use NASA IP must describe their planned developments with the IP. The NASA Research Application should be added as an attachment at the end of the proposal and will not count towards the page limit.

Part 4: Work Plan
Include a detailed description of the Phase II R/R&D plan to meet the technical objectives. The plan should indicate what will be done, where it will be done, and how the R/R&D will be carried out. Discuss in detail the methods planned to achieve each task or objective. Task descriptions, schedules, resource allocations, estimated task hours for each key personnel and planned accomplishments including project milestones shall be included.

STTR: In addition, the work plan will specifically address the percentage and type of work to be performed by the SBC and the RI. The plan will provide evidence that the SBC will exercise management direction and control of the performance of the STTR effort, including situations in which the PI may be an employee of the RI.

Part 5: Related R/R&D
Describe significant current and/or previous R/R&D that is directly related to the proposal including any conducted by the PI or by the offeror. Describe how it relates to the proposed effort and any planned coordination with outside sources. The offeror must persuade reviewers of his or her awareness of key recent R/R&D conducted by others in the specific subject area. As an option, the offer may use this section to include bibliographic references.

Part 6: Key Personnel and Bibliography of Directly Related Work
Identify key personnel involved in Phase II activities whose expertise and functions are essential to the success of the project. Provide bibliographic information including directly related education and experience.

The PI is considered key to the success of the effort and must make a substantial commitment to the project. The following requirements are applicable:

Functions: The functions of the PI are: planning and directing the project; leading it technically and making substantial personal contributions during its implementation; serving as the primary contact with NASA on the project; and ensuring that the work proceeds according to contract agreements. Competent management of PI functions is essential to project success. The Phase II proposal shall describe the nature of the PI's activities and the amount of time that the PI will personally apply to the project. The amount of time the PI proposes to spend on the project must be acceptable to the Contracting Officer.

Qualifications: The qualifications and capabilities of the proposed PI and the basis for PI selection are to be clearly presented in the proposal. NASA has the sole right to accept or reject a PI based on factors such as education, experience, demonstrated ability and competence, and any other evidence related to the specific assignment.

Eligibility: This part shall also establish and confirm the eligibility of the PI, and indicate the extent to which other proposals recently submitted or planned for submission in the year and existing projects commit the time of the PI concurrently with this proposed activity. Any attempt to circumvent the restriction on PIs working more than half time for an academic or a nonprofit organization by substituting an ineligible PI will result in rejection of the proposal. However, for an STTR the PI can be primarily employed by either the SBC or the RI. Please see section 1.5.3 for further explanation.

Note: If the Phase II PI is different than that proposed under the Phase I, please provide rational for the change.

Part 7: Phase III Efforts, Commercialization and Business Planning
Present a plan for commercialization (Phase III) of the proposed innovation. Commercialization encompasses the transition of technology into products and services for NASA mission programs, other Government agencies and non-Government markets. The commercialization plan, at a minimum, shall address the following areas:

(1) Market Feasibility and Competition: Describe (a) the target market(s) of the innovation and the associated product or service, (b) the competitive advantage(s) of the product or service; (c) key potential customers, including NASA mission programs and prime contractors; (d) projected market size (NASA, other Government and/or non-Government); (e) the projected time to market and estimated market share within five years from market-entry; and (f) anticipated competition from alternative technologies, products and services and/or competing domestic or foreign entities.

(2) Commercialization Strategy and Relevance to the Offeror: Present the commercialization strategy for the innovation and associated product or service and its relationship to the SBC's business plans for the next five years. Infusion into NASA missions and projects is an option for commercialization strategy.

(3) Key Management, Technical Personnel and Organizational Structure: Describe: (a) the skills and experiences of key management and technical personnel in technology commercialization; (b) current organizational structure; and (c) plans and timelines for obtaining expertise and personnel necessary for commercialization.

(4) Production and Operations: Describe product development to date as well as milestones and plans for reaching production level, including plans for obtaining necessary physical resources.

(5) Financial Planning: Delineate private financial resources committed to the development and transition of the innovation into market-ready product or service. Describe the projected financial requirements and the expected or committed capital and funding sources necessary to support the planned commercialization of the innovation. Provide evidence of current financial condition (e.g., standard financial statements including a current cash flow statement).

(6) Intellectual Property: Describe plans and current status of efforts to secure intellectual property rights (e.g., patents, copyrights, trade secrets) necessary to obtain investment, attain at least a temporal competitive advantage, and achieve planned commercialization.

Part 8: Facilities/Equipment
General: Describe available equipment and physical facilities necessary to carry out the proposed Phase II and projected Phase III efforts. Items of equipment or facilities to be purchased (as detailed in the cost proposal) shall be justified under this section.

Use of Government facilities or property: In accordance with the Federal Acquisition Regulations (FAR) Part 45, it is NASA's policy not to provide facilities (capital equipment, tooling, test and computer facilities, etc.) for the performance of work under SBIR/STTR contracts. Generally an SBC will furnish its own facilities to perform the proposed work on the contract. Government-wide SBIR and STTR policies restrict the use of any SBIR/STTR funds for the use of Government equipment and facilities. This does not preclude an SBC from utilizing a Government facility or Government equipment, but any charges for such use may not be paid for with SBIR/STTR funds (SBA SBIR Policy Directive, Section 9 (f) (3)). In rare and unique circumstances, SBA may issue a case-by-case waiver to this provision after review of an agency's written justification. NASA may not and cannot fund the use of the Federal facility or personnel for the SBIR/STTR project with NASA program or project money.

When a proposed project or product demonstration requires the use of unique Government facilities or equipment, but does not require funding from the SBIR/STTR programs, then the offeror must provide a letter from the Government agency that verifies the availability. Failure to provide the site manager's written authorization of use of Government property may invalidate any proposal selection.

When a proposed project or product demonstration requires the use of unique Government facilities or equipment to be funded by the SBIR/STTR programs, then the offeror must provide a) a letter from the SBC Official explaining why the SBIR/STTR research project requires the use of the Federal facility or personnel, including data that verifies the absence of non-Federal facilities or personnel capable of supporting the research effort, and b) a statement, signed by the appropriate Government official at the facility, verifying that it will be available for the required effort. Failure to provide this explanation and the site manager's written authorization of use may invalidate any proposal selection. Additionally, any proposer requiring the use of Government property or facilities must, within five (5) days of notification of selection for negotiations, provide to the NASA Shared Services Center Contracting Officer all required documentation, to include, an agreement by and between the Contractor and the appropriate Government facility, executed by the Government official authorized to approve such use. The Agreement must delineate the terms of use, associated costs, property and facility responsibilities and liabilities.

A waiver from the SBA is required before a proposer can use SBIR/STTR funds for Government equipment or facilities. Proposals requiring waivers must explain why the waiver is appropriate. NASA will provide this explanation to SBA during the Agency waiver process. NASA cannot guarantee that a waiver from this policy can be obtained from SBA.

Part 9: Subcontracts and Consultants

Subject to the restrictions set forth below**,** the SBC may establish business arrangements with other entities or individuals to participate in performance of the proposed R/R&D effort. The offeror must describe all subcontracting or other business arrangements, and identify the relevant organizations and/or individuals with whom arrangements are planned. The expertise to be provided by the entities must be described in detail, as well as the functions, services, number of hours and labor rates. Offerors are responsible for ensuring that all organizations and individuals proposed to be utilized are actually available for the time periods required. Subcontract costs should be documented in the subcontractor/consultant budget section in Form C. Subcontractors' and consultants' work has the same place of performance restrictions as stated in Section 1.5.2. The following restrictions apply to the use of subcontracts/consultants:

SBIR Phase II	STTR Phase II
The proposed subcontracted business arrangements must not exceed 50 percent of the research and/or analytical work (as determined by the total cost of the proposed subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any).	A minimum of 40 percent of the research or analytical work must be performed by the proposing SBC and 30 percent by the RI. The proposed subcontracted business arrangements must not exceed 30 percent of the research and/or analytical work (as determined by the total cost of the subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any).

Example:

Total price to include profit - $725,000
Profit - $21,750
Total price less profit - $725,000 - $21,750 = $703,250
Subcontractor cost - $250,000
G&A - 5%
G&A on subcontractor cost - $250,000 x 5% = $12,500
Subcontractor cost plus G&A - $250,000 + $12,500 = $262,500
Percentage of subcontracting effort – subcontractor cost plus G&A / total price less profit - $262,500/$703,250 = 37.3%

For an SBIR Phase II this is acceptable since it is below the limitation of 50%.
For an STTR Phase II this is unacceptable since it is above 30% limitation.

Part 10: Potential Post Applications (Commercialization)

Building upon Section 3.2.4, Part 7**,** further specify the potential NASA and commercial applications of the innovation and the associated potential customers; such as NASA mission programs and projects, within target markets. Potential NASA applications include the projected utilization of proposed contract deliverables (e.g., prototypes, test units, software) and resulting products and services by NASA organizations and contractors.

Part 11a: Essentially Equivalent and Duplicate Proposals and Awards

WARNING – While it is permissible with proposal notification to submit identical proposals or proposals containing a significant amount of essentially equivalent work for consideration under numerous Federal program solicitations, it is unlawful to enter into funding agreements requiring essentially equivalent work. Offerors are at risk for submitting essentially equivalent proposals and therefore, are strongly encouraged to disclose these issues to the soliciting agency to resolve the matter prior to award. See Part 11b.

If an applicant elects to submit identical proposals or proposals containing a significant amount of essentially equivalent work under other Federal program solicitations, a statement must be included in each such proposal indicating:

1) The name and address of the agencies to which proposals were submitted or from which awards were received.
2) Date of proposal submission or date of award.
3) Title, number, and date of solicitations under which proposals were submitted or awards received.
4) The specific applicable research topics for each proposal submitted for award received.
5) Titles of research projects.
6) Name and title of principal investigator or project manager for each proposal submitted or award received.

A summary of essentially equivalent work information is also required on Form A.

Part 11b: Related Research and Development Proposals and Awards

All federal agencies have a mandate to reduce waste, fraud, and abuse in federally funded programs. The submission of essentially equivalent work and the acceptance of multiple awards for essentially equivalent work in the SBIR/STTR program has been identified as an area of abuse. SBIR/STTR funding agencies and the Office of the Inspector General are actively evaluating proposals and awards to eliminate this problem. Related research and development includes proposals and awards that do not meet the definition of "Essentially Equivalent Work" (see Section 2.6), but are related to the technology innovation in the proposal being submitted. Related research and development could be interpreted as essentially equivalent work by outside reviewers without additional information. Therefore, if you are submitting closely related proposals or your firm has closely related research and development that is currently or previously funded by NASA or other federal agencies, it is to your advantage to describe the relationships between this proposal and related efforts clearly delineating why this should not be considered an essentially equivalent work effort. These explanations should not be longer than one page, will not be included in the page count, and will not be part of the technical evaluation of the proposal.

3.2.5 Capital Commitments Addendum Supporting Phase II and Phase III

Describe and document capital commitments from non-SBIR/STTR sources or from internal SBC funds for pursuit of Phase II and Phase III efforts. Offerors for Phase II contracts are strongly urged to obtain non-SBIR/STTR funding support commitments for follow-on Phase III activities and additional support of the Phase II from parties other than the proposing firm. Funding support commitments must show that a specific and substantial amount will be made available to the firm to pursue the stated Phase II and/or Phase III objectives. They must indicate the source, date, and conditions or contingencies under which the funds will be made available. Alternatively, self-commitments of the same type and magnitude that are required from outside sources can be considered. If a Phase III will be funded internally, offerors should describe their financial position.

Evidence of funding support commitments from outside parties must be provided in writing and should accompany the Phase II proposal. Letters of commitment should specify available funding commitments, other resources to be provided, and any contingent conditions. Expressions of technical interest by such parties in the Phase II research or of potential future financial support are insufficient and will not be accepted as support commitments by NASA. Letters of commitment should be added as an addendum to the Phase II proposal. This addendum will not be counted against the 50-page limitation.

3.2.6 Phase III Awards resulting from NASA SBIR/STTR Awards

If the SBC has received any Phase III awards resulting from work on any NASA SBIR or STTR awards, provide the related Phase I or Phase II contract number, name of the Phase III awarding agency, date of award, funding agreement number, amount, project title, period of performance and current commercialization status for each award. This listing is not included in the 50-page limit and content should be limited to information requested above. An electronic form will be provided during the submissions process.

3.2.7 TAV Subtopic Application

If proposing to use a TAV application, then offeror must submit a NASA Research License Application described in Section 1.6 and describe the technical objectives in Part 3 of the proposal (see Section 3.2.4, Part 3). This application will not be counted against the 50-page limit.

SBIR Phase II awards that continue development of NASA IP begun under a Phase I TAV subtopic award, will include the grant of a non-exclusive, royalty-free research license to use the NASA IP during the Phase II award. The Phase II proposal must identify the Phase I TAV subtopic award by contract number and identifies the NASA IP by patent number. There is no need to submit a NASA license application if an application was submitted with the Phase I proposal, for further information see Section 5.7.6.

3.2.8 Briefing Chart

A one-page briefing chart is required to assist in the ranking and advocacy of proposals prior to selection. Submission of the briefing chart is not counted against the 50-page limit, and *must not* contain any proprietary data or ITAR restricted data. An example chart is provided in Appendix A. An electronic form will be provided during the submissions process.

3.2.9 Contractor Responsibility Information

No later then 10 days after the notification of selection for negotiations the offeror shall provide a signed statement from your financial institutions stating whether or not your firm is in good standing and how long you have been with the institution.

Note: Companies with Prior NASA SBIR/STTR Awards

NASA has instituted a comprehensive commercialization survey/data gathering process for companies with prior NASA SBIR/STTR awards. Information received from SBIR/STTR awardees completing the survey is kept confidential, and will not be made public except in broad aggregate, with no company-specific attribution. The commercialization metrics survey is a required part of the proposal submissions process and must be completed via the Proposal Submission Electronic Handbook.

3.2.10 Allocation of Rights Agreement (STTR awards only)

No more than 10 working days after the Selection Announcement for negotiation, the offeror should provide to the Contracting Officer, a completed **Allocation of Rights Agreement (ARA),** which has been signed by authorized representatives of the SBC, RI and subcontractors and consultants, as applicable. The ARA shall state the allocation of intellectual property rights with respect to the proposed STTR activity and planned follow-on research, development and/or commercialization. A sample ARA is available in Section 8 of this Solicitation.

In compliance with the SBA STTR Policy Directive 8.(c) (1) STTR proposers are notified that a completed Allocation of Rights Agreement (ARA), which has been signed by authorized representatives of the SBC, RI and subcontractors and consultants, as applicable is required to be completed and executed prior to commencement of work under the STTR program. The ARA shall state the allocation of intellectual property rights with respect to the proposed STTR activity and planned follow-on research, development and/or commercialization. The SBC must certify in all proposals that the agreement is satisfactory to the SBC.

4. Method of Selection and Evaluation Criteria

4.1 Phase II Proposals

All Phase II proposals will be evaluated and ranked on a competitive basis. Proposals will be initially screened to determine responsiveness. Proposals determined to be responsive to the administrative requirements of this Solicitation and having a reasonable potential of meeting a NASA need, as evidenced by the technical abstract included in the Proposal Summary (Form B), will be technically evaluated by NASA personnel to determine the most promising technical and scientific approaches. Each proposal will be reviewed on its own merit. NASA is under no obligation to fund any proposal or any specific number of proposals in a given topic. It also may elect to fund several or none of the proposed approaches to the same topic or subtopic.

4.1.1 Evaluation Process

The Phase II evaluation process is similar to the Phase I process. Each proposal will be reviewed by NASA scientists and engineers and by qualified experts outside of NASA as needed. In addition, those proposals with high technical merit will be reviewed for commercial merit. NASA may use a peer review panel to evaluate commercial merit. Panel membership may include non-NASA personnel with expertise in business development and technology commercialization.

4.1.2 Phase II Evaluation Criteria

NASA intends to select for award those proposals that best meet the Government's need(s). Note: Past Performance will not be a separate evaluation factor but will be evaluated under factors 1 and 4 below. The evaluation of Phase II proposals under this Solicitation will apply the following factors described below:

Factor 1: Scientific/Technical Merit and Feasibility
The proposed R/R&D effort will be evaluated on its originality, the feasibility of the innovation, and potential technical value. In addition, past performance of Phase I will be evaluated to determine the degree to which Phase I objectives were met, and whether the Phase I results indicate a Phase II project is appropriate.

Factor 2: Experience, Qualifications and Facilities
The technical capabilities and experience of the PI or project manager, key personnel, staff, consultants and subcontractors, if any, are evaluated for consistency with the research effort and their degree of commitment and availability. The necessary instrumentation or facilities required must show to be adequate and any reliance on external sources, such as Government Furnished Equipment or Facilities, addressed (Section 3.2.4).

Factor 3: Effectiveness of the Proposed Work Plan
The work plan will be reviewed for its comprehensiveness, effective use of available resources, labor distribution, and the proposed schedule for meeting the Phase II objectives. The methods planned to achieve each objective or task should be discussed in detail. The proposed path beyond Phase II for further development and infusion into a NASA mission or program will also be reviewed. Please see Factor 5 for price evaluation criteria.

STTR: The clear delineation of responsibilities of the SBC and RI for the success of the proposed cooperative R/R&D effort will be evaluated. The offeror must demonstrate the ability to organize for effective conversion of intellectual property into products and services of value to NASA and the commercial marketplace.

Factor 4: Commercial Potential and Feasibility
The proposal will be evaluated for the commercial potential and feasibility of the proposed innovation and associated products and services. The offeror's experience and record in technology commercialization,

current funding commitments from private or non-SBIR funding sources, existing and projected commitments for Phase III funding, investment, sales, licensing, and other indicators of commercial potential and feasibility will be considered along with the commercialization plan for the innovation. Evaluation of the commercialization plan and the overall proposal will include consideration of the following areas:

(1) Commercial Potential and Feasibility of the Innovation: This includes assessment of (a) the transition of the innovation into a well-defined product or service; (b) a realistic target market niche; (c) a product or service that has strong potential for meeting a well-defined need within the target market; and (d) a commitment of necessary financial, physical, and/or personnel resources.

(2) Intent and Commitment of the Offeror: This includes assessing the commercialization of the innovation for (a) importance to the offeror's current business and strategic planning; (b) reliance on (or lack thereof) Government markets; and (c) adequacy of funding sources necessary to bring technology to identified market.

(3) Capability of the Offeror to Realize Commercialization: This includes assessment of (a) the offeror's past performance, experience, and success in technology commercialization; (b) the likelihood that the offeror will be able to obtain the remaining necessary financial, technical, and personnel-related resources; and (c) the current strength and continued financial viability of the offeror.

Commercialization encompasses the infusion of innovative technology into products and services for NASA mission programs, other Government agencies and non-Government markets.

Factor 5: Price Reasonableness
The offeror's cost proposal will be evaluated for price reasonableness based on the information provided in (Form C). NASA will comply with the FAR and NASA FAR Supplement (NFS) to evaluate the proposed price/cost to be fair and reasonable.

After completion of evaluation for price reasonableness and determination of responsibility the contracting officer shall submit a recommendation for award to the Source Selection Official.

Scoring of Factors and Weighting: Factors 1, 2, and 3 will be scored numerically with Factor 1 worth 50 percent and Factors 2 and 3 each worth 25 percent. The sum of the scores for Factors 1, 2, and 3 will comprise the Technical Merit score. Proposals receiving numerical scores of 85 percent or higher will be evaluated and rated for their commercial potential. The evaluation for Factor 4, Commercial Potential and Feasibility, will be in the form of an adjectival rating (Excellent, Very Good, Average, Below Average, Poor). For Phase II proposals, commercial merit is a critical factor. Factors 1 - 4 will be evaluated and used in the selection of proposals for negotiation. Factor 5 will be evaluated and used in the selection for award.

4.1.3 Selection

Proposals recommended for negotiations will be forwarded to the Program Management Office for analysis and presented to the Source Selection Official and Mission Directorate Representatives. Final selection decisions will consider the recommendations, overall NASA priorities, program balance and available funding, as well as any other evaluations or assessments (particularly pertaining to commercial potential). The Source Selection Official has the final authority for choosing the specific proposals for contract negotiation. Each proposal selected for negotiation will be evaluated for cost/price reasonableness. After completion of evaluation for cost/price reasonableness and a determination of responsibility the contracting officer will submit a recommendation for award to the Source Selection Official.

The list of proposals selected for negotiation will be posted on the NASA SBIR/STTR Website (http://sbir.nasa.gov). All firms will receive a formal notification letter. A Contracting Officer will negotiate an appropriate contract to be signed by both parties before work begins.

4.2 Debriefing of Unsuccessful Offerors

After selection for negotiations have been announced, debriefings for unsuccessful proposals will be available to the offeror's corporate official or designee via e-mail. Telephone requests for debriefings will not be accepted. Debriefings are not opportunities to reopen selection decisions. They are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal in order to help offerors identify constructive future action by the offeror. Debriefings will not disclose the identity of the proposal evaluators, proposal scores, the content of, or comparisons with other proposals.

To request debriefings on proposals, offerors must request via e-mail to the SBIR/STTR Program Support Office at sbir@reisys.com within 60 days after selection announcement. Late requests will not be honored.

5. Considerations

5.1 Awards

5.1.1 Availability of Funds

All Phase II awards are subject to availability of funds. NASA has no obligation to make any specific number of awards based on this Solicitation, and may elect to make several or no awards in any specific technical topic or subtopic.

SBIR	STTR
➢ NASA anticipates that approximately 45 percent of the successfully completed Phase I projects from the SBIR 2011 Solicitation will be selected for Phase II. Phase II agreements will be firm-fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $700,000.	➢ NASA anticipates that approximately 45 percent of the successfully completed Phase I projects from the STTR 2011 Solicitation will be selected for Phase II. Phase II agreements will be firm-fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $700,000.

5.1.2 Contracting

To simplify contract award and reduce processing time, all contractors selected for Phase II contracts should ensure that:

(1) All information in your proposal is current, e.g., your address has not changed, the proposed PI is the same, etc.
(2) Your firm is registered in CCR and all information is current. NASA uses the CCR to populate its contract and payment systems; if the information in the CCR is not current, your award and payments will be delayed.
(3) The representations and certifications in ORCA (Online Representations and Certifications Application) are current.
(4) The VETS 100 report submitted by your firm to the Department of Labor is current.
(5) Your firm HAS NOT proposed a Co-Principal Investigator.
(6) STTR awardees should execute their Allocation of Rights Agreement within 10 days of the Selection for Negotiation Announcement.
(7) Your firm timely responds to all communications from the NSSC Contracting Officer.

From the time of proposal selection until the award of a contract, all communications shall be submitted electronically to NSSC-SBIR-STTR@nasa.gov.

Note: Costs incurred prior to and in anticipation of award of a contract are entirely the risk of the contractor in the event that a contract is not subsequently awarded. A selection notification is not to be misconstrued as an award notification to commence work.

5.2 Phase II Reporting

The technical reports are required as described in the contract and are to be provided to NASA. These reports shall document progress made on the project and activities required for completion. Periodic certification for payment will be required as stated in the contract. A final report must be submitted to NASA upon completion of the Phase II R/R&D effort in accordance with applicable contract provisions.

All reports are required to be submitted electronically via the EHB. Everyone with access to the NASA network will be required to use the NASA Account Management System (NAMS). This is the Agency's centralized system for requesting and maintaining accounts for NASA IT systems and applications. The system contains user account information, access requests, and account maintenance processes for NASA employees, contractors, and remote users such as educators and foreign users. A basic background check is required for this account.

5.3 Payment Schedule for Phase II

All NASA SBIR and STTR contracts are firm-fixed-price contracts. The exact payment terms for Phase II will be included in the contract. The progress payment method will not be authorized, but other forms of financing arrangements will be considered.

Invoices: All invoices are required to be submitted electronically via the SBIR/STTR website in the EHB.

5.4 Release of Proposal Information

In submitting a proposal, the offeror agrees to permit the Government to disclose publicly the information contained on the Proposal Cover (Form A) and the Proposal Summary (Form B). Other proposal data is considered to be the property of the offeror, and NASA will protect it from public disclosure to the extent permitted by law including the Freedom of Information Act (FOIA).

5.5 Access to Proprietary Data by Non-NASA Personnel

5.5.1 Non-NASA Reviewers

In addition to Government personnel, NASA, at its discretion and in accordance with 1815.207-71 of the NASA FAR Supplement, may utilize qualified individuals from outside the Government in the proposal review process. Any decision to obtain an outside evaluation shall take into consideration requirements for the avoidance of organizational or personal conflicts of interest and the competitive relationship, if any, between the prospective contractor or subcontractor(s) and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

5.5.2 Non-NASA Access to Confidential Business Information

In the conduct of proposal processing and potential contract administration, the Agency may find it necessary to provide proposal access to other NASA contractor and subcontractor personnel. NASA will provide access to such data only under contracts that contain an appropriate NFS 1852.237-72 Access to Sensitive Information clause that requires the contractors to fully protect the information from unauthorized use or disclosure.

5.6 Proprietary Information in the Proposal Submission

If proprietary information is provided by an applicant in a proposal, which constitutes a trade secret, proprietary commercial or financial information, confidential personal information or data affecting the national security, it will be treated in confidence to the extent permitted by law. This information must be clearly marked by the applicant as confidential proprietary information. NASA will treat in confidence pages listed as proprietary in the following legend that appears on Cover Sheet (Form A) of the proposal:

"This data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal, provided that a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement and pursuant to applicable law.

This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ____ of this proposal."

Note: Do not label the entire proposal proprietary. The Proposal Cover (Form A), the Proposal Summary (Form B), and the Briefing Chart should not contain proprietary information**;** and any page numbers that would correspond to these must not be designated proprietary in Form A.

Information contained in unsuccessful proposals will remain the property of the applicant. The Government will, however, retain copies of all proposals.

5.7 Limited Rights Information and Data

The clause at FAR 52.227-20, Rights in Data—SBIR/STTR Program, governs rights to data used in, or first produced under, any Phase I or Phase II contract. The following is a brief description of FAR 52.227-20, it is not intended to supplement or replace the FAR.

5.7.1 Non-Proprietary Data

Some data of a general nature are to be furnished to NASA without restriction (i.e., with unlimited rights) and may be published by NASA. This data will normally be limited to the project summaries accompanying any periodic progress reports and the final reports required to be submitted. The requirement will be specifically set forth in any contract resulting from this Solicitation.

5.7.2 Proprietary Data

When data that is required to be delivered under an SBIR/STTR contract qualifies as “proprietary,” i.e., either data developed at private expense that embody trade secrets or are commercial or financial and confidential or privileged, or computer software developed at private expense that is a trade secret, the contractor, if the contractor desires to continue protection of such proprietary data, shall not deliver such data to the Government, but instead shall deliver form, fit, and function data.

5.7.3 Non-Disclosure Period

For a period of 4 years after acceptance of all items to be delivered under an SBIR/STTR contract, the Government agrees to use these data for Government purposes only, and they shall not be disclosed outside the Government (including disclosure for procurement purposes) during such period without permission of the Contractor, except that, subject to the foregoing use and disclosure prohibitions, such data may be disclosed for use by support Contractors. After the aforesaid 4-year period, the Government has a royalty-free license to use, and to authorize others to use on its behalf, these data for Government purposes, but is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of these data by third parties.

5.7.4 Copyrights

Subject to certain licenses granted by the contractor to the Government, the contractor receives copyright to any data first produced by the contractor in the performance of an SBIR/STTR contract.

5.7.5 Invention Reporting, Election of Title and Patent Application Filing

NASA SBIR and STTR contracts will include FAR 52.227-11 Patent Rights – Ownership by the Contractor, which requires the SBIR/STTR contractors to do the following. Contractors must disclose all subject inventions to NASA within two (2) months of the inventor’s report to the awardees. A subject invention is any invention or discovery which is or may be patentable, and is conceived or first actually reduced to practice in the performance of the contract. Once the contractor discloses a subject invention, the contractor has up to 2 years to notify the Government whether it elects to retain title to the subject invention. If the contractor elects to retain title, a patent application covering the subject invention must be filed within 1 year. If the contractor fails to do any of these within time specified periods, the Government has the right to obtain title. To the extent authorized by 35 USC 205, the Government will not make public any information disclosing such inventions, allowing the contractor the permissible time to file a patent.

The awardee may use whatever format is convenient to report inventions. NASA prefers that the awardee use either the electronic or paper version of NASA Form 1679, Disclosure of Invention and New Technology (Including Software), to report inventions. Both the electronic and paper versions of NASA Form 1679 may be accessed at the electronic New Technology Reporting Web site http://ntr.ndc.nasa.gov/. A New Technology Summary Report (NTSR) listing all inventions developed under the contract or certifying that no inventions were developed must be also be submitted. Both reports shall also be uploaded to the SBIR/STTR Electronic Handbook (EHB) at https://ehb8.gsfc.nasa.gov/contracts/public/firmHome.do

5.7.6 NASA-owned Patents (NASA IP)

SBIR Phase II awards that continue development of NASA IP begun under a Phase I TAV subtopic award, will include the grant of a non-exclusive, royalty-free research license to use the NASA IP during the Phase II award. The Phase II proposal must identify the Phase I TAV subtopic award by contract number and identifies the NASA IP by patent number. There is no need to submit a NASA license application if an application was submitted with the Phase I proposal. SBIR offerors are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NASA background patent is granted until an SBIR awardee applies for, negotiates and receives such a license. Awardees of solicited subtopics that identify specific NASA-owned background patented will be given the opportunity to negotiate a non-exclusive commercialization license to such background inventions or if available, an exclusive commercialization license to such background inventions. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 CFR Part 404.

5.8 Cost Sharing

Cost sharing occurs when a Contractor proposes to bear some of the burden of reasonable, allocable and allowable contract costs. Cost sharing is permitted, but not required for proposals under this Solicitation. Cost sharing is not an evaluation factor in consideration of your proposal. Cost sharing, if included, should be shown in the budget summary. No profit will be paid on the cost-sharing portion of the contract.

5.9 Profit or Fee

Phase II contracts may include a reasonable profit. The reasonableness of proposed profit is determined by the Contracting Officer during contract negotiations. Reference FAR 15.404-4.

5.10 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as an SBC in accordance with the definition in Section 2.19. A statement of how the workload will be distributed, managed, and charged should be included in the proposal. A copy or comprehensive summary of the joint venture agreement or partnership agreement should be appended to the proposal. This will not count as part of the page limit for the Phase II proposal.

5.11 Essentially Equivalent Awards and Prior Work

If an award is made pursuant to a proposal submitted under either SBIR or STTR Solicitations, the firm will be required to certify that it has not previously been paid nor is currently being paid for essentially equivalent work by any agency of the Federal Government. Failure to report essentially equivalent or duplicate efforts can lead to the termination of contracts or civil or criminal penalties

5.12 Contractor Commitments

Upon award of a contract, the contractor will be required to make certain legal commitments through acceptance of numerous clauses in the Phase II contract. The outline of this section illustrates the types of clauses that will be included. This is not a complete list of clauses to be included in Phase II contracts, nor does it contain specific wording of these clauses. Copies of complete provisions will be made available prior to contract negotiations.

5.12.1 Standards of Work

Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.

5.12.2 52.246-9 Inspection of Research and Development (Short Form)

Work performed under the contract is subject to Government inspection and evaluation at all reasonable times.

5.12.3 52.215-2 Audit and Records - Negotiations

The Comptroller General (or a duly authorized representative) shall have the right to examine any directly pertinent records of the contractor involving transactions related to the contract.

5.12.4 52.233-1 Disputes

Any disputes concerning the contract that cannot be resolved by mutual agreement shall be decided by the Contracting Officer with right of appeal.

5.12.5 52.222-4 Contract Work Hours and Safety Standards Act – Overtime Compensation

The contractor may not require a non-exempt employee to work more than 40 hours in a workweek unless the employee is paid for overtime.

5.12.6 52.222-26 Equal Opportunity for Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

The contractor will not discriminate against any employee or applicant for employment because of race, color, religion, age, sex, or national origin.

5.12.7 52.222-35 Equal Opportunity for Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.

5.12.8 52.222-36 Affirmative Action for Workers with Disabilities

The contractor will not discriminate against any employee or applicant for employment because he or she is physically or mentally handicapped.

5.12.9 52.203-12 Limitation on Payments to Influence Certain Federal Transactions

No member of or delegate to Congress shall benefit from an SBIR or STTR contract.

5.12.10 52.203-5 Covenant Against Contingent Fees

No person or agency has been employed to solicit or to secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the contractor for the purpose of securing business.

5.12.11 52.203-3 Gratuities

The contract may be terminated by the Government if any gratuities have been offered to any representative of the Government to secure the contract.

5.12.12 52.227-2 Notice and Assistance Regarding Patent and Copyright Infringement

The contractor shall report to NASA each notice or claim of patent infringement based on the performance of the contract.

5.12.13 52.225-1 Buy American Act-Supplies

Congress intends that the awardee of a funding agreement under the SBIR/STTR Program should, when purchasing any equipment or a product with funds provided through the funding agreement, purchase only American-made equipment and products, to the extent possible, in keeping with the overall purposes of this program.

5.12.14 1852.225-70 Export Licenses

The contractor shall comply with all U.S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR). Offerors are responsible for ensuring that all employees who will work on this contract are eligible under export control and International Traffic in Arms (ITAR) regulations. Any employee who is not a U.S. citizen or a permanent resident may be restricted from working on this contract if the technology is restricted under export control and ITAR regulations unless the prior approval of the Department of State or the Department of Commerce is obtained via a technical assistance agreement or an export license. Violations of these regulations can result in criminal or civil penalties. For further information on ITAR visit http://www.pmddtc.state.gov/regulations_laws/itar.html. For additional assistance, refer to http://sbir.gsfc.nasa.gov/SBIR/export_control.html or contact the ARC export control administrator, Mary Williams, at mary.p.williams@nasa.gov.

5.12.15 Government Furnished and Contractor Acquired Property

Title to property furnished by the Government or acquired with Government funds will be vested with the NASA, unless it is determined that transfer of title to the contractor would be more cost effective than recovery of the equipment by NASA.

5.13 Additional Information

5.13.1 Precedence of Contract Over Solicitation

This Program Solicitation reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR/STTR contract, the terms of the contract are controlling.

5.13.2 Evidence of Contractor Responsibility

In addition to the information required to be submitted in Section 3.2.10, before award of an SBIR or STTR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to establish responsibility of the offeror. Contractor responsibility includes all resources required for contractor performance, i.e., financial capability, work force, and facilities.

5.14 Required Registrations and Submissions

5.14.1 Central Contractor Registration

Offerors should be aware of the requirement to register in the Central Contractor Registration (CCR) database prior to contract award. **To avoid a potential delay in contract award, offerors are required to register prior to submitting a proposal. Additionally, firms must certify the NAICS code of 541712.**

The CCR database is the primary repository for contractor information required for the conduct of business with NASA. It is maintained by the Department of Defense. To be registered in the CCR database, all mandatory information, which includes the DUNS or DUNS+4 number, and a CAGE code, must be validated in the CCR system. The DUNS number or Data Universal Number System is a 9-digit number assigned by Dun and Bradstreet Information Services (http://www.dnb.com) to identify unique business entities. The DUNS+4 is similar, but includes a 4-digit suffix that may be assigned by a parent (controlling) business concern. The CAGE code or Commercial Government and Entity Code is assigned by the Defense Logistics Information Service (DLIS) to identify a commercial or Government entity. If an SBC does not have a CAGE code, one will be assigned during the CCR registration process.

The DoD has established a goal of registering an applicant in the CCR database within 48 hours after receipt of a complete and accurate application via the Internet. However, registration of an applicant submitting an application through a method other than the Internet may take up to 30 days. Therefore, offerors that are not registered should consider applying for registration immediately upon receipt of this solicitation. Offerors and contractors may obtain information on CCR registration and annual confirmation requirements via the Internet at http://www.ccr.gov or by calling 888-CCR-2423 (888-227-2423).

5.14.2 52.204-8 Annual Representations and Certifications

Offerors should be aware of the requirement that the Representation and Certifications required from Government contractors must be completed through the Online Representations and Certifications Application (ORCA) website https://orca.bpn.gov/login.aspx. FAC 01-26 implements the final rule for this directive and requires that all offerors provide representations and certifications electronically via the BPN website; to update the representations and certifications as necessary, but at least annually, to keep them current, accurate and complete. NASA will not enter into any contract wherein the Contractor is not compliant with the requirements stipulated herein.

5.14.3 52.222-37 Employment Reports on Special Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

In accordance with Title 38, United States Code, Section 4212(d), the U.S. Department of Labor (DOL), Veterans' Employment and Training Service (VETS) collects and compiles data on the Federal Contractor Program Veterans' Employment Report (VETS-100 Report) from Federal contractors and subcontractors who receive Federal contracts that meet the threshold amount of $100,000.00. The VETS-100 reporting cycle begins annually on August 1 and ends September 30. Any federal contractor or prospective contractor that has been awarded or will be awarded a federal contract with a value of $100,000.00 or greater must have a current VETS 100 report on file. Please visit the DOL VETS 100 website at http://www.dol.gov/vets/programs/fcp/main.htm. NASA will not enter into any contract wherein the firm is not compliant with the requirements stipulated herein.

5.14.4 Software Development Standards

Offerors proposing projects involving the development of software should comply with the requirements of NASA Procedural Requirements (NPR) 7150.2, “NASA Software Engineering Requirements” are available online at http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7150&s=2.

5.14.5 Human and/or Animal Subject

Due to the complexity of the approval process, use of human and/or animal subjects may significantly delay contract award for Phase II.

Offerors should be aware of the requirement that an approved protocol by a NASA Review Board is required if the proposed work include human or animal subject. An approved protocol shall be provided to the Contracting Officer before an award can be made. Offerors shall identify the use of human or animal subject on Form A. For additional information, contact the NASA SBIR/STTR Program Management Office at ARC-SBIR-PMO@mail.nasa.gov. Reference 14 CFR 1230 and 1232.

5.14.6 Toxic Chemical

Submission of this certification is a prerequisite for making or entering into this contract imposed by Executive Order 12969, August 8, 1995. Offerors shall identify the use of toxic chemical(s) on Form A. Reference FAR 52.223-13 Certification of Toxic Chemical Release Reporting.

5.14.7 Hazardous Materials

Offerors must list any hazardous material to be delivered under this contract. The apparently successful offeror agrees to submit, for each item as required prior to award, a Material Safety Data Sheet, meeting the requirements of 29 CFR 1910.1200(g) and the latest version of Federal Standard No. 313, for all hazardous material identified in paragraph (b) of this clause. Data shall be submitted in accordance with Federal Standard No. 313, whether or not the apparently successful offeror is the actual manufacturer of these items. Failure to submit the Material Safety Data Sheet prior to award may result in the apparently successful offeror being considered non-responsible and ineligible for award. Offerors shall identify the use of hazardous materials on Form A. Reference FAR 52.223-3 Hazardous Material identification and Material Safety Identification.

5.14.8 HSPD-12

Firms that require access to federally controlled facilities for six consecutive months or more must adhere to the following:

PIV Card Issuance Procedures in accordance with FAR clause 52.204-9 Personal Identity Verification of Contractor Personnel

Purpose: To establish procedures to ensure that recipients of contracts are subject to essentially the same credentialing requirements as Federal Employees when performance requires physical access to a Federally-controlled facility or access to a Federal information system **for six consecutive months or more**. (Federally - controlled facilities and Federal information system are defined in FAR 2.101(b)(2)).

Background: Homeland Security Presidential Directive 12 (HSPD-12), "Policy for a Common Identification Standard for Federal Employees and Contractors", and Federal Information Processing Standards Publication (FIPS PUB) Number 201, "Personal Identity Verification (PIV) of Federal Employees and Contractors" require agencies to establish and implement procedures to create and use a Government-wide secure and reliable form of identification NLT October 27, 2005. See: http://csrc.nist.gov/publications/fips/fips201-1/FIPS-201-1-chng1.pdf. In accordance with the FAR clause 52.204-9 Personal Identity Verification of Contractor Personnel which states in parts contractor shall comply with the requirements of this clause and shall ensure that individuals needing such access shall provide the personal background and biographical information requested by NASA.

If applicable, detailed procedures for the issuance of a PIV credential can be found at the following URL: http://itcd.hq.nasa.gov/PIV.html.

5.15 False Statements

Knowingly and willfully making any false, fictitious, or fraudulent statements or representations may be a felony under the Federal Criminal False Statement Act (18 U.S.C. Sec 1001), punishable by a fine of up to $10,000, up to five years in prison, or both. The Office of the Inspector General has full access to all proposals submitted to NASA.

6. Submission of Proposals

6.1 Submission Requirements

NASA uses electronically supported business processes for the SBIR/STTR programs. An offeror must have Internet access and an e-mail address. Paper submissions are not accepted.

The Electronic Handbook (EHB) for submitting proposals is located at http://sbir.nasa.gov. The Proposal Submission EHB will guide the firms through the steps for submitting an SBIR/STTR proposal. All EHB submissions are through a secure connection. Communication between NASA's SBIR/STTR programs and the firm is primarily through a combination of EHBs and e-mail.

6.2 Submission Process

SBCs must register in the EHB to begin the submission process. It is recommended that the Business Official, or an authorized representative designated by the Business Official, be the first person to register for the SBC. The SBC's Employer Identification Number (EIN)/Taxpayer Identification Number is required during registration.

For successful proposal submission, SBCs must complete all three forms online, upload their technical proposal in an acceptable format, and have the Business Official electronically endorse the proposal. Electronic endorsement of the proposal is handled online with no additional software requirements. The term "technical proposal" refers to the part of the submission as described in Section 3.2.4.

STTR: The Research Institution is required to electronically endorse the Cooperative Agreement prior to the SBC endorsement of the completed proposal submission.

6.2.1 What Needs to Be Submitted

The entire proposal including Forms A, B, C, the briefing chart, and the commercialization metrics survey must be submitted/filled out via the Submissions EHB located on the NASA SBIR/STTR website. (Note: Other forms of submissions such as postal, paper, fax, diskette, or e-mail attachments are not acceptable).

(1) Forms A, B, and C are to be completed online.
(2) The technical proposal is uploaded from your computer via the Internet utilizing secure communication protocol.
(3) Firms must submit a briefing chart online, which is not included in the page count (see Sections 3.2.9).
(4) The commercialization metrics survey is required and to be completed online.

6.2.2 Technical Proposal Submissions

NASA converts all technical proposal files to PDF format for evaluation. Therefore, NASA requests that technical proposals be submitted in PDF format. Other acceptable formats are MS Works, MS Word, and WordPerfect. Note: Due to PDF difficulties with non-standard fonts, Unix and TeX users should output technical proposal files in DVI format.

Graphics
For reasons of space conservation and simplicity the offeror is encouraged, but not required, to embed graphics within the document. For graphics submitted as separate files, the acceptable file formats (and their respective extensions) are: Bit-Mapped (.bmp), Graphics Interchange Format (.gif), JPEG (.jpg), PC Paintbrush (.pcx), WordPerfect Graphic (.wpg), and Tagged-Image Format (.tif). Embedded animation or video will not be considered for evaluation.

Virus Check
The offeror is responsible for performing a virus check on each submitted technical proposal. As a standard part of entering the proposal into the processing system, NASA will scan each submitted electronic technical proposal for viruses. **The detection, by NASA, of a virus on any electronically submitted technical proposal, may cause rejection of the proposal.**

6.2.3 Technical Proposal Uploads

Firms will upload their proposals using the Submissions EHB. Directions will be provided to assist users. All transactions via the EHB are encrypted for security. Firms cannot submit security/password protected technical proposal and/or briefing chart files, as reviewers may not be able to open and read the files. An e-mail will be sent acknowledging each successful upload. An example is provided below:

Sample E-mail for Successful Upload of Technical Proposal

Subject: Successful Upload of Technical Proposal

Upload of Technical Document for your NASA SBIR/STTR Proposal No. _________

This message is to confirm the successful upload of your technical proposal document for:

Proposal No. ____________
(Uploaded File Name/Size/Date)

Please note that any previous uploads are no longer considered as part of your submission.

This e-mail is NOT A RECEIPT OF SUBMISSION of your entire proposal

IMPORTANT! The Business Official or an authorized representative must electronically endorse the proposal in the Electronic Handbook using the "Endorse Proposal" step. Upon endorsement, you will receive an e-mail that will be your official receipt of proposal submission.

Thank you for your participation in NASA's SBIR/STTR Program.

NASA SBIR/STTR Program Support Office

You may upload the technical proposal multiple times, with each new upload replacing the previous version, but only the final uploaded and electronically endorsed version will be considered for review.

6.3 Deadline for Phase II Proposal Receipt

All Phase II proposal submissions must be received no later than the last day of the Phase I contract, via the NASA SBIR/STTR Website (http://sbir.nasa.gov). The EHB will be available for Internet submissions approximately 6 weeks prior to completion date of Phase I contracts. Any proposal received after that date and time shall be considered late and handled according to NASA FAR Supplement 1815.208.

6.4 Acknowledgment of Proposal Receipt

The final proposal submission includes successful completion of Form A (electronically endorsed by the SBC Official), Form B, Form C, the uploaded technical proposal, and the briefing chart. NASA will acknowledge receipt of electronically submitted proposals upon endorsement by the SBC Official to the SBC Official's e-mail address as provided on the proposal cover sheet. If a proposal acknowledgment is not received, the offeror should call NASA SBIR/STTR Program Support Office at 301-937-0888. An example is provided below:

Sample E-mail for Official Confirmation of Receipt of Full Proposal:

Subject: Official Receipt of your NASA SBIR/STTR Proposal No. _______________

Confirmation No. __________________

This message is to acknowledge electronic receipt of your NASA SBIR/STTR Proposal No. _______________. Your proposal, including the forms and the technical document, has been received at the NASA SBIR/STTR Support Office.

SBIR/STTR 2011 Phase II xx.xx-xxxx (Title)
Form A completed on:
Form B completed on:
Form C completed on:
Technical Proposal Uploaded on:
File Name:
File Type:
File Size:
Briefing Chart completed on:
Proposal endorsed electronically by:

This is your official confirmation of receipt. Please save this email for your records, as no other receipt will be provided. The SBIR announcement for negotiation is currently scheduled for October 2012 or April 2013 for STTR, and will be posted via the SBIR/STTR website (http://sbir.nasa.gov).

Thank you for your participation in the NASA SBIR/STTR Program.

NASA SBIR/STTR Program Support Office

6.5 Withdrawal of Proposals

Prior to the close of submissions, proposals may be withdrawn via the Proposal Submission Electronic Handbook hosted on the NASA SBIR/STTR Website (http://sbir.nasa.gov). In order to withdraw a proposal after the deadline, the designated SBC Official must send written notification via email to sbir@reisys.com.

6.6 Service of Protests

Protests, as defined in Section 33.101 of the FAR, that are filed directly with an agency and copies of any protests that are filed with the General Accounting Office (GAO) shall be served on the Contracting Officer by obtaining written and dated acknowledgement of receipt from the NASA SBIR/STTR Program contact listed below:

Cassandra Williams
NASA Shared Services Center
Building 1111, C Road
Stennis Space Center, MS 39529
Cassandra.Williams-1@nasa.gov

The copy of any protest shall be received within one calendar day of filing a protest with the GAO.

7. Scientific and Technical Information Sources

7.1 NASA Websites

General sources relating to scientific and technical information at NASA is available via the following web sites:

NASA Budget Documents, Strategic Plans, and Performance Reports:
http://www.nasa.gov/about/budget/index.html
NASA Organizational Structure: http://www.nasa.gov/centers/hq/organization/index.html
NASA Office of the Chief Technologist (OCT): http://www.nasa.gov/offices/oct/home/index.html
NASA SBIR/STTR Programs: http://sbir.nasa.gov

7.2 United States Small Business Administration (SBA)

The Policy Directives for the SBIR/STTR Programs may be obtained from the following source. SBA information can also be obtained at: http://www.sba.gov.

U.S. Small Business Administration
Office of Technology – Mail Code 6470
409 Third Street, S.W.
Washington, DC 20416
Phone: 202-205-6450

7.3 National Technical Information Service

The National Technical Information Service is an agency of the Department of Commerce and is the Federal Government's largest central resource for Government-funded scientific, technical, engineering, and business related information. For information regarding their various services and fees, call or write:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 703-605-6000
URL: http://www.ntis.gov

8. Submission Forms and Certifications

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Firm Certifications

As defined in Section 2 of the Solicitation, the offeror qualifies as a:

a. Small Business Concern (SBC)	Yes	No
Number of employees: _____		
b. The firm is owned and operated in the United States	Yes	No
c. Socially and Economically Disadvantaged SBC	Yes	No
d. Woman-owned SBC	Yes	No
i) Economically Disadvantaged Women-owned SBC	Yes	No
e. HUBZone-owned SBC	Yes	No
f. Veteran-owned SBC	Yes	No
i) Service Disabled Veteran-owned SBC	Yes	No

Guidelines for Completing Firm Certifications

Firm level certifications that are applicable across all proposal submissions submitted to this Solicitation must be completed via the “Certifications” section of the Proposal Submission Electronic Handbook. The offeror must answer Yes or No as applicable.

Form A – SBIR Cover Sheet

Subtopic No.
Proposal Number: _ _ . _ _ - _ _ _ _
Topic Title:
Subtopic Title:
Proposal Title:

Firm Name:
Mailing Address:
City:
State/Zip:
Phone:
Fax:
EIN/Tax Id:

ACN (Authorized Contract Negotiator) Name:
ACN E-mail:
ACN Phone: Extension:
DUNS + 4:
Cage Code:
Amount Requested: $__________ (auto-populated upon completion of Budge Form C)
Duration: ____ months

OFFEROR CERTIFIES THAT:

As defined in Section 1.5.3 of the Solicitation, the offeror certifies:

a. During performance of the contract, the Principal Investigator is "primarily employed" by the organization as defined in the SBIR Solicitation Yes No
Note: Co-PI is not acceptable.

As defined in Section 3.2.4 Part 11 of the Solicitation, indicate if:

b. Essentially equivalent work under this project has been submitted for other Federal funding Yes No

i) If yes, provide information on essentially equivalent proposal submissions below:

Proposal No.	Proposal Title	Date of Submission	Soliciting Agency	(Anticipated) Selection Announcement Date

c. Funding has been received for essentially equivalent work under this project by any other Federal grant, contract, or subcontract Yes No

As described in Section 3 of this solicitation, the offeror meets the following requirements completely:

d. All 11 parts of the technical proposal are included in part order and the page limitation is met	Yes	No
e. Subcontracts/consultants proposed?	Yes	No
i) If yes, does the proposal comply with the subcontractor/consultant limitation? (Section 3.2.4 Part 9)	Yes	No
f. Government equipment or facilities required?	Yes	No
i) If yes, is a signed statement of availability enclosed in Part 8?	Yes	No
ii) If yes, is a non-SBIR funding source identified in Part 8?	Yes	No

In accordance with Section 5.12.14 of the Solicitation as applicable:

g. The offeror understands and shall comply with export control regulations	Yes	No

In accordance with Section 5 of the Solicitation as applicable, indicate if any of the following will be used (must comply with federal regulations):

h. Human Subject	Yes	No
i. Animal Subject	Yes	No
j. Toxic Chemicals	Yes	No
k. Hazardous Materials	Yes	No

As referenced in Section 1.2 of the Solicitation, indicate if the R&D to be performed is related to:

l. Renewable Energy	Yes	No
m. Manufacturing	Yes	No

I understand that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

ENDORSEMENT:

Corporate/Business Official:
Name:
Title:
Phone:
E-mail

Endorsed by:
Date:

PROPRIETARY NOTICE (If Applicable, See Sections 5.5, 5.6)

NOTICE: This data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal, provided that a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages __________ of this proposal.

Note: Do not mark the entire proposal as proprietary. Forms A and B (pages 1 and 2 of your proposal submission) cannot contain proprietary data. (See Section 3.2.3 of the 2011 Solicitation)

Guidelines for Completing SBIR Cover Sheet

Complete Cover Sheet Form A electronically via the Proposal Submission Electronic Handbook.

Proposal Number: This number does not change. The proposal number consists of the four-digit subtopic number and four-digit system-generated number.

Topic Title: Select the topic that this proposal will address. Refer to Section 9 for topic descriptions.

Subtopic Title: Select the subtopic that this proposal will address. Refer to Section 9 for subtopic descriptions.

Proposal Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title. Avoid words like "development" and "study."

Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

Mailing Address: Must match CCR address and should be the address where mail is received.
City, State, Zip: City, 2-letter State designation (i.e. TX for Texas), 9-digit Zip code (i.e. 20705-3106)
Phone, Fax: Number including area code
EIN/Tax ID: Employer Identification Number/Taxpayer ID

ACN Name: Enter the name of the Authorized Contract Negotiator from your firm
ACN E-mail: Email address
ACN Phone, Ext.: Number including area code and extension (if applicable)

DUNS + 4: 9-digit Data Universal Number System; a 4-digit suffix is also required if owned by a parent concern. For information on obtaining a DUNS number go to http://www.dnb.com.

CAGE Code: Commercial Government and Entity Code that is issued by the Central Contractor Registration (CCR). For information on obtaining a CAGE Code, go to http://www.ccr.gov.

Amount Requested: Proposal amount auto-populated from Budget Summary. The amount requested should not exceed $700,000 (see Sections 1.4, 5.1.1).

Duration: Proposed duration in months. The requested duration should not exceed 24 months (see Sections 1.4, 5.1.1).

Certifications: Answer Yes or No as applicable for certifications a – m (see the referenced sections for definitions). Where applicable, SBCs should make sure that their certifications on Form A agree with the content of their technical proposal.

a. The Principal Investigator is required to be "primarily employed" by the organization as defined in Section 1.5.3 of the Solicitation.
b. If essentially equivalent work under this project has been submitted to other Federal Agencies/programs for funding, then the SBC must provide the proposal number, proposal title, date of submission, and soliciting agency. The selection announcement date should also be provided if known.
c. It is unlawful to enter into federally funded agreements requiring essentially equivalent work. By answering "No" the SBC confirms that work under this project has not been funded under any other Federal grant, contract or subcontract.
d. As stated in section 3.2 of the Solicitation, the technical proposal must not exceed the 50-page limitation and must consist of all eleven (11) required parts.

e. By answering “Yes”, the SBC certifies that subcontracts/consultants have been proposed and arrangements have been made to perform on the contract, if awarded.
   ii) Proposed subcontractor/consultant business arrangements must not exceed 50 percent of the research and/or analytical work (as determined by the total cost of the proposed subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any). Refer to Section 3.2.4, Part 9 of the Solicitation.

f. By answering “Yes”, the SBC certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities. By answering “No”, the SBC certifies that no such Government Furnished Facilities or Government Furnished Equipment is required to perform the proposed activities. See Section 3.2.4 Part 8 of the Solicitation.
   iii) If proposing to use Government Furnished Facilities or Equipment, a signed statement of availability must be included in Part 8 of the Technical Proposal that describes the uniqueness of the facility and its availability to the offeror at specified times, signed by the appropriate Government official.
   iv) If “Yes,” the SBC certifies that it has a confirmed, non-SBIR funding source for whatever charges may be incurred when utilizing the required Government facility. If “No,” a waiver from the SBA is required before a proposer can use SBIR/STTR funds for Government equipment or facilities. Proposals requiring waivers must explain why the waiver is appropriate.

g. Offerors are responsible for ensuring compliance with export control and International Traffic in Arms (ITAR) regulations. All employees who will work on this contract must be eligible under these regulations or the offeror must have in place a valid export license or technical assistance agreement. Violations of these regulations can result in criminal or civil penalties.

h-k. Offeror must indicate by answering “Yes” or “No” as applicable if human subjects, animal subjects, toxic chemicals and/or hazardous materials will be used. SBCs must be in compliance with federal regulations. See Sections 5.14.5, 5.14.6, and 5.14.7 of the Solicitation.

l. Answer “Yes” if this proposal has a connection to energy efficiency or alternative and renewable energy. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to energy efficiency or alternative and renewable energy. See Section 1.2 of the Solicitation.

m. Answer “Yes” if this proposal has a connection to manufacturing. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to manufacturing. See Section 1.2 of the Solicitation.

<u>Electronic Endorsement</u>:
Endorsement of the proposal by the Business Official certifies an understanding that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

Electronic endorsement is performed by the authorized Business Official from the “Endorsement” link located on the Activity Worksheet for each proposal. Electronic endorsement is the final step in the proposal submission process and can only be performed when all required sections of the proposal submission are complete.

Once endorsed, the name and date of endorsement will populate under the Endorsement section of the Cover Sheet Form A.

Form B – SBIR Proposal Summary

Subtopic No.
Proposal Number: _ _ . _ _ - _ _ _ _
Subtopic Title:
Proposal Title:

Small Business Concern:
Name:
Address:
City/State/Zip:
Phone:

Principal Investigator/Project Manager:
Name:
Address:
City/State/Zip:
Phone: Extension:
E-mail:

Estimated Technology Readiness Level (TRL) at beginning and end of contract:
Begin: _____
End: _____

Technology Available (TAV) Subtopics: **(Applicable only for proposals submitted under S3.05 and S3.08)**

S3.05 or S3.08 is a Technology Available (TAV) subtopic that includes NASA Intellectual Property (IP).

Do you plan to use the NASA IP under the award? Yes No

If yes, and a license application was not submitted under the Phase I Award, click here to access the NASA Research License Application that must be completed and appended to your technical proposal. If a NASA Research License Application was submitted under the Phase I award, please identify the Phase I Award by contract number and identify the NASA patent by patent number in Part 3 of the proposal.

Technical Abstract: (Limit 2,000 characters, approximately 200 words)

Potential NASA Application(s): (Limit 1,500 characters, approximately 150 words)

Potential Non-NASA Application(s): (Limit 1,500 characters, approximately 150 words)

Technology Taxonomy: (Select only the technologies relevant to this specific proposal)
NASA's technology taxonomy has been developed by the SBIR-STTR program to disseminate awareness of proposed and awarded R/R&D in the agency. It is a listing of over 100 technologies, sorted into broad categories, of interest to NASA.

Guidelines for Completing SBIR Proposal Summary

Complete Proposal Summary Form B electronically via the Proposal Submission Electronic Handbook.

Proposal Number: Auto-populated with proposal number as shown on Cover Sheet.

Subtopic Title: Auto-populated with subtopic title as shown on Cover Sheet.

Proposal Title: Auto-populated with proposal title as shown on Cover Sheet.

Small Business Concern: Auto-populated with firm information as shown on Cover Sheet.

Principal Investigator/Project Manager: Enter the full name of the PI/PM and include all required contact information.

Technology Readiness Level (TRL): Provide the estimated Technology Readiness Level (TRL) at the beginning and end of the contract. See Section 2.23 and Appendix B for TRL definitions.

Technology Available (TAV) Subtopics: TAV subtopics S3.05 and S3.08 may include an offer to license NASA IP on a non-exclusive, royalty-free basis for research use under the SBIR award. When included in a TAV subtopic as an available technology, the use of the NASA IP is strictly voluntary. Refer to section 1.6 of the Solicitation.

Answer “Yes” only if the proposal is being submitted to subtopic S3.05 or S3.08 and includes NASA Intellectual Property (IP) planned for research use under the performance of the contract.

Technical Abstract: Summary of the offeror’s proposed project is limited to 2,000 characters, approximately 200 words, and shall summarize the implications of the approach and the anticipated results of the Phase II. NASA will reject a proposal if the technical abstract is determined to be non-responsive to the subtopic. **The abstract must not contain proprietary information and must describe the NASA need addressed by the proposed R/R&D effort.**

Potential NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Potential Non-NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Technology Taxonomy: Selections for the technology taxonomy are limited to technologies supported or relevant to the specific proposal. The listing of technologies for the taxonomy is provided in Appendix C.

Form C – SBIR Budget Summary

PROPOSAL NUMBER:
SMALL BUSINESS CONCERN:

---

(1) DIRECT LABOR:

Category	Description	Education	Years of Experience	Hours	Rate	Total
____________	____________________	______________	_________	_____	________	______________
____________	____________________	______________	_________	_____	________	______________
____________	____________________	______________	_________	_____	________	______________

TOTAL DIRECT LABOR:
(1) $ ____________

Are the labor rates fully loaded? Yes No
If yes, explain any costs that apply:

Comments:

Document uploaded for labor rate documentation: (file name)

(2) OVERHEAD COST;

______% of Total Direct Labor or $ ______

OVERHEAD COST:
(2) $ ____________

Comments:

Overhead Cost Sources:
____
____
____

(3) OTHER DIRECT COSTS (ODCs):

Materials:
- Description: ______________________________
- Vendor: _________________________________
- Quantity: ___________ Cost: ________________
- Consumable: Yes No
- Competitively Sourced?: Yes No
- Used Exclusively for this Contract?: Yes No
- Supporting Comments: ______________________
- Supporting Documents: (file name)

Supplies:
Description: ________________________________
Vendor: ___________________________________
Quantity: ___________ Cost: ________________
Consumable: Yes No
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Equipment:
Description: ________________________________
Vendor: ___________________________________
Quantity: ___________ Cost: ________________
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Other:

Travel:
Location From: _______________ Location To: _______________
Number of People: _____________ Number of Days: ___________
Purpose of Trip: ____
Airfare: _____________________ Car Rental: ________________
Per Diem: ___________________ Other Costs: _______________
Total Costs: _________________
Sources of Estimates: ______________________________________
Explanation/Justification: __________________________________

Explanation of ODCs:
Provide any additional information on the Other Direct Costs listed above, including the basis used for estimating the costs.

Subcontractor/Consultants:	Total Cost:
____________________________________	__________________
____________________________________	__________________
____________________________________	__________________

(Note: Separate Budget Summaries completed for all proposed Subcontractors/Consultants via the Subcontractors/Consultants section of Form C)

TOTAL OTHER DIRECT COSTS:
(3) $ _____________

(1)+(2)+(3)=(4)

SUBTOTAL:
(4) $ _____________

(5) GENERAL & ADMINISTRATIVE (G&A) COSTS
______% of Subtotal or $ ______

G&A COSTS:

	(5)	$	____________

Comments:
If an audit rate is not available, provide a detailed explanation of the cost base used to develop the G&A rate and if possible, a historical actual G&A rate for the past three years.

G&A Cost Elements:
____
____
____

(4)+(5)=(6)	TOTAL COSTS (6)	$	____________
(7) ADD PROFIT or SUBTRACT COST SHARING (As applicable)	PROFIT/COST SHARING: (7)	$	____________

Comments:

(6)+(7)=(8)	AMOUNT REQUESTED: (8)	$	____________

GOVERNMENT FACILITIES OR EQUIPMENT:

If you require the use of a Government Facility or Equipment, identify it below as well as in Part 8 of your technical proposal. (See certification l on Form A)

AUDIT AGENCY:

If your company's accounting system has been audited, are the rates from that audit agreement used for this proposal?

__ The rates listed in the negotiated rate agreement were used to prepare the budget summary
__ Other rates were used to prepare the budget summary
__ My company’s accounting system has not been audited

If the listed rates are not being used to prepare the budget summary, please provide an explanation:

Guidelines for Preparing SBIR Budget Summary

Complete Budget Summary Form C electronically.

The offeror shall electronically submit a price proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting and estimating system.

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, in the text boxes or via uploads as indicated in the electronic form.

Offerors with questions about the appropriate classification of costs are advised to consult with an experienced accountant that has experience in government contracting and cost accounting principals. Information provided by the Defense Contract Audit Administration in their publication "Information for Contractors" may also be useful. This publication is available on-line at http://www.dcaa.mil/dcaap7641.90.pdf.

Firm: Same as Cover Sheet.

Proposal Number: Same as Cover Sheet.

Direct Labor: Select the appropriate labor category for each person who will be working directly on the proposed research effort and provide the labor description, level of education, years of experience, total number of hours, and labor rate. Detail the labor hours used for each year of the proposed research effort separately.

Indicate if the direct labor rates are fully loaded and, if yes, explain any costs that are included in the rate such as fringe benefits, etc. Provide the breakout rate such as the labor hour rate, health benefits, life insurance etc. Some examples of direct labor include Principal Investigator, Engineer, Scientist, Analyst or Research Assistant/Laboratory Assistant. All listed categories shall be directly related to proposed work to be performed under contract with NASA. Any contributions from non-technical personnel proposed under direct labor shall be explicitly explained. Labor rates that do not compare favorably to comparable state average rates at http://www.bls.gov require additional documentation, supporting the proposed rate or salary.

Note: Costs associated with company executives, accountants or administrative support are typically included in a company’s general and administrative costs. If these costs are being proposed as direct labor then provide the details of how the proposed hours were allocated to this effort and verify that these costs are not also covered in your overhead or G&A rate.

Overhead Cost: Specify current rate and base. Use current rate(s) negotiated with your firm’s cognizant Federal-auditing agency, if available. A rate that has not been audited requires a detailed explanation of the cost base used to develop the rate and if possible, historical actual overhead rates for the past three years.

Specify the cost elements of the company’s overhead costs in the text boxes provided. Possible overhead cost elements include insurance, sick leave, and vacation.

Note: If no labor overhead rate is proposed and the proposed direct labor includes all fringe benefits, you may enter “0” for the overhead cost line.

Other Direct Costs (ODCs):
Refer to FAR 31.205 – Selected Costs for determination of cost allowability.

Materials and Supplies: Under the Materials and Supplies sections, indicate type, vendor, quantity required, and cost. Identify whether each item is consumable, which year it will be purchased, if it was competitively sourced, and

if it will be used exclusively for this contract. Your proposed cost shall be justified and supporting documents should be uploaded. General materials or supplies without adequate explanation of the components, quantity and use of said items are not an acceptable breakdown. In the supporting comments block, provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc…). The Contracting Officer will make the final determination.

Special Tooling, Testing, and Test Equipment: The need for these items, if proposed, will be carefully reviewed. Equipment must be made in the USA to the maximum extent practical. The offeror should provide competitive quotes to support the proposed costs or should justify why only one source is available. Competitive quotes may be signed quotes from vendors or copies of catalogue pages. Normally the costs of any equipment should be quoted on a purchase basis, unless the offeror can demonstrate that lease or rent of the equipment is clearly advantageous to the government. The Contracting Officer will make the final determination. Upload supporting documentation as necessary. In the supporting comments block provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc.). The Contracting Officer will make the final determination.

Travel: All proposed travel must be necessary for the success of the research. Include a detailed accounting of all proposed expenses to include the purpose of proposed trips, number of trips, travelers per trip, as well as meals, hotel, and rental car estimated costs. Sources of estimate should be identified when travel is proposed along with a justification for each trip. Proposed travel costs shall be in accordance with the Federal Travel Regulation http://www.gsa.gov/federaltravelregulation.

Subcontracts/Consultants: Subcontracts/Consultants costs are included in the Other Direct Costs total. A separate budget summary must be completed for each subcontract/consultant proposed. Further instructions are provided in the Subcontracts/Consultants section below.

Note: Do not add subcontractors or consultants as a line item under the ODCs section of Form C. It will automatically be added to the ODCs upon completion of the separate Subcontractor/Consultant budget summary form.

Other: List all other direct costs that are not otherwise included in the categories described above such as rental of facilities, etc…

Note: The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Firms should be prepared to justify all material, supplies, and equipment costs during negotiations. See section 3.2.4 Part 8 for further guidance.

Explanation of ODCs: Provide any additional information for the proposed ODCs, including basis for cost estimation, in the text box provided.

Subcontracts/Consultants: List consultants by name and specify, for each, the number of hours and hourly costs. Detailed quotes from subcontractors should be provided in the same format. Note that a subcontract entered into for performance of research or research and development differs from an arrangement with a vendor to provide a service such as machining, analysis with test equipment or use of computer time. The costs of such arrangements with vendors should be covered under Special Tooling, Testing, Test Equipment and Material or under Other Direct Costs. Upon request of the contracting officer, the subcontractor's cost proposals may be sealed or mailed directly for government eyes only.

A letter of commitment shall be uploaded for each proposed subcontractor/consultant from the Subcontractor/Consultant Letter of Commitment section of the subcontractor/consultant budget summary form. If a commitment letter is not available, you shall provide an explanation in the text box to include a point of contact and contact information in order for NASA to obtain the required document to confirm availability to perform the proposed work during the proposed timeframe. Note that not providing the information now may delay award and contract negotiations.

General and Administrative (G&A) Costs: Specify a current rate and base to which G&A costs will be applied. If available, use the current rate recommendations from the cognizant Federal-auditing agency. If an audit rate is not available, provide a detailed explanation of the cost base used to develop the rate and if possible, a historical actual G&A rate for the past three years.

Specify the elements of the company's G&A costs in the text boxes provided. Possible G&A cost elements include Rent, Utilities, and Management.

Profit/Cost Sharing: See Section 5.9. Profit is to be added to total cost, while shared costs are to be subtracted from total cost, as applicable.

Amount Requested: The amount requested is equal to the sum of the Direct Labor, Overhead, ODCs, G&A and any profit, less any cost sharing. The amount requested cannot exceed $700,000 for Phase II.

Government Facilities and Equipment: If you require the use of Government Facilities or Equipment, identify the Government facilities or equipment in the text box provided, as well as in Part 8 of your technical proposal. Please note that this section SHALL be completed if you certified in Form A that you will require the use of Government Facilities. Leave this section BLANK if you DO NOT require the use of Government facilities or equipment.

Audit Information: Complete the Audit Information section of Form C to indicate if your company's accounting system has been audited and if the rates from that audit agreement are used for this proposal.

Note: There is a separate "Audit Information" section linked from your Activity Worksheet that must also be completed.

SBIR Check List

For assistance in completing your Phase II proposal, use the following checklist to ensure your submission is complete.

1. **The entire proposal including any supplemental material shall not exceed a total of 50 8.5 x 11 inch pages** (Section 3.2.2).

2. The proposal and innovation is submitted for one subtopic only (Section 3.1).

3. The entire proposal is submitted consistent with the requirements and in the order outlined in Section 3.2.

4. The technical proposal contains all eleven parts in order (Section 3.2.4).

5. The 1-page briefing chart does not include any proprietary data (Section 3.2.8).

6. Certifications in Form A are completed, and agree with the content of the technical proposal.

7. Proposed funding does not exceed $700,000 (Sections 1.4, 5.1.1).

8. Proposed project duration does not exceed 6 months (Sections 1.4, 5.1.1).

9. Entire proposal including Forms A, B, and C submitted via the Internet.

10. Form A electronically endorsed by the SBC Official.

11. **Phase II proposal submissions will be due after the last day of the Phase I contract.** (Section 6.3).

Form A – STTR Cover Sheet

Subtopic No.
Proposal Number: _ _ . _ _ - _ _ _ _
Topic Title:
Subtopic Title:
Proposal Title:

Firm Name:	Research Institution Name:
Mailing Address:	Mailing Address:
City:	City:
State/Zip:	State/Zip:
Phone:	Phone:
Fax:	Fax:
EIN/Tax Id:	EIN/Tax Id:

ACN (Authorized Contract Negotiator) Name:
ACN E-mail:
ACN Phone: Extension:
DUNS + 4:
Cage Code:
Amount Requested: $__________ (auto-populated upon completion of Budge Form C)
Duration: ____ months

OFFEROR CERTIFIES THAT:

As described in section 2.14 of the Solicitation, the partnering Research Institution qualifies as a:

a. FFRDC	Yes	No
b. Nonprofit Research Institute	Yes	No
c. Nonprofit College or University	Yes	No

As defined in Section 3.2.4 Part 11 of the Solicitation, indicate if

d. Essentially equivalent work under this project has been submitted for other Federal funding	Yes	No

i) If yes, provide information on essentially equivalent proposal submissions below:

Proposal No.	Proposal Title	Date of Submission	Soliciting Agency	(Anticipated) Selection Announcement Date
________	________________________	________	________	__________
________	________________________	________	________	__________
________	________________________	________	________	__________

e. Funding has been received for essentially equivalent work under this project by any other Federal grant, contract, or subcontract	Yes	No

As described in Section 3 of this solicitation, the offeror meets the following requirements completely:

f. Cooperative Agreement electronically endorsed by the SBC and RI	Yes	No
g. A Signed Allocation of Rights Agreement will be available for the Contracting Officer at time of selection	Yes	No
h. All 11 parts of the technical proposal are included in part order and the page limitation is met	Yes	No
i. Subcontracts/consultants proposed? (Other than RI)	Yes	No
i) If yes, does the proposal comply with the subcontractor/consultant limitation? (Section 3.2.4 Part 9)	Yes	No
j. Government equipment or facilities required?	Yes	No
i) If yes, is a signed statement of availability enclosed in Part 8?	Yes	No
ii) If yes, is a non-STTR funding source identified in Part 8?	Yes	No

In accordance with Section 5.12.14 of the Solicitation as applicable:

k. The offeror understands and shall comply with export control regulations	Yes	No

In accordance with Section 5 of the Solicitation as applicable, indicate if any of the following will be used (must comply with federal regulations):

l. Human Subject	Yes	No
m. Animal Subject	Yes	No
n. Toxic Chemicals	Yes	No
o. Hazardous Materials	Yes	No

As referenced in Section 1.2 of the Solicitation, indicate if the R&D to be performed is related to:

p. Renewable Energy	Yes	No
q. Manufacturing	Yes	No

The SBC will perform ___ % of the work and the RI will perform ___% of the work on this project.

I understand that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

ENDORSEMENT:

Corporate/Business Official:
Name:
Title:
Phone:
E-mail

Endorsed by:
Date:

PROPRIETARY NOTICE (If Applicable, See Sections 5.5, 5.6)

NOTICE: This data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal, provided that a funding agreement is awarded to the offeror as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages __________ of this proposal.

Note: Do not mark the entire proposal as proprietary. Forms A and B (pages 1 and 2 of your proposal submission) cannot contain proprietary data. (See Section 3.2.3 of the 2011 Solicitation)

Guidelines for Completing STTR Cover Sheet

Complete Cover Sheet Form A electronically via the Proposal Submission Electronic Handbook.

Proposal Number: This number does not change. The proposal number consists of the four-digit subtopic number and four-digit system-generated number.

Topic Title: Select the topic that this proposal will address. Refer to Section 9 for topic descriptions.

Subtopic Title: Select the subtopic that this proposal will address. Refer to Section 9 for subtopic descriptions.

Proposal Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title. Avoid words like "development" and "study."

Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

Research Institution Name: Enter the full name of the partnering Research Institution.

Mailing Address: Must match CCR address and should be the address where mail is received.
City, State, Zip: City, 2-letter State designation (i.e. TX for Texas), 9-digit Zip code (i.e. 20705-3106)
Phone, Fax: Number including area code
EIN/Tax ID: Employer Identification Number/Taxpayer ID

ACN Name: Enter the name of the Authorized Contract Negotiator from your firm
ACN E-mail: Email address
ACN Phone, Ext.: Number including area code and extension (if applicable)

DUNS + 4: 9-digit Data Universal Number System; a 4-digit suffix is also required if owned by a parent concern. For information on obtaining a DUNS number go to http://www.dnb.com.

CAGE Code: Commercial Government and Entity Code that is issued by the Central Contractor Registration (CCR). For information on obtaining a CAGE Code, go to http://www.ccr.gov.

Amount Requested: Proposal amount auto-populated from Budget Summary. The amount requested should not exceed $700,000 (see Sections 1.4, 5.1.1).

Duration: Proposed duration in months. The requested duration should not exceed 24 months (see Sections 1.4, 5.1.1).

Certifications: Answer Yes or No as applicable for certifications a – m (see the referenced sections for definitions). Where applicable, SBCs should make sure that their certifications on Form A agree with the content of their technical proposal.

a-c. Indicate whether the Research Institution (RI) qualifies as a FFRDC, Nonprofit Research Institution, or a Nonprofit College/University. (Only one of these should be marked as “Yes”).

d. If essentially equivalent work under this project has been submitted to other Federal Agencies/programs for funding, then the SBC must provide the proposal number, proposal title, date of submission, and soliciting agency. The selection announcement date should also be provided if known.

e. It is unlawful to enter into federally funded agreements requiring essentially equivalent work. By answering “No” the SBC confirms that work under this project has not been funded under any other Federal grant, contract or subcontract.

f. The Cooperative Agreement electronically endorsed by the authorized SBC Official and RI Official. Refer to Section 6.2 of the Solicitation. Note: Endorsement is performed via the “Endorsement” link located in the Activity Worksheet for each proposal.

g. Following the Selection Announcement for negotiation, the offeror must provide to the Contracting Officer, a completed Allocation of Rights Agreement (ARA). The ARA shall state the allocation of intellectual property rights with respect to the proposed STTR activity and planned follow-on research, development and/or commercialization. See Section 3.2.10 of the Solicitation.

h. As stated in section 3.2 of the Solicitation, the technical proposal must not exceed the 50-page limitation and must consist of all eleven (11) required parts.

i. By answering "Yes", the SBC certifies that subcontracts/consultants have been proposed and arrangements have been made to perform on the contract, if awarded.
   i) Proposed subcontractor/consultant business arrangements must not exceed 30 percent of the research and/or analytical work (as determined by the total cost of the proposed subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (total contract price including cost sharing, if any, less profit if any). Refer to Section 3.2.4, Part 9 of the Solicitation.

j. By answering "Yes", the SBC certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities. By answering "No", the SBC certifies that no such Government Furnished Facilities or Government Furnished Equipment is required to perform the proposed activities. See Section 3.2.4 Part 8 of the Solicitation.
   i) If proposing to use Government Furnished Facilities or Equipment, a signed statement of availability must be included in Part 8 of the Technical Proposal that describes the uniqueness of the facility and its availability to the offeror at specified times, signed by the appropriate Government official.
   ii) If "Yes," the SBC certifies that it has a confirmed, non-SBIR funding source for whatever charges may be incurred when utilizing the required Government facility. If "No," a waiver from the SBA is required before a proposer can use SBIR/STTR funds for Government equipment or facilities. Proposals requiring waivers must explain why the waiver is appropriate.

k. Offerors are responsible for ensuring compliance with export control and International Traffic in Arms (ITAR) regulations. All employees who will work on this contract must be eligible under these regulations or the offeror must have in place a valid export license or technical assistance agreement. Violations of these regulations can result in criminal or civil penalties.

l-o. Offeror must indicate by answering "Yes" or "No" as applicable if human subjects, animal subjects, toxic chemicals and/or hazardous materials will be used. SBCs must be in compliance with federal regulations. See Sections 5.14.5, 5.14.6, and 5.14.7 of the Solicitation.

p. Answer "Yes" if this proposal has a connection to energy efficiency or alternative and renewable energy. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to energy efficiency or alternative and renewable energy. See Section 1.2 of the Solicitation.

q. Answer "Yes" if this proposal has a connection to manufacturing. This should also be indicated in Part 5 (Related R/R&D) of the proposal with a brief explanation of how it is related to manufacturing. See Section 1.2 of the Solicitation.

<u>Electronic Endorsement</u>:

Endorsement of the proposal by the Business Official certifies an understanding that providing false information is a criminal offense under Title 18 US Code, Section 1001, False Statements, as well as Title 18 US Code, Section 287, False Claims.

Electronic endorsement is performed by the authorized Business Official from the "Endorsement" link located on the Activity Worksheet for each proposal. Electronic endorsement is the final step in the proposal submission process and can only be performed when all required sections of the proposal submission are complete.

Once endorsed, the name and date of endorsement will populate under the Endorsement section of the Cover Sheet Form A.

Form B – STTR Proposal Summary

Subtopic No.
Proposal Number: _ _ . _ _ - _ _ _ _
Subtopic Title:
Proposal Title:

Small Business Concern:
Name:
Address:
City/State/Zip:
Phone:

Research Institution:
Name:
Address:
City/State/Zip:
Phone:

Principal Investigator/Project Manager:
Name:
Address:
City/State/Zip:
Phone: Extension:
E-mail:

Estimated Technology Readiness Level (TRL) at beginning and end of contract:
Begin: _____
End: _____

Technical Abstract: (Limit 2,000 characters, approximately 200 words)

Potential NASA Application(s): (Limit 1,500 characters, approximately 150 words)

Potential Non-NASA Application(s): (Limit 1,500 characters, approximately 150 words)

Technology Taxonomy: (Select only the technologies relevant to this specific proposal)
NASA's technology taxonomy has been developed by the SBIR-STTR program to disseminate awareness of proposed and awarded R/R&D in the agency. It is a listing of over 100 technologies, sorted into broad categories, of interest to NASA.

Guidelines for Completing STTR Proposal Summary

Complete Proposal Summary Form B electronically via the Proposal Submission Electronic Handbook.

Proposal Number: Auto-populated with proposal number as shown on Cover Sheet.

Subtopic Title: Auto-populated with subtopic title as shown on Cover Sheet.

Proposal Title: Auto-populated with proposal title as shown on Cover Sheet.

Small Business Concern: Auto-populated with firm information as shown on Cover Sheet.

Research Institution: Auto-populated with RI information as shown on Cover Sheet.

Principal Investigator/Project Manager: Enter the full name of the PI/PM and include all required contact information.

Technology Readiness Level (TRL): Provide the estimated Technology Readiness Level (TRL) at the beginning and end of the contract. See Section 2.23 and Appendix B for TRL definitions.

Technical Abstract: Summary of the offeror's proposed project is limited to 2,000 characters, approximately 200 words, and shall summarize the implications of the approach and the anticipated results of the Phase II. NASA will reject a proposal if the technical abstract is determined to be non-responsive to the subtopic. **The abstract must not contain proprietary information and must describe the NASA need addressed by the proposed R/R&D effort.**

Potential NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Potential Non-NASA Application(s): Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. The response is limited to 1,500 characters, approximately 150 words.

Technology Taxonomy: Selections for the technology taxonomy are limited to technologies supported or relevant to the specific proposal. The listing of technologies for the taxonomy is provided in Appendix C.

Form C – STTR Budget Summary

PROPOSAL NUMBER:
SMALL BUSINESS CONCERN:

---

(1) DIRECT LABOR:

Category	Description	Education	Years of Experience	Hours	Rate	Total
____________	____________________	_____________	________	_____	_______	_____________
____________	____________________	_____________	________	_____	_______	_____________
____________	____________________	_____________	________	_____	_______	_____________

TOTAL DIRECT LABOR:
(1) $ ____________

Are the labor rates fully loaded? Yes No
If yes, explain any costs that apply:

Comments:

Document uploaded for labor rate documentation: (file name)

(2) OVERHEAD COST;

______% of Total Direct Labor or $ ______

OVERHEAD COST:
(2) $ ____________

Comments:

Overhead Cost Sources:
____
____
____

(3) OTHER DIRECT COSTS (ODCs):

Materials:
Description: _______________________________
Vendor: __________________________________
Quantity: ___________ Cost: ________________
Consumable: Yes No
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Supplies:

Description: ______________________________
Vendor: _________________________________
Quantity: ___________ Cost: ________________
Consumable: Yes No
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Equipment:

Description: ______________________________
Vendor: _________________________________
Quantity: ___________ Cost: ________________
Competitively Sourced?: Yes No
Used Exclusively for this Contract?: Yes No
Supporting Comments: ______________________
Supporting Documents: (file name)

Other:

Travel:

Location From: _______________ Location To: _______________
Number of People: _____________ Number of Days: ___________
Purpose of Trip: ____
Airfare: _____________________ Car Rental: ________________
Per Diem: ___________________ Other Costs: _______________
Total Costs: _________________
Sources of Estimates: _____________________________________
Explanation/Justification: __________________________________

Explanation of ODCs:
Provide any additional information on the Other Direct Costs listed above, including the basis used for estimating the costs.

Subcontractor/Consultants: Total Cost:

___________________________________ _________________
___________________________________ _________________

(Note: Separate Budget Summaries completed for all proposed Subcontractors/Consultants via the Subcontractors/Consultants section of Form C)

Research Institution: Total Cost:

___________________________________ _________________

(Note: Separate Budget Summary completed for the Research Institution via the Research Institution section of Form C)

TOTAL OTHER DIRECT COSTS:
(3) $ ____________

(1)+(2)+(3)=(4)	SUBTOTAL: (4)	$	____________
(5) GENERAL & ADMINISTRATIVE (G&A) COSTS ______% of Subtotal or $ ______	G&A COSTS: (5)	$	____________

Comments:
If an audit rate is not available, provide a detailed explanation of the cost base used to develop the G&A rate and if possible, a historical actual G&A rate for the past three years.

G&A Cost Elements:
____
____
____

(4)+(5)=(6)	TOTAL COSTS (6)	$	____________
(7) ADD PROFIT or SUBTRACT COST SHARING (As applicable)	PROFIT/COST SHARING: (7)	$	____________

Comments:

(6)+(7)=(8)	AMOUNT REQUESTED: (8)	$	____________

GOVERNMENT FACILITIES OR EQUIPMENT:

If you require the use of a Government Facility or Equipment, identify it below as well as in Part 8 of your technical proposal. (See certification l on Form A)

AUDIT AGENCY:

If your company's accounting system has been audited, are the rates from that audit agreement used for this proposal?

__ The rates listed in the negotiated rate agreement were used to prepare the budget summary
__ Other rates were used to prepare the budget summary
__ My company’s accounting system has not been audited

If the listed rates are not being used to prepare the budget summary, please provide an explanation:

Guidelines for Preparing STTR Budget Summary

Complete Budget Summary Form C electronically.

The offeror shall electronically submit a price proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting and estimating system.

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, in the text boxes or via uploads as indicated in the electronic form.

Offerors with questions about the appropriate classification of costs are advised to consult with an experienced accountant that has experience in government contracting and cost accounting principals. Information provided by the Defense Contract Audit Administration in their publication "Information for Contractors" may also be useful. This publication is available on-line at http://www.dcaa.mil/dcaap7641.90.pdf.

Firm: Same as Cover Sheet.

Proposal Number: Same as Cover Sheet.

Direct Labor: Select the appropriate labor category for each person who will be working directly on the proposed research effort and provide the labor description, level of education, years of experience, total number of hours, and labor rate. Detail the labor hours used for each year of the proposed research effort separately.

Indicate if the direct labor rates are fully loaded and, if yes, explain any costs that are included in the rate such as fringe benefits, etc. Provide the breakout rate such as the labor hour rate, health benefits, life insurance etc. Some examples of direct labor include Principal Investigator, Engineer, Scientist, Analyst or Research Assistant/Laboratory Assistant. All listed categories shall be directly related to proposed work to be performed under contract with NASA. Any contributions from non-technical personnel proposed under direct labor shall be explicitly explained. Labor rates that do not compare favorably to comparable state average rates at http://www.bls.gov require additional documentation, supporting the proposed rate or salary.

Note: Costs associated with company executives, accountants or administrative support are typically included in a company's general and administrative costs. If these costs are being proposed as direct labor then provide the details of how the proposed hours were allocated to this effort and verify that these costs are not also covered in your overhead or G&A rate.

Overhead Cost: Specify current rate and base. Use current rate(s) negotiated with your firm's cognizant Federal-auditing agency, if available. A rate that has not been audited requires a detailed explanation of the cost base used to develop the rate and if possible, historical actual overhead rates for the past three years.

Specify the cost elements of the company's overhead costs in the text boxes provided. Possible overhead cost elements include insurance, sick leave, and vacation.

Note: If no labor overhead rate is proposed and the proposed direct labor includes all fringe benefits, you may enter "0" for the overhead cost line.

Other Direct Costs (ODCs):
Refer to FAR 31.205 – Selected Costs for determination of cost allowability.

<u>Materials and Supplies:</u> Under the Materials and Supplies sections, indicate type, vendor, quantity required, and cost. Identify whether each item is consumable, which year it will be purchased, if it was competitively sourced, and

if it will be used exclusively for this contract. Your proposed cost shall be justified and supporting documents should be uploaded. General materials or supplies without adequate explanation of the components, quantity and use of said items are not an acceptable breakdown. In the supporting comments block, provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc…). The Contracting Officer will make the final determination.

Special Tooling, Testing, and Test Equipment: The need for these items, if proposed, will be carefully reviewed. Equipment must be made in the USA to the maximum extent practical. The offeror should provide competitive quotes to support the proposed costs or should justify why only one source is available. Competitive quotes may be signed quotes from vendors or copies of catalogue pages. Normally the costs of any equipment should be quoted on a purchase basis, unless the offeror can demonstrate that lease or rent of the equipment is clearly advantageous to the government. The Contracting Officer will make the final determination. Upload supporting documentation as necessary. In the supporting comments block provide the basis for the proposed price (vendor quote, competitive quotes, catalog price, estimate etc.). The Contracting Officer will make the final determination.

Travel: All proposed travel must be necessary for the success of the research. Include a detailed accounting of all proposed expenses to include the purpose of proposed trips, number of trips, travelers per trip, as well as meals, hotel, and rental car estimated costs. Sources of estimate should be identified when travel is proposed along with a justification for each trip. Proposed travel costs shall be in accordance with the Federal Travel Regulation http://www.gsa.gov/federaltravelregulation.

Subcontracts/Consultants: Subcontracts/Consultants costs are included in the Other Direct Costs total. A separate budget summary must be completed for each subcontract/consultant proposed. Further instructions are provided in the Subcontracts/Consultants section below.

Note: Do not add subcontractors or consultants as a line item under the ODCs section of Form C. It will automatically be added to the ODCs upon completion of the separate Subcontractor/Consultant budget summary form.

Research Institution: Research Institution costs are included in the Other Direct Costs total. A separate budget summary must be completed for the Research Institution. Further instructions are provided in the Research Institution section below.

Note: Do not add the Research Institution as a line item under the ODCs section of Form C. It will automatically be added to the ODCs upon completion of the separate Research Institution budget summary form.

Other: List all other direct costs that are not otherwise included in the categories described above such as rental of facilities, etc.

Note: The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Firms should be prepared to justify all material, supplies, and equipment costs during negotiations. See section 3.2.4 Part 8 for further guidance.

Explanation of ODCs: Provide any additional information for the proposed ODCs, including basis for cost estimation, in the text box provided.

Subcontracts/Consultants: List consultants by name and specify, for each, the number of hours and hourly costs. Detailed quotes from subcontractors should be provided in the same format. Note that a subcontract entered into for performance of research or research and development differs from an arrangement with a vendor to provide a service such as machining, analysis with test equipment or use of computer time. The costs of such arrangements with vendors should be covered under Special Tooling, Testing, Test Equipment and Material or under Other Direct

Costs. Upon request of the contracting officer, the subcontractor's cost proposals may be sealed or mailed directly for government eyes only.

A letter of commitment shall be uploaded for each proposed subcontractor/consultant from the Subcontractor/Consultant Letter of Commitment section of the subcontractor/consultant budget summary form. If a commitment letter is not available, you shall provide an explanation in the text box to include a point of contact and contact information in order for NASA to obtain the required document to confirm availability to perform the proposed work during the proposed timeframe. Note that not providing the information now may delay award and contract negotiations.

Research Institution: Provide detailed budget information for the costs associated with the Research Institution.

General and Administrative (G&A) Costs: Specify a current rate and base to which G&A costs will be applied. If available, use the current rate recommendations from the cognizant Federal-auditing agency. If an audit rate is not available, provide a detailed explanation of the cost base used to develop the rate and if possible, a historical actual G&A rate for the past three years.

Specify the elements of the company's G&A costs in the text boxes provided. Possible G&A cost elements include Rent, Utilities, and Management.

Profit/Cost Sharing: See Section 5.9. Profit is to be added to total cost, while shared costs are to be subtracted from total cost, as applicable.

Amount Requested: The amount requested is equal to the sum of the Direct Labor, Overhead, ODCs, G&A and any profit, less any cost sharing. The amount requested cannot exceed $700,000 for Phase II.

Government Facilities and Equipment: If you require the use of Government Facilities or Equipment, identify the Government facilities or equipment in the text box provided, as well as in Part 8 of your technical proposal. Please note that this section SHALL be completed if you certified in Form A that you will require the use of Government Facilities. Leave this section BLANK if you DO NOT require the use of Government facilities or equipment.

Audit Information: Complete the Audit Information section of Form C to indicate if your company's accounting system has been audited and if the rates from that audit agreement are used for this proposal.

Note: There is a separate "Audit Information" section linked from your Activity Worksheet that must also be completed.

Model Cooperative R/R&D Agreement

By virtue of the signatures of our authorized representatives, _________(Small Business Concern)___________, and _____________________________(Research Institution)__________________________ have agreed to cooperate on the _________(Proposal Title)_________ Project, in accordance with the proposal being submitted with this agreement.

This agreement shall be binding until the completion of all Phase I activities, at a minimum. If the________ _______(Proposal Title)_________ Project is selected to continue into Phase II, the agreement may also be binding in Phase II activities that are funded by NASA, then this agreement shall be binding until those activities are completed. The agreement may also be binding in Phase III activities that are funded by NASA.

After notification of Phase I selection and prior to contract release, we shall prepare and submit, if requested by NASA, an **Allocation of Rights Agreement**, which shall state our rights to the intellectual property and technology to be developed and commercialized by the _______________(Proposal Title)_________ Project. We understand that our contract cannot be approved and project activities may not commence until the **Allocation of Rights Agreement** has been signed and certified to NASA.

Please direct all questions and comments to _____(Small Business Concern representative) at (Phone Number)____.

________Signature_____________________

________Name/title____________________

________Small Business Concern_________

________Signature_____________________

________Name/title____________________

________Research Institution_____________

Small Business Technology Transfer (STTR) Program Model Allocation of Rights Agreement

This Agreement between ____, a small business concern organized as a ________________________ under the laws of ________________ and having a principal place of business at ____ ___________________, ("SBC") and ____, a research institution having a principal place of business at _________________________ ________________,("RI") is entered into for the purpose of allocating between the parties certain rights relating to an STTR project to be carried out by SBC and RI (hereinafter referred to as the "PARTIES") under an STTR funding agreement that may be awarded by ____NASA_____ to SBC to fund a proposal entitled "____" submitted, or to be submitted, to by SBC on or about _________________________, 20___.

1. Applicability of this Agreement.

(a) This Agreement shall be applicable only to matters relating to the STTR project referred to in the preamble above.

(b) If a funding agreement for STTR project is awarded to SBC based upon the STTR proposal referred to in the preamble above, SBC will promptly provide a copy of such funding agreement to RI, and SBC will make a sub-award to RI in accordance with the funding agreement, the proposal, and this Agreement. If the terms of such funding agreement appear to be inconsistent with the provisions of this Agreement, the Parties will attempt in good faith to resolve any such inconsistencies.

However, if such resolution is not achieved within a reasonable period, SBC shall not be obligated to award nor RI to accept the sub-award. If a sub-award is made by SBC and accepted by RI, this Agreement shall not be applicable to contradict the terms of such sub-award or of the funding agreement awarded by NASA to SBC except on the grounds of fraud, misrepresentation, or mistake, but shall be considered to resolve ambiguities in the terms of the sub-award.

(c) The provisions of this Agreement shall apply to any and all consultants, subcontractors, independent contractors, or other individuals employed by SBC or RI for the purposes of this STTR project.

2. Background Intellectual Property.

(a) "Background Intellectual Property" means property and the legal right therein of either or both parties developed before or independent of this Agreement including inventions, patent applications, patents, copyrights, trademarks, mask works, trade secrets and any information embodying proprietary data such as technical data and computer software.

(b) This Agreement shall not be construed as implying that either party hereto shall have the right to use Background Intellectual Property of the other in connection with this STTR project except as otherwise provided hereunder.

(1) The following Background Intellectual Property of SBC may be used nonexclusively and except as noted, without compensation by RI in connection with research or development activities for this STTR project (if "none" so state): ____________________________________ ____ ____;

(2) The following Background Intellectual Property of RI may be used nonexclusively and, except as noted, without compensation by SBC in connection with research or development activities for this STTR project (if "none" so state): ____
____
____;

(3) The following Background Intellectual Property of RI may be used by SBC nonexclusively in connection with commercialization of the results of this STTR project, to the extent that such use is reasonably necessary for practical, efficient and competitive commercialization of such results but not for commercialization independent of the commercialization of such results, subject to any rights of the Government therein and upon the condition that SBC pay to RI, in addition to any other royalty including any royalty specified in the following list, a royalty of _____% of net sales or leases made by or under the authority of SBC of any product or service that embodies, or the manufacture or normal use of which entails the use of, all or any part of such Background Intellectual Property (if "none" so state): ____
____
____.

3. Project Intellectual Property.

(a) "Project Intellectual Property" means the legal rights relating to inventions (including Subject Inventions as defined in 37 CFR § 401), patent applications, patents, copyrights, trademarks, mask works, trade secrets and any other legally protectable information, including computer software, first made or generated during the performance of this STTR Agreement.

(b) Except as otherwise provided herein, ownership of Project Intellectual Property shall vest in the party whose personnel conceived the subject matter, and such party may perfect legal protection in its own name and at its own expense. Jointly made or generated Project Intellectual Property shall be jointly owned by the Parties unless otherwise agreed in writing. The SBC shall have the first option to perfect the rights in jointly made or generated Project Intellectual Property unless otherwise agreed in writing.

(1) The rights to any revenues and profits, resulting from any product, process, or other innovation or invention based on the cooperative shall be allocated between the SBC and the RI as follows:

SBC Percent: ________ RI Percent: ________

(2) Expenses and other liabilities associated with the development and marketing of any product, process, or other innovation or invention shall be allocated as follows: the SBC will be responsible for ______ percent and the RI will be responsible for ______ percent.

(c) The Parties agree to disclose to each other, in writing, each and every Subject Invention, which may be patentable or otherwise protectable under the United States patent laws in Title 35, United States Code. The Parties acknowledge that they will disclose Subject Inventions to each other and the Agency within two months after their respective inventor(s) first disclose the invention in writing to the person(s) responsible for patent matters of the disclosing Party. All written disclosures of such inventions shall contain sufficient detail of the invention, identification of any statutory bars, and shall be marked confidential, in accordance with 35 U.S.C. § 205.

(d) Each party hereto may use Project Intellectual Property of the other nonexclusively and without compensation in connection with research or development activities for this STTR project, including inclusion in STTR project reports to the AGENCY and proposals to the AGENCY for continued funding of this STTR project through additional phases.

(e) In addition to the Government's rights under the Patent Rights clause of 37 CFR § 401.14, the Parties agree that the Government shall have an irrevocable, royalty free, nonexclusive license for any Governmental purpose in any Project Intellectual Property.

(f) SBC will have an option to commercialize the Project Intellectual Property of RI, subject to any rights of the Government therein, as follows—

(1) Where Project Intellectual Property of RI is a potentially patentable invention, SBC will have an exclusive option for a license to such invention, for an initial option period of _______ months after such invention has been reported to SBC. SBC may, at its election and subject to the patent expense reimbursement provisions of this section, extend such option for an additional _______ months by giving written notice of such election to RI prior to the expiration of the initial option period. During the period of such option following notice by SBC of election to extend, RI will pursue and maintain any patent protection for the invention requested in writing by SBC and, except with the written consent of SBC or upon the failure of SBC to reimburse patenting expenses as required under this section, will not voluntarily discontinue the pursuit and maintenance of any United States patent protection for the invention initiated by RI or of any patent protection requested by SBC. For any invention for which SBC gives notice of its election to extend the option, SBC will, within ______ days after invoice, reimburse RI for the expenses incurred by RI prior to expiration or termination of the option period in pursuing and maintaining (i) any United States patent protection initiated by RI and (ii) any patent protection requested by SBC. SBC may terminate such option at will by giving written notice to RI, in which case further accrual of reimbursable patenting expenses hereunder, other than prior commitments not practically revocable, will cease upon RI's receipt of such notice. At any time prior to the expiration or termination of an option, SBC may exercise such option by giving written notice to RI, whereupon the parties will promptly and in good faith enter into negotiations for a license under RI's patent rights in the invention for SBC to make, use and/or sell products and/or services that embody, or the development, manufacture and/or use of which involves employment of, the invention. The terms of such license will include: (i) payment of reasonable royalties to RI on sales of products or services which embody, or the development, manufacture or use of which involves employment of, the invention; (ii) reimbursement by SBC of expenses incurred by RI in seeking and maintaining patent protection for the invention in countries covered by the license (which reimbursement, as well as any such patent expenses incurred directly by SBC with RI's authorization, insofar as deriving from RI's interest in such invention, may be offset in full against up to _______ of accrued royalties in excess of any minimum royalties due RI); and, in the case of an exclusive license, (3) reasonable commercialization milestones and/or minimum royalties.

(2) Where Project Intellectual Property of RI is other than a potentially patentable invention, SBC will have an exclusive option for a license, for an option period extending until ______ months following completion of RI's performance of that phase of this STTR project in which such Project Intellectual Property of RI was developed by RI. SBC may exercise such option by giving written notice to RI, whereupon the parties will promptly and in good faith enter into negotiations for a license under RI's interest in the subject matter for SBC to make, use and/or sell products or services which embody, or the development, manufacture and/or use of which involve employment of, such Project Intellectual Property of RI. The terms of such license will include: (i) payment of reasonable royalties to RI on sales of products or services that embody, or the development, manufacture or use of which involves employment of, the Project Intellectual Property of RI and, in the case of an exclusive license, (ii) reasonable commercialization milestones and/or minimum royalties.

(3) Where more than one royalty might otherwise be due in respect of any unit of product or service under a license pursuant to this Agreement, the parties shall in good faith negotiate to ameliorate any effect thereof that would threaten the commercial viability of the affected products or services by providing in such license(s) for a reasonable discount or cap on total royalties due in respect of any such unit.

4. Follow-on Research or Development.

All follow-on work, including any licenses, contracts, subcontracts, sublicenses or arrangements of any type, shall contain appropriate provisions to implement the Project Intellectual Property rights provisions of this agreement and insure that the Parties and the Government obtain and retain such rights granted herein in all future resulting research, development, or commercialization work.

5. Confidentiality/Publication.

(a) Background Intellectual Property and Project Intellectual Property of a party, as well as other proprietary or confidential information of a party, disclosed by that party to the other in connection with this STTR project shall be received and held in confidence by the receiving party and, except with the consent of the disclosing party or as permitted under this Agreement, neither used by the receiving party nor disclosed by the receiving party to others, provided that the receiving party has notice that such information is regarded by the disclosing party as proprietary or confidential. However, these confidentiality obligations shall not apply to use or disclosure by the receiving party after such information is or becomes known to the public without breach of this provision or is or becomes known to the receiving party from a source reasonably believed to be independent of the disclosing party or is developed by or for the receiving party independently of its disclosure by the disclosing party.

(b) Subject to the terms of paragraph (a) above, either party may publish its results from this STTR project. However, the publishing party will give a right of refusal to the other party with respect to a proposed publication, as well as a _____ day period in which to review proposed publications and submit comments, which will be given full consideration before publication. Furthermore, upon request of the reviewing party, publication will be deferred for up to ______ additional days for preparation and filing of a patent application which the reviewing party has the right to file or to have filed at its request by the publishing party.

6. Liability.

(a) Each party disclaims all warranties running to the other or through the other to third parties, whether express or implied, including without limitation warranties of merchantability, fitness for a particular purpose, and freedom from infringement, as to any information, result, design, prototype, product or process deriving directly or indirectly and in whole or part from such party in connection with this STTR project.

(b) SBC will indemnify and hold harmless RI with regard to any claims arising in connection with commercialization of the results of this STTR project by or under the authority of SBC. The PARTIES will indemnify and hold harmless the Government with regard to any claims arising in connection with commercialization of the results of this STTR project.

7. Termination.

(a) This agreement may be terminated by either Party upon __ days written notice to the other Party. This agreement may also be terminated by either Party in the event of the failure of the other Party to comply with the terms of this agreement.

(b) In the event of termination by either Party, each Party shall be responsible for its share of the costs incurred through the effective date of termination, as well as its share of the costs incurred after the effective date of termination, and which are related to the termination. The confidentiality, use, and/or nondisclosure obligations of this agreement shall survive any termination of this agreement.

AGREED TO AND ACCEPTED--

Small Business Concern

By:_________________________________ Date:_____________
Print Name:____
Title:____

Research Institution

By:_________________________________ Date:____________
Print Name:____
Title:____

STTR Check List

For assistance in completing your Phase II proposal, use the following checklist to ensure your submission is complete.

For assistance in completing your Phase II proposal, use the following checklist to ensure your submission is complete.

14. **The entire proposal including any supplemental material shall not exceed a total of 25 8.5 x 11 inch pages, including Cooperative Agreement** (Sections 3.2.2, 3.2.5).

15. The proposal and innovation is submitted for one subtopic only (Section 3.1).

16. The entire proposal is submitted consistent with the requirements and in the order outlined in Section 3.2.

17. The technical proposal contains all eleven parts in order (Section 3.2.4).

18. The 1-page briefing chart does not include any proprietary data (Section 3.2.8).

19. Certifications in Form A are completed, and agree with the content of the technical proposal.

20. Proposed funding does not exceed $125,000 (Sections 1.4).

21. Proposed project duration does not exceed 12 months (Sections 1.4).

22. Cooperative Agreement has been electronically endorsed by both the SBC Official and RI (Sections 3.2.5, 6.2).

23. Entire proposal including Forms A, B, C, and Cooperative Agreement submitted via the Internet.

24. Form A electronically endorsed by the SBC Official.

25. **Phase II proposal submissions will be due after the last day of the Phase I contract.** (Section 6.3).

26. Signed Allocation of Rights Agreement available for Contracting Officer at time of selection.

9. Research Topics for SBIR and STTR

9.1 SBIR Research Topics

Introduction

The SBIR Program Solicitation topics and subtopics are developed by the NASA Mission Directorates and Centers in coordination with the NASA SBIR/STTR programs.

There are four NASA Mission Directorates (MDs):

Aeronautics Research
Exploration Systems
Science
Space Operations

9.1.1 AERONAUTICS RESEARCH

NASA's Aeronautics Research Mission Directorate (ARMD) expands the boundaries of aeronautical knowledge for the benefit of the Nation and the broad aeronautics community, which includes the Agency's partners in academia, industry, and other government agencies. ARMD is conducting high-quality, cutting-edge research that will lead to revolutionary concepts, technologies, and capabilities that enable radical change to both the airspace system and the aircraft that fly within it, facilitating a safer, more environmentally friendly, and more efficient air transportation system. At the same time, we are ensuring that aeronautics research and critical core competencies continue to play a vital role in support of NASA’s goals for both manned and robotic space exploration.

ARMD conducts cutting-edge research that produces concepts, tools, and technologies that enable the design of vehicles that fly safely through any atmosphere at any speed. In addition, ARMD is directly addressing fundamental research challenges that must be overcome in order to implement the Next Generation Air Transportation System (NextGen). This research will yield revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the National Air Space. In conjunction with expanding air traffic management capabilities, research is being conducted to help address substantial noise, emissions, efficiency, performance, and safety challenges that are required to ensure vehicles can support the NextGen vision.

NASA's Aeronautics Research Mission Directorate (ARMD) supports the Agency's goal (Goal 4) to advance aeronautics research for societal benefit. The ARMD research plans directly support the National Aeronautics Research and Development Policy and accompanying Executive Order signed by the President on December 20, 2006.

http://www.aeronautics.nasa.gov/

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TOPIC: A1 Aviation Safety

The Aviation Safety Program conducts fundamental research and technology development of known and predicted safety concerns as the nation transitions to the Next Generation Air Transportation System (NextGen). Future challenges to maintaining aviation safety arise from expected significant increases in air traffic, continued operation of legacy vehicles, introduction of new vehicle concepts, increased reliance on automation, and increased operating complexity. Further design challenges also exist where safety barriers may prevent the technical innovations necessary to achieve NextGen capacity and efficiency goals. The program seeks capabilities furthering the practice of proactive safety management and design methodologies and solutions to predict and prevent safety issues, to monitor for them in-flight and mitigate against them should they occur, to analyze and design them out of complex system behaviors, and to constantly analyze designs and operational data for potential hazards. AvSP's top ten technical challenges are:

- Assurance of Flight Critical Systems.
- Discovery of Safety Issues.
- Automation Design Tools.
- Prognostic Algorithm Design.
- Vehicle Health Assurance.
- Crew-System Interactions and Decisions.
- Loss of Control Prevention, Mitigation, and Recovery.
- Engine Icing.
- Airframe Icing.
- Atmospheric Hazard Sensing and Mitigation.

AvSP includes three research projects:

The System-wide Safety Assurance Technologies Project provides knowledge, concepts and methods to proactively manage increasing complexity in the design and operation of vehicles and the air transportation systems, including advanced approaches to enable improved and cost-effective verification and validation of flight-critical systems.

The Vehicle Systems Safety Technologies Project provides knowledge, concepts and methods to avoid, detect, mitigate, and recover from hazardous flight conditions, and to maintain vehicle airworthiness and health.

The Atmospheric Environment Safety Technologies Project investigates sources of risk and provides technology needed to help ensure safe flight in and around atmospheric hazards.

NASA seeks highly innovative proposals that will complement its work in science and technologies that build upon and advance the Agency's unique safety-related research capabilities vital to aviation safety. Additional information is available at (http://www.aeronautics.nasa.gov/programs_avsafe.htm).

A1.01 Aviation External Hazard Sensor Technologies
Lead Center: LaRC
Participating Center(s): ARC

NASA is concerned with new and innovative methods for detection, identification, evaluation, and monitoring of in-flight hazards to aviation. NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-flight hazard avoidance and mitigation. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices.

A key objective of the NASA Aviation Safety Program is to support the research of technology, systems, and methods that will facilitate transformation of the National Airspace System to Next Generation Air Transportation System (NextGen) (information available at www.jpdo.gov). The general approach to the development of airborne sensors for NextGen is to encourage the development of multi-use, adaptable, and effective sensors that will have a strong benefit to safety. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are required for NextGen.

Under this subtopic, proposals are invited that explore new and improved sensors and sensor systems for the detection and monitoring of hazards to aircraft before they are encountered. The scope of this subtopic does not include human factors and development of human interfaces, including displays and alerts, except where explicitly requested in association with special topics. Primary emphasis is on airborne applications, but in some cases the development of ground-based sensor technology may be supported. Approaches that use multiple sensors in combination to improve hazard detection and quantification of hazard levels are also of interest.

At this time, there are some areas of particular interest to NASA, and these are described below. They are provided as encouragement but not intended to exclude other proposals that fit this subtopic. These areas of interest include two specific hazards to aircraft and specific advancements in fundamental radar technology. The interest in radar technology can be considered to be independent of the interest in the two hazards. While NASA is interested in all aviation hazards, wake vortices and turbulence are of particular interest. Proposals associated with remote sensing investigations addressing these hazards are encouraged. This emphasis is not intended to discourage proposals targeting other or additional hazards such as reduced visibility, terrain, airborne obstacles, volcanic ash, convective weather, lightning, gust fronts, cross winds, and wind shear.

Airborne detection of wake vortices is considered challenging due to the fact that detection must be possible in nearly all weather conditions, in order to be practical, and because of the size and nature of the phenomena. Proposals are encouraged for the development of novel coherent and direct detection lidar systems and associated components that allow accurate meteorological wind and aerosol measurements suitable for wake vortex characterization. Lidar development includes, but is not limited to, novel transceiver architectures, efficient signal processing methodologies, wake processing algorithms and real time data reduction and display schemes. Improvements in size, weight, range, system efficiency, sensitivity, and reliability based on emerging technologies are desired.

NASA has made a major investment in the development of new and enhanced technologies to enable detection of turbulence to improve aviation safety. Progress has been made in efforts to quantify hazard levels from convectively induced turbulence events and to make these quantitative assessments available to civil and commercial aviation. NASA is interested in expanding these prior efforts to take advantage of the newly developing turbulence monitoring technologies, particularly those focused on clear air turbulence (CAT). NASA welcomes proposals that explore the methods, algorithms and quantitative assessment of turbulence for the purpose of increasing aviation safety and augmenting currently available data in support of NextGen operations.

In order to detect and/or discriminate some meteorological hazards, future radars will need multi-frequency and/or polarimetric capabilities. NASA seeks new system/component designs and hazard detection applications for airborne weather radars based upon extending the current design to incorporate multi-frequencies and/or polarimetric capabilities. In addition, the current generation of weather radar is fundamentally limited by its ability to scan the airspace; consequently, NASA is seeking novel designs and enhancements to produce electronically scanned antennas/radars.

A1.02 Inflight Icing Hazard Mitigation Technology
Lead Center: GRC

NASA is concerned with the prevention of encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. Under this subtopic, proposals are invited that explore new and dramatically improved technologies related to inflight airframe and engine icing hazards for manned and unmanned vehicles. Technologies of interest should address the detection, measurement, and/or the mitigation of the hazards of flight into supercooled liquid water clouds and flight into regions of high ice crystal density. With these emphases in mind, products and technologies that can be made affordable and capable of retrofit into the current aviation system and aircraft, as well as for use in the future are sought.

Areas of interest include, but are not limited to:

- Non-destructive digitization of ice accretions on wind tunnel wing models. NASA has a need for methods to digitize ice shapes with rough external surfaces and internal voids as can occur with accretions on highly swept wing. Current methods based upon scanning with line-of-sight optical digitization methods have been found inadequate for these ice shapes.
- New instruments are needed utilizing innovative concepts to measure ice-crystal/liquid water mixed phase clouds in ground test facilities and in flight. Cloud properties of interest include: crystal/droplet temperature, material phase, particle size, speed, cloud liquid-water content, ice-water content, air temperature, and humidity. Non-intrusive measurement techniques capable of providing the spatial distribution of these properties across an engine duct with a diameter of at least 3 feet are particularly of interest.
- New instruments or measurement techniques are also needed for the detailed study of the ice accretion process on wing surfaces and internal engine components. Properties of particular interest are heat transfer, accretion extent, and ice density. The measurement of these properties needs to be non-interfering.

A1.03 Durable Propulsion Components
Lead Center: GRC

The mitigation and management of aging and durability-related hazards in future civilian and military aircraft will require advanced materials, concepts, and techniques. NASA is engaged in the research of materials (metals, ceramics, and composites) and characterization/validation test techniques to mitigate aging and durability issues and to enable advanced material suitability and concepts.

Proposals are sought for the development of physics-based probabilistic fatigue life models for powder metallurgy disk superalloys, which include both crystal plasticity and surface environmental damage modes. The models would capture the evolution of fatigue damage due to crystallographic slip within multiple grains of variable orientation and size, as well as damage due to environmental interactions at the surfaces of compressor and turbine powder metallurgy superalloy disks. This research opportunity is focused on quantifying, modeling and validating each of these damage modes during simple cyclic and dwell fatigue cycles, and then later for simulated service in aerospace gas turbine engine disk materials. Work may involve use of uniform gage and notched fatigue specimens to simulate key disk features, potentially utilizing varied disk surface finish conditions and associated residual stress and cold work. The simulated load history and temperature gas turbine engine conditions should approximate turbine service history reflective of the new generation of gas turbine engines and include the effect of superimposed dwell cycles. NASA will be an active participant in Phase I of the research effort by providing superalloy disk sections, for the proposer to machine into specimens, mechanically test, analyze, and model evolution of these damage modes. Technology innovations may take the form of the unique quantification of the effect of service history on these damage modes, and include analytical modeling descriptions of the evolution of these parameters as a function of simulated service history. The technology innovations may also include models and algorithms extrapolating this damage to service conditions outside of those tested during the program.

A1.04 Airframe Design and Sustainment
Lead Center: LaRC
Participating Center(s): DFRC, GRC

Conventional aircraft airframe structures have achieved a high level of reliability through decades of experience, incremental technology changes, and an empirically based building block design methodology. Emerging and next generation aircraft will employ new lightweight materials and structural concepts that have very different characteristics than our current experience base. One element in NASA's effort to ensure the integrity of future vehicles is research to improve the reliability of airframe structures through enhanced computational methods to predict structural integrity and life, and validating correlation between computational models and the as-manufactured and as-maintained aircraft structure.

NASA seeks tools and methods for improved understanding and prediction of structural response, and experimental methods for measuring and evaluating the performance of new airframe structural designs. Specific areas of interest include the following:

- Improved structural analysis methods for complex metallic and composite airframe components using novel multi-scale as well as global-local computational codes. The methods used for these solutions need to detail the initiation and progression of damage to determine accurate estimates of residual life and or strength of complex airframe structures. Robust numerical algorithms are required to simulate the nonlinear behavior of damage progression coupled with geometric and material nonlinearity.
- Correlation between computational models and airframe structures:
    - Experimental methods for detailed characterization of as-manufactured structures relative to the as-designed configuration, to identify deviations in geometry, material application, and possibly identify manufacturing anomalies.
    - Advanced experimental methods for full-field assessment of strain during structural or flight tests for the purpose of validating computational models, and identifying hot-spots in the structure that are not represented in the models. Ease of application on built-up structures will be a significant factor.
    - Technologies to measure residual stresses in structures resulting from manufacturing processes and fit-up during structural assembly, as these residual stresses may severely compromise design margins.
- Repair technology for metallic or composite structures:
    - Novel approaches to arrest damage and return structural integrity (other than replacement, grind out, scarf, or bonded or bolted doublers).
    - Validation of structural repair: technology to interrogate an applied repair to validate the design of the repair, and correct application of the repair. The intent will be to determine whether the repair performs as expected to return structural integrity.

Technology innovations may take the form of tools, models, algorithms, and devices.

All proposals should discuss means for verification and validation of proposed methods and tools in operationally valid, or end-user, contexts.

A1.05 Sensing and Diagnostic Capabilities for Degradation in Aircraft Materials and Structures
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

Many conventional nondestructive evaluation (NDE) and integrated vehicle health management (IVHM) techniques have been used for flaw detection, but have shown little potential for much broader application. One element in NASA's effort to ensure the integrity of future vehicles is research to identify changes in fundamental material properties as indicators of material aging-related hazards before they become critical. For example, composites can exhibit a number of micromechanisms such as fiber buckling and breakage, matrix cracking and delaminations as precursor to failure. For complex metallic components an inability to determine residual stress state limits the validity of predictions of the fatigue life of the component.

To further these goals, NDE and IVHM technologies are being sought for the nondestructive characterization of age-related degradation in complex materials and structures. Innovative and novel approaches to using NDE technologies to measure properties related to manufacturing defects, flaws, and material aging. Measurement techniques, models, and analysis methods related to quantifying material thermal properties, elastic properties, density, microcrack formation, fiber buckling and breakage, etc. in complex composite material systems, adhesively bonded/built-up and/or polymer-matrix composite sandwich structures are of particular interest. Other NDE and IVHM technologies being sought are those that enable the quantitative assessment of the strength of an adhesive region of bonded joints and repairs or enable the rapid inspection of large area structures. The anticipated outcome of successful proposals would be both a Phase II prototype technology for the use of the developed technique and a demonstration of the technology showing its ability to measure a relevant material property or structural damage in the advanced materials and structures in subsonic aircraft.

A1.06 Propulsion Health State Assessment and Management
Lead Center: GRC
Participating Center(s): DFRC

The emphasis for this subtopic is on propulsion system health management, in order to predict, prevent, or accommodate safety-significant malfunctions and damage. Past advances in this area have helped improve the reliability and safety of aircraft propulsion systems; however, propulsion system component failures are still a contributing factor in numerous aircraft accidents and incidents. Advances in technology are sought which help to further reduce the occurrence of and/or mitigate the effects of safety-significant propulsion system malfunctions and damage. Specifically the following are sought: propulsion health management technologies such as instrumentation, sensors, health monitoring algorithms, and fault accommodating logic, which will detect, diagnose, prevent, assess, and allow recovery from propulsion system malfunctions, degradation, or damage. Specific technologies of interest include:

- Self-awareness and diagnosis of gas path, combustion, and overall engine state (containment systems and rotating and static components), and fault-tolerant system architectures.
- Analytical and data-driven techniques for diagnosing incipient faults in the presence deterioration, engine-to-engine variation, and transient operating conditions.
- Innovative sensing techniques for the cost-effective assessment of turbomachinery health in harsh high-temperature environments including high temperature sensors including fiber optic and Microsystems, rotatodynamics monitoring, energy harvesting, communication, and packaging.
- Prognostic techniques for the accurate assessment of remaining component life while in-flight.

A1.07 Avionics Health State Assessment and Management
Lead Center: ARC
Participating Center(s): LaRC

Shielded twisted-pair cables are already in common use on-board aircraft and spacecraft, and are destined to be ubiquitous in the all-electric aircraft designs of the future. At present, however, easy to use commercially available connector interfaces between this type of cable and electrical test equipment (such as oscilloscopes, network analyzers, or handheld diagnostic units) are not readily available, and custom-built test fixtures are the norm. Given the widespread use of this cable type in other commercial wiring applications such as DSL, NASA is investing in the research and development of a commercial-grade product to address this need. Proposals are therefore sought for the design of a novel electrical connector system (or small portable interface board) that can interface the coaxial SMA (or 2.9 mm) ports of typical high-end electrical test equipment with a shielded twisted-pair (STP) cable (2 inner conductors surrounded by a shield). The design should provide two 50 ohm coaxial SMA (or 2.9 mm) inputs, each used to individually excite the common and differential modes of the cable, and one output connection to the STP cable itself. In addition, the design should minimize the mode cross coupling caused by the connector in the frequency range of interest (0-10 GHz). Finally, a critical part of the design must include a calibration method and set of calibration standards for obtaining a high-quality Vector Network Analyzer (VNA) based measurement (using a standard VNA) of the 4 port 4x4 S-parameter matrix covering the differential and common mode ports on each end of the TSP cable from 0-10 GHz.

Proposals should address the design and the numerical verification of the connector and calibration standards in Phase I, with the experimental validation and the prototype construction reserved for Phase II. Use of a commercial electromagnetics simulator such as COMSOL is strongly encouraged. While the design does not need to be compact or inexpensive at this stage, any obvious impediments to its subsequent miniaturization or commercialization will be considered a serious weakness.

A1.08 Crew Systems Technologies for Improved Aviation Safety
Lead Center: LaRC

The NASA Aviation Safety program aims to model and develop integrated crew-system interaction (ICSI) concepts and to subsequently evaluate this concept in a relevant operational environment in comparison to state-of-the-art. NASA seeks proposals for novel technologies and evaluation tools with high potential to support an ICSI with effective crew-system interactions in the context of NextGen operational requirements (e.g., 4D trajectory-based operations, visual operations in non-visual meteorological conditions, etc.) and assumptions (e.g., net-centric information management environment) (NextGen described in http://www.faa.gov/nextgen/).

To improve these interactions, we seek interventions that proactively identify and mitigate NextGen flight deck risks; address documented crew-related causal factors in accidents; and improve the ability to unobtrusively, effectively, and sensitively evaluate and model crew and crew-automation system performance. In particular, we seek proposals for the development of advanced technologies that address:

- Crew challenges associated with piloting terminal area 4D Trajectory-Based Operations in Instrument Meteorological Conditions (IMC).
- Displays, decision-support, and automation interaction under off-nominal conditions; in particular in that lead to spatial disorientation and loss of energy state awareness leading to loss-of-control (LOC).
- The appropriate levels of integrity for new classes of information to be made available to the crew as a result of NextGen’s net centric information management environment.
- Pilot proficiency in increasingly automated flight decks (e.g., manual handing skill erosion).
- Optimal methods for information presentation as distributed over time and display space for multiple operators to maximize crew information processing and coordination.
- Appropriate trust in, and therefore use of, automation and complex information sources by, for example, conveying constraints on automation reliability and information certainty/timeliness.
- Effective joint cognitive system design and evaluation with multiple intelligent agents (human and automated, proximal and remote).
- Improved oculometer, neurophysiological, or other sensors and/or data integration methods that would improve the ability to characterize operator functional status in real time.
- Improved human-system interaction through effectively modulating operator state, and/or effectively adapting interfaces and automation in response to this functional status.
- Evaluation of adaptive and adaptable crew-system interfaces.
- A priori assessment of human error likelihood and consequence in NextGen scenarios

Phase I proposals that demonstrate relevance to the NASA Aviation Safety Program's VSST and/or SSAT programs, include a detailed resource-loaded schedule, literature-based justification, highly competent staffing, prescription for Phase II work, and clear path to commercialization or utilization in NASA programs are most valued.

A1.09 Integrated Vehicle Dynamics Modeling Methods for LOC Conditions
Lead Center: LaRC
Participating Center(s): ARC, GRC

Effective characterization of LOC conditions requires inclusion of the flight dynamics effects from multiple disciplines, including aerodynamics, structures, propulsion, and aeroelasticity. However, the types of data and data sets obtained from modeling in these various disciplines can be quite disparate, even within a discipline (e.g., wind-tunnel static versus dynamic data versus CFD flow-field data), and is exacerbated when we consider the non-linear parts of the flight envelope. Further, disciplines have varying levels of sensitivity to certain flight conditions.

Of interest are software tools that could take such disparate types of information and provide methods to manage and integrate them in a single environment to provide flight-dynamics-relevant implications. Examples include translating thrust response into force and moment increments to superimpose on the nominal aerodynamics, or applying aerodynamic load distributions to key structural components to define flight envelope boundaries based on structural load limits. Such tools can also be useful in highlighting flight conditions where data sets overlap and thus may provide good integrated model fidelity, versus conditions where fidelity may be limited, helping provide guidance on where research emphasis should be placed. Overall, concepts should be aimed at facilitating integrated model implementation into a flight simulation environment.

A1.10 Advanced Dynamic Testing Capability for Abnormal Flight Conditions
Lead Center: LaRC

The goal of developing a comprehensive methodology for obtaining appropriate aerodynamic math models for flight vehicles over a greatly expanded flight envelope requires a more general formulation of the aerodynamic model that more accurately characterizes nonlinear steady and unsteady aerodynamics. This leads to greater demands in the development of dynamic test techniques and correspondingly more demands on test facility capabilities. This topic is for the design and software for a prototype dynamic test rig for wind or water tunnel application, with guidance for scaling up to large facilities. The concept should be aimed at providing high-automation and productivity for arbitrary, programmable, multi-axis motions, and should consider the following test capabilities that are considered an important subset of possible motions for characterizing vehicle dynamics characteristics under abnormal flight conditions: conventional single-axis forced oscillation; constant-rate motion through the use of square and triangle waveforms; steady and oscillatory coning motions; inclined axis coning; coupled, multi-axis motion; and wide-band inputs, such as Schroeder sweeps. Design should include considerations for mitigating blockage and interference effects.

A1.11 Transport Aircraft Simulator Motion Fidelity For Abnormal Flight Conditions
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

Piloted simulation remains an important enabling tool for a wide variety of research aimed at commercial aviation safety. Over the past decade, significant advances in aerodynamic modeling of large transport airplanes at high angles of attack are providing new capabilities for prediction of flight behavior in off-nominal or out-of-envelope conditions. As a result, piloted simulation is now being considered for flight training specifically aimed at stall and post-stall conditions. In addition, other technology areas focused on the problem of loss-of-control accidents, such as advanced controls and crew systems, now stand to benefit from this enhanced simulation capability.

Simulator motion often plays an important role in simulator fidelity. For example, hexapod motion systems are commonly used for airline flight training and are justified by the increased transfer of training with the added realism of cockpit accelerations. However, it is recognized that all motion systems have limitations and therefore maneuvers must be designed to stay within the limits of the system’s capabilities and range of effectiveness. The problem of aircraft upsets and loss-of-control typically involves large-amplitude motions due to extended excursions in vehicle attitudes and angular rates, and the desire to emulate the resulting accelerations has added a new challenge to simulator motion fidelity. A response to this need has been proposals for new motion systems that provide sustained cockpit accelerations that are possible during upset events. Over the past decade, limited research has been conducted on the effects of motion on upset training (both ground-based and in-flight simulation) and one approach has involved analysis of pilot performance with various types of training.

This subtopic requests a broad study of the requirements and capabilities for simulator motion systems across the range of current and proposed systems, including fixed-base, hexapod, continuous-g and in-flight simulation. It is intended that this research be aimed at large-amplitude motions and address simulation facility requirements for research and training or other uses for a broad range of applications and technologies. In addition, proposals for new or enhanced motion cueing systems are encouraged if justified by this study.

Desired outcomes of this research include but are not limited to the following:

- Analysis of motion system requirements and cueing algorithms for large-amplitude maneuvers, including out-of-envelope or loss-of-control events for large transport airplanes.
- A comparison of maneuver envelopes for current and proposed simulator motion devices.
- Analysis of the state-of-the-art of motion systems that includes anticipated new requirements.
- Physiological considerations for transfer of fidelity and realism of cockpit motion environments.
- Benefits of various motion capabilities based on physiological factors, transfer of training, and other criteria as appropriate.
- Integration of aerodynamic buffet effects and other cockpit noise and vibration sources.
- Any other topics that are considered necessary to advance the state-of-the-art and utility of motion systems. for large amplitude maneuvers.
- Long-term recommended research and potential advantages of advanced simulator motion fidelity.

A1.12 Propulsion System Performance Prediction for Integrated Flight and Propulsion Control
Lead Center: GRC
Participating Center(s): LaRC

In current aircraft, the flight and propulsion controls are designed independently and pilots manually integrate them through manipulation of the cockpit controls. Although the pilot manages these individual systems well under normal conditions, an integrated design approach would be able to achieve maximum benefit from these systems under abnormal conditions, especially for energy management and coordinated control for upset prevention and recovery. NextGen operations might also benefit, especially relative to 4-D trajectory management. If properly integrated up front in the flight control design, the propulsion system could be an effective flight control actuator. However, in order to optimally integrate the two systems, the engine performance must be known. The propulsion performance is dependent on operating condition, and many safety constraints make it highly nonlinear. Thus it is necessary to have a system that can continuously predict the engine performance and constraints at the current operating condition and communicate this to the flight control system to facilitate optimal flight and propulsion integration. Ideally, the flight control system should be able to treat the propulsion system as a linear time-varying constrained system for real-time control purposes. Including the propulsion system in the flight control design provides another degree of freedom for the designer, and because the propulsion system is such a powerful actuator, it is one that potentially enhances upset prevention and recovery. Developing the ability to use the propulsion system to augment the flight control while still providing traditional pilot interaction with the cockpit controls can improve maneuverability and safety transparently.

Under this research subtopic, an approach to predicting, and communicating engine dynamic response that facilitates integrated flight and propulsion control would be developed. This is a prerequisite to utilizing the engines as flight control actuators to improve maneuverability and aid in upset prevention and recovery.

Potential NASA resources:
Commercial Modular Aero-Propulsion System Simulation40k (C-MAPSS40k) and Generic Transport Model (GTM).

A1.13 Advanced Upset Protection System
Lead Center: DFRC
Participating Center(s): ARC, GRC, LaRC

One of the common causes for Loss of control (LOC) is the crew's lack of awareness of the current energy state relative to the current mission phase and inappropriate response to a low or high-energy state. Technologies to prevent the development of an inappropriate energy state via manual aids and automatic approaches are crucial for the prevention of loss of control.

In large airplanes, energy management refers to the ability to know and control the complex combination of the aircraft's airspeed and speed trend, altitude and vertical speed, configuration, and thrust. For example, near-terminal operations (takeoff and landing) require precise control of airspeed to achieve optimum performance while maintaining safe stall margin, and altitude management is critical for approaches. The penalty for improper energy management can be de-stabilized approaches, excessive pilot workload leading to distraction, and ultimately inadequate altitude or airspeed to recover from a loss-of-control event (e.g., stall). Many loss-of-control incidents/accidents can be attributed to improper management of airspeed, especially those leading to aerodynamic stall or departure from controlled flight.

Under this research subtopic, an envelope protection system would be developed to prevent low and high energy states based on the aircraft's current mission phase objectives. The envelope protection system should investigate the automatic use of the propulsion system, landing gear and secondary flight controls to maintain energy state. Methods to display information on system status to the pilot should also be considered to prevent adverse pilot interaction with the envelope protection system. Use on both current and NextGen aircraft should also be considered.

A1.14 Detection, Identification, and Mitigation of Sensor Failures
Lead Center: LaRC
Participating Center(s): ARC, DFRC

Faults related to aircraft sensing systems have been a major cause of loss-of-control accidents and incidents. For example, an airspeed sensing system fault is suspected of setting into motion a chain of events that resulted in the loss of Air France flight 447 (June 2009); a faulty altimeter is suspected in the stall and crash of Turkish Airline flight 1951 (February 2009); and faulty angle-of-attack sensing is suspected of causing violent uncommanded motion in Qantas Flight 72 (October 2008). Sensor redundancy is essential to ensure safety and reliability of the flight systems; however, redundancy alone may not be sufficient to avoid problems due to common mode failures across redundant sensors (such as suspected Pitot tube icing in all airspeed sensors). Therefore, research is needed to utilize all information available from multiple- possibly diverse- sensors in order to rapidly detect and isolate sensor faults in real time. The research would involve information fusion across multiple sensors, detection of erroneous behavior within a sensor or sensor suite, and mitigation of information loss through algorithmic redundancy and design to estimate the lost information from a failed sensor. The aim of the research would be to develop technology to prevent loss of control due to sensing system faults.

A1.15 Unmanned Vehicle Design for Loss-of-Control Flight Research
Lead Center: LaRC
Participating Center(s): DFRC

Recent advances in unmanned vehicle systems have enabled subscale flight testing using remotely piloted or autonomous vehicles to obtain high fidelity estimates of key aircraft performance parameters. An important requirement for obtaining relevant dynamic flight data from subscale vehicles is to apply dynamic scaling to the aircraft, so as to provide scaled inertial and mass properties, as well as geometric similitude.

The use of these vehicles is of particular interest in aviation safety studies because they allow exploration into unusual flight attitudes and upset conditions that are difficult to test in full scale aircraft due to structural limits and other safety concerns. Models of the stall and departure characteristics, as can be identified through flight testing, are needed to improve both aircraft training simulators as well as allow the design of control systems to reduce loss-of-control accidents.

Proposals are sought for a subscale civil transport vehicle design for remotely operated flight testing that allows a wide range of vehicle configurations. The vehicle should be modular in construction to emulate configurations representative of both conventional tail jet transports with under-wing engines and T-tail transports with rear mounted engines. In addition, the design should allow ballasting to achieve a range of target inertias and center of gravity locations. The ability to introduce flexible components for aeroelastic effects, as well components to model structural and control surface failures are also of interest.

Proposals should address construction methods that allow tradeoffs in costs and complexity while maintaining structural integrity required for loss-of-control flight testing. Control surfaces should be distributed to provide redundancy and allow for experiments involving actuator failures and in-flight dynamic simulation. Vehicle size should be consistent with commercially available turbine engines and allow road transport with manual field assembly.

A1.16 Validation Methods for Safety-Critical Systems Operating under LOC Conditions
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

Validation of future complex integrated systems designed to ensure flight safety under off-nominal conditions associated with aircraft loss of control is a significant challenge. Future systems will ensure vehicle flight safety by integrating vehicle health management functions, resilient control functions, flight safety assessment and prediction functions, and crew interface and variable autonomy functions. Each of these functions is characterized by algorithmic diversity that must be addressed in the validation process. Vehicle health management involves diagnostic and prognostic algorithms that utilize stochastic decision-based reasoning and extensive information processing and data fusion. Resilient control functions can involve adaptive control algorithms that utilize time-varying parameters and/or hybrid system switching. Flight safety management may involve diagnostic and prognostic reasoning algorithms as well as control theoretic algorithms. Crew interface functions involve displays that are human-factors-based and require information processing and reasoning, and variable autonomy will require assessment and reasoning algorithms. Onboard modeling functions will involve system identification algorithms and databases. Normal operating conditions of the future may extend beyond current-day operational limits. Moreover, safe operation under off-nominal conditions that could lead to loss-of-control events will be a focus of the system design. In particular, operation under abnormal flight conditions, external hazards and disturbances, adverse onboard conditions, and key combinations of these conditions will be a major part of the operational complexity required for future safety-critical systems. Future air transportation systems must also be considered under operational complexity, such as requirements for dense all-weather operations, self separation of aircraft, and mixed capabilities of aircraft operating in the same airspace, including current and future vehicle configurations as well as piloted and autonomous vehicles.

System validation is a confirmation that the algorithms are performing the intended function under all possible operating conditions. The validation process must be capable of identifying potentially problematic regions of operation (and their boundaries) and exposing system limitations – particularly for operation under off-nominal and hazardous conditions related to loss of control. New methods, metrics, and software tools must be established for algorithms that cannot be thoroughly evaluated using existing methods. Innovative research proposals are sought to address any of the following areas:

- Analytical Validation Methods.
- Predictive Capability Assessment Methods.
- Real-Time (or Run-Time) Validation Methods.

Analytical validation methods are comprised of a set of analytical methods and tools that facilitate the accurate prediction of system properties under various operating and off-nominal conditions. A wide variety of analytical methods will be needed to evaluate stability and performance of various and dissimilar system functions, robustness to adverse and abnormal conditions, and reliability under errors, faults, failures, and damage. These methods and software tools will be utilized offline and prior to implementation in representative avionics system software and hardware. These methods will enable analysis under a wide range of conditions, and be used to facilitate nonlinear simulation-based and experimental evaluations under selected potentially problematic conditions in order to expose system deficiencies and limitations over a very large operational space. Analytical methods and tools applicable to determining stability, performance, robustness, and reliability of nonlinear, time-varying, and/or hybrid systems involving control theoretic, diagnostic/prognostic, and/or reasoning systems are sought.

Predictive capability assessment is an evaluation of the validity and level of confidence that can be placed in the validation process and results under nominal and off-nominal conditions (and their associated boundaries). The need for this evaluation arises from the inability to fully evaluate these technologies under actual loss-of-control conditions. A detailed disclosure is required of model, simulation, and emulation validity for the off-nominal conditions being considered in the validation, interactions that have been neglected, assumptions that have been made, and uncertainties associated with the models and data. Cross-correlations should be utilized between analytical, simulation and ground test, and flight test results in order to corroborate the results and promote efficiency in covering the very large space of operational and off-nominal conditions being evaluated. The level of confidence in the validation process and results must be established for subsystem technologies as well as the fully integrated system. This includes an evaluation of error propagation effects across subsystems, and an evaluation of integrated system effectiveness in mitigating off-nominal conditions and preventing cascading errors, faults, and failures across subsystems. Metrics for performing this evaluation are also needed. Uncertainty-based and/or statistical-based methods and tools that enable the determination of level of confidence in the validation of uncertain systems operating under extreme conditions are sought.

Real-time (or run-time) validation methods are needed for the onboard monitoring of crucial system properties whose violation could compromise safety of flight. These properties might include closed-loop stability, robustness margins, or underlying theoretical assumptions that must not be violated. This information could be used as part of a real-time safety-of-flight assessment system for the vehicle. Real-time methods and software tools are sought that enable onboard validation of nonlinear, time-varying, and reasoning systems.

A1.17 Data Mining and Knowledge Discovery
Lead Center: ARC

The fulfillment of the SSAT project's goal requires the ability to transform the vast amount of data produced by the aircraft and associated systems and people into actionable knowledge that will aid in detection, causal analysis, and prediction at levels ranging from the aircraft-level, to the fleet-level, and ultimately to the level of the national airspace. The vastness of this data means that data mining methods must be efficient and scalable so that they can return results quickly. Additionally, much of this data will be distributed among multiple systems. Data mining methods that can operate on the distributed data directly are critical because centralizing large volumes of data is typically impractical. However, these methods must be provably able to return the same results as what a comparable method would return if the data could be centralized because this is a critical part of verifying and validating these algorithms, which is important for aviation safety applications. Additionally, algorithms that can learn in an online fashion---can learn from new data in incremental fashion without having to re-learn from the old data---will be important to allow deployed algorithms to update themselves as the national airspace evolves. The data is also heterogeneous: it consists of text data (e.g., aviation safety reports), discrete sequences (e.g., pilot switches, phases of flight), continuous time-series data (e.g., flight-recorded data), radar track data, and others. Data mining methods that can operate on such diverse data are needed because no one data source is likely to be sufficient for anomaly detection, causal analysis, and prediction.

This topic will yield efficient and scalable data-driven algorithms for anomaly detection, causal analysis, and prediction that are able to operate at levels ranging from the aircraft level to the fleet level. To that end, the methods must be able to efficiently learn from vast historical time-series datasets (at least 10 TB) that are heterogeneous (contain continuous, discrete, and/or text data). Distributed data-driven algorithms that provably return the same results as a comparable method that requires data to be centralized are also of great interest. Online algorithms that can update their models in incremental fashion are also of great interest for this subtopic.

A1.18 Prognostics and Decision Making
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

The benefit of prognostics will be realized by converting remaining life estimates and dynamically changing context information into actionable decisions. These decisions can then be enacted at the appropriate level, depending on the prognostic time horizon and safety criticality of the affected area. In particular, information about RUL could be used either reflexively, through resource re-allocation, through mission replanning, or through appropriate maintenance action.

To maximize the impact, it is necessary to provide an accurate and precise prognostic output, carefully manage uncertainty, and provide an appropriate contingency. This effort addresses the development of innovative methods, technologies, and tools for the prognosis of aircraft faults and failures in aircraft systems and how to decide on remedial actions.

Areas of interest include the development of methods for estimation of RUL, which take into account future operational and environmental conditions; for dealing with inherent uncertainties; for building physics-based models of degradation; for generation of example aging and degradation datasets on relevant components or subsystems; and for development of validation and verification methodologies for prognostics.

Research should be conducted to demonstrate technical feasibility during Phase I and to show a path toward a Phase II technology demonstration. Proposals are solicited that address aspects of the following areas:

- Novel RUL prediction techniques that improve accuracy, precision, and robustness of RUL output, for example through the fusion of different methods.
- Uncertainty representation and management (reduction of prediction uncertainty bounds) methods. Proposers are encouraged to consider uncertainties due to measurement noise, imperfect models and algorithms, as well as uncertainties stemming from future anticipated loads and environmental conditions.
- Contingency management methods that act on predictive information. Particular interest is for methods that address the medium-and long term prognostic horizons.
- Verification and validation methods for prognostic algorithms.
- Aircraft relevant test beds that can generate aging and degradation datasets for the development and testing of prognostic techniques.

All methods should be demonstrated on a set of fault modes for a device or component such as composite airframe structures, engine turbomachinery and hot structures, avionics, electrical power systems, or electronics. Prognostic performance needs to be measured on benchmark data sets using prognostic metrics for accuracy, precision, and robustness. Metrics should include prognostic horizon (PH), alpha-lambda, relative accuracy (RA), convergence, and R_delta.

A1.19 Technologies for Improved Design and Analysis of Safety-Critical Dynamic Systems
Lead Center: ARC

The NASA Aviation Safety program seeks proposals to support the development of robust human interactive, dynamic, safety-critical systems. The aviation Safety program is particularly interested in methods and tools that support predictive analysis of Human – Automation Interaction of mixed initiative systems in complex environments.

Information complexity in aviation systems is increasing exponentially, and designers and evaluators of these systems need tools to understand, manage, and estimate the performance and safety characteristics early in the design process. NASA seeks innovative design methods and tools for representing the complex human-automation interactions that will be part of future safety-critical, dynamic, mixed initiative systems. In addition, NASA seeks tools and methods for estimating, measuring, and/or evaluating the performance of these designs throughout the lifecycle from preliminary design to operational use - with an emphasis on the early stages of conceptual design. Specific areas of interest include the following:

- Computational/modeling approaches to support determining appropriate human-automation function allocations with respect to safety and reliability. Specifically these methods should focus on metrics that describe the robustness and resilience of a proposed human - automation function allocation.
- Analysis tools and methods that improve the application of human-centered design principles to the design and certification of mixed human-automated systems.
- Design and analysis methods or tools to better predict and assess human and system performance in relevant operational environments (e.g., future generations of air traffic management) , particularly in regards to procedural errors. Specifically, this work should include performance estimates that account for differences in training and proficiency.
- Analysis tools to support the use of mixed initiative systems in off-nominal conditions.
- Tools that provide validated human performance analysis early in the design process.

Proposals should describe novel design methods, metrics, and/or tools with high potential to serve the objectives of the Human Systems Solutions element of NASA's Aviation Safety Program’s System-wide Safety Assurance Technologies project. Successful Phase I proposals should provide a literature review that on which the proposed work is based, a detailed schedule, and should culminate in a final report that specifies, and a Phase II proposal that would realize, tools that improve the analysis process for human-automation systems in aerospace, or improves the ability to assess effectiveness of such systems during the design phase. All proposals should discuss means for verification and validation of proposed methods and tools in operationally valid, or end-user, contexts.

A1.20 Verification and Validation of Flight-Critical Systems
Lead Center: ARC
Participating Center(s): DFRC, LaRC

The Aviation Safety program has been put in charge of addressing the JPDO concerns that current V&V techniques are not sufficient to verify and validate NextGen. This is reflected in the VVFCS element under the SSAT project in the Aviation Safety program.

VVFCS has four major themes:

- Argument-based safety assurance, which aims at unifying and formalizing how V&V results for ground and airborne software systems are folded into a safety argument for certification.
- Distributed Systems, which aims at developing guidance on the V&V of distributed applications, e.g., communication topologies, mixed-criticality architectures, and fault tolerance schemes.
- Authority and Autonomy, which explores the modeling and analysis of authority problems in the NAS when viewed as a distributed system within which automation and humans interact.

- Software-intensive systems, which focuses on early, formal methods for the V&V of software systems.

This year, VVFCS is interested in technologies that can be transitioned (meaning that tools are made available) to industry in the following areas:

- Run-time monitoring.
- Safety case.
- Static analysis.
- Code libraries implementing fundamental technologies that can be used in formal method research, such as:
    - Memory and time efficient decision procedures.
    - Memory and time efficient abstractions for static analysis.

TOPIC: A2 Fundamental Aeronautics

The Fundamental Aeronautics Program conducts cutting-edge research to achieve technological capabilities necessary to overcome national challenges in air transportation including reduced noise, emissions, and fuel consumption, increased mobility through a faster means of transportation, and the ability to ascend/descend through planetary atmospheres. These technological capabilities enable design solutions for performance and environmental challenges of future air vehicles. Research in revolutionary aircraft configurations, lighter and stronger materials, improved propulsion systems, and advanced concepts for high lift and drag reduction all target the efficiency and environmental compatibility of future air vehicles. The program develops physics-based, multidisciplinary design, analysis and optimization tools to enable evaluation of new vehicle designs and to assess the potential impact of design innovations on a vehicle's overall performance. The FA Program consists of four projects:

- Subsonic Fixed Wing addresses the challenge of enabling revolutionary energy efficiency improvements of subsonic/transonic transport aircraft that dramatic reduce harmful emissions and noise for sustained growth of the air transportation system Improvements in prediction tools and new experimental methods Noise prediction and reduction technologies for airframe and propulsion systems Emissions reduction technologies and prediction tools Improved vehicle performance through design and development of lightweight, multifunctional and durable structural components, low drag aerodynamic components, and higher bypass ratio engines with efficient power plants, and advanced aircraft configurations Reduce take off and landing field length requirements Multi-disciplinary design and analysis tools and processes.
- Subsonic Rotary Wing addresses the challenge of radically improving the transportation system using rotary wing vehicles by increasing speed, range, and payload while decreasing noise and emissions. Enable variable-speed rotor concepts Contain the external noise within the landing area and reduce internal noise Assess multiple active rotorcraft concepts Advance technologies such as crashworthiness, safe operations in icing conditions, and condition based maintenance methodologies.
- Supersonics addresses the challenge of eliminating the environmental and performance barriers that prevent practical supersonic vehicles (cruise efficiency, noise and emissions, performance) Efficiency (supersonic cruise, light weight and durability at high temperature) Jet noise reduction relative to an unsuppressed jet Light weight and durability at high temperature) Environmental challenges (airport noise, sonic boom, high altitude emissions) Performance challenges (aero-propulso-servo-elastic analysis and design, cruise lift/drag ratio) Multidisciplinary design, analysis and optimization challenges.
- Hypersonics addresses the challenge of enabling airbreathing access to space and high mass entry, descent, and landing into planetary atmospheres Fundamental research to enable very-high speed flight (for airbreathing launch vehicles) and Entry, Descent and Landing into planetary atmospheres High-temperature materials, thermal protection systems (single and multi-use), airbreathing propulsion, aero-thermodynamics, multi-disciplinary analysis and design, guidance, navigation, and control, advanced experimental capabilities, and supersonic decelerator technologies Accurate predictive models for high-speed compressible flow including turbulence, heating, ablation, combustion, and their interactions in order

to reduce the uncertainty in predictions of aerodynamic heat loads during the design of hypersonic vehicles Additional information: (http://www.aeronautics.nasa.gov/fap/index.html).

A2.01 Materials and Structures for Future Aircraft
Lead Center: GRC
Participating Center(s): ARC, DFRC, LaRC

Advanced materials and structures technologies are needed in all four of the NASA Fundamental Aeronautics Program research thrusts (Subsonics Fixed Wing, Subsonics Rotary Wing, Supersonics, and Hypersonics) to enable the design and development of advanced future aircraft. Proposals are sought that address specific design and development challenges associated with airframe and propulsion systems. These proposals should be linked to improvements in aircraft performance indicators such as vehicle weight, fuel consumption, noise, lift, drag, durability, and emissions. In general, the technologies of interest cover five research themes:

Fundamental Materials Development, Processing and Characterization
Innovative approaches to enhance the durability, processability, performance and reliability of advanced materials (metals, ceramics, polymers, composites, nanostructured materials, hybrids and coatings). In particular, proposals are sought in:

- Advanced high temperature materials for aircraft engine and airframe components and thermal protection systems, including advanced blade and disk alloys, ceramics and CMCs, polymers and PMCs, nanostructured materials, hybrid materials and coatings to improve environmental durability.
- New adaptive materials such as piezoelectric ceramics, shape memory alloys, shape memory polymers, and variable stiffness materials and methods to integrate these materials into airframe and/or aircraft engine structures to change component shape, dampen vibrations, and/or attenuate acoustic transmission through the structure.
- Multifunctional materials and structural concepts for engine and airframe structures, such as novel approaches to power harvesting and thermal management, lightning strike mitigating, self-sensing, and materials for wireless sensing and actuation.
- New high strength fibers, in particular low density, high strength and stiffness carbon fibers.
- Innovative processing methods to reduce component manufacturing costs and improve damage tolerance, performance and reliability of ceramics, shape memory alloys, polymers, composites, and hybrids, nanostructured and multifunctional materials and coatings.
- Development of joining and integration technologies including fasteners and/or chemical joining methods for ceramic-to-ceramic, metal-to-metal (with an emphasis on joining dissimilar forms of nickel base superalloys, e.g., powder metallurgy to cast or directionally solidified alloys), and metal-to-ceramic as well as solid state joining methods such as advanced friction stir welding.
- Innovative methods for the evaluation of advanced materials and structural concepts (in particular multifunctional and/or adaptive) under simulated operating conditions, including combinations of electrical, thermal and mechanical loads.
- Nondestructive evaluation (NDE) methods for the detection of as-fabricated flaws and in-service damage for textile polymeric, ceramic and metal matrix composites, nanostructured materials and hybrids. NDE methods that provide quantitative information on residual structural performance are preferred.

Structural Analysis Tools and Procedures
Robust and efficient design methods and tools for advanced materials and structural concepts (in particular multifunctional and/or adaptive components) including variable fidelity methods, uncertainty based design and optimization methods, multi-scale computational modeling, and multi-physics modeling and simulation tools. In particular, proposals are sought in:

- Multiscale design tools for aircraft and engine structures that integrate novel materials, mechanism design, and structural subcomponent design into systems level designs.

- Life prediction tools for textile composites including fiber architecture modeling methods that enable the development of physics-based hierarchical analysis methods. Fiber architecture models that address yarn-to-yarn and ply-to-ply interactions covering a wide range of textile perform structures in either a relaxed or compressed deformation state as well as tools to predict debonding and delamination of through thickness reinforced (stitched, z-pinned) composites are of particular interest.
- Tools to predict durability and damage tolerance of new material forms including metallic-composite hybrids, friction stir-welded metallic materials and powder metallurgy-formed materials.
- Meso scale tools to guide materials placement to enable tailored load paths in multifunctional structures for enhanced damage tolerance.

Computational Materials Development Tools
Methods to predict properties, damage tolerance, and/or durability of both airframe and propulsion materials, thermal protection systems and ablatives based upon chemistry and processing for conventional as well as functionally graded, nanostructured, multifunctional and adaptive materials. In particular proposals are sought in:

- Ab-initio methods that enable the development of coatings for multiple uses at temperatures above 3000°F in an air environment.
- Computational tool development for structure-property modeling of adaptive materials such as piezoelectric ceramics, shape memory alloys, shape memory polymers to characterize their physical and mechanical behavior under the influence of an external stimulus.
- Computational and analytical tools to enable molecular design of polymeric and/nanostructured materials with tailored multifunctional characteristics.
- Computational microstructural and thermodynamic analysis tools and technique development for designing new lightweight alloy compositions for subsonic airframe and engines from first principles, functionally graded (chemically or microstructurally) materials, and/or novel metals processing techniques to accelerate materials development and understanding of processing-structure-property relationships.
- Software tools to predict temperature dependent phase chemistries, volume fractions, shape and size distributions, and lattice parameters of phases in a broad range of nickel and iron-nickel based superalloys. Toolset should utilize thermodynamic and kinetic databases and models that are fully accessible, which allow modifications and user-input to expand experimental databases and refine model predictions.

Advanced Structural Concepts
New concepts for airframe and propulsion components incorporating new light weight concepts as well as "smart" structural concepts such as those incorporating self-diagnostics with adaptive materials, multifunctional component concepts to reduce mass and improve durability and performance, lightweight, efficient drive systems and electric motors for use in advanced turboelectric propulsion systems for aircraft, and new concepts for robust thermal protection systems for high-mass planetary entry, descent and landing. In particular, proposals are sought in:

- Innovative structural concepts, materials, manufacturing and fabrication leading to reliable, entry descent and landing systems including deployable rigid and flexible heat shields and structurally integrated multifunctional systems. Of particular interest are high temperature honeycombs, hat stiffeners, rigid fibrous and foam insulators, as well as high temperature adhesives, films and fabrics for advanced flexible heat shields.
- New actuator concepts employing shape memory alloys.
- Advanced mechanical component technologies including self-lubricating coatings, oil-free bearings, and seals.
- Advanced material and component technologies to enable the development of mechanical and electrical drive system to enable the development of turboelectric propulsion systems, which utilize power from a single turbine engine generator to drive multiple propulsive fans. Innovative concepts are sought for AC-tolerant, low loss (< 10 W/kA-m) conductors or superconductors for the stators of synchronous motors or generators operating at > 1.5 T field and 500 Hz electrical frequency; and high efficiency (= 30% of

Carnot), low mass (<6kg/kW input) cryo-refrigerators for 20 to 65°K. Input power between 10 and 100 kW is envisioned in applications, but scalable small demonstrations are acceptable.
- Novel structural designs for integrated fan cases that combine hardwall composite cases for blade containment with acoustic treatments as well as concepts that integrate the case with the fan inlet to maximize structural, acoustic attenuation and weight benefits.
- Innovative approaches to structural sensors for extreme environments (>1800°F) including the development and validation of improved methods (i.e., adhesives, plasma spraying techniques, etc.) for attaching sensors to advanced high-temperature materials as well as approaches to measure strain, temperature, heat flux and/or acceleration of structural components.

A2.02 Combustion for Aerospace Vehicles
Lead Center: GRC
Participating Center(s): LaRC

Combustion research is critical for the development of future aerospace vehicles. Vehicles for subsonic and supersonic flight regimes will be required to emit extremely low amounts of gaseous and particulate emissions to satisfy increasingly stringent emissions regulations. Hypersonic vehicles require combustion systems capable of sustaining stable and efficient combustion in very high speed flow fields where fuel/air mixing must be accomplished very rapidly and residence times for combustion are extremely limited; a major challenge is developing scaling laws that will allow the size of scramjet engines to be increased by a factor of 10, i.e., to mass flow rates of 100 lbm/sec. Fundamental combustion research coupled with associated physics based model development of combustion processes will provide the foundation for technology development critical for aerospace vehicles. Combustion for aerospace vehicles typically involves multi-phase, multi-component fuel, turbulent, unsteady, 3D, reacting flows where much of the physics of the processes are not completely understood. CFD codes used for combustion do not currently have the predictive capability that is typically found for non reacting flows. Practical aerospace combustion concepts typically require very rapid mixing of the fuel and air with a minimum pressure loss to achieve complete combustion in the smallest volume. Reducing emissions may require combustor operation where combustion instability can be an issue and active control may be required. Areas of specific interest where research is solicited includes:

- Development of laser-based diagnostics and novel experimental techniques for measurements in reacting flows.
- Two-phase flow simulation models and validation data under supercritical conditions.
- Development of ultra-sensitive instruments for measuring gas turbine black carbon emissions at temperatures and pressures characteristic of commercial aircraft cruise altitudes.
- High frequency actuators (bandwidth ~1000 Hz) that can be used to modulate fuel flow at multiple fuel injection locations (with individual Flow Numbers of 3 to 5) with minimal fuel pressure drop for active combustion control.
- Combustion instability modeling and validation.
- Novel combustion simulation methodologies.
- Concepts that will allow the scaling of scramjet engines burning hydrogen and/or hydrocarbon fuels.

The following areas are of particular interest:

- The effect that size has on mixing, injection, and thermal loading losses.
- The effect of size on mixing and flame propagation.
- The effect of size on injection strategies.
- The scaling of ignition devices, flameholders, and mixing devices.
- The effect that the size and thickness of the incoming boundary layer has on ignition devices and flameholders.

- Whether there is a ratio between the size of inviscid stirring structures and turbulent structures that is optimal for rapid mixing.

A2.03 Aero-Acoustics
Lead Center: LaRC
Participating Center(s): ARC, GRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, and advanced aerospace vehicles. In support of the Fundamental Aeronautics Program, improvements in noise prediction, measurement methods and control are needed for subsonic and supersonic vehicles, including fan, jet, turbomachinery, engine core, open rotor, propeller and airframe noise sources. In addition, improvements in prediction and control of noise transmitted through aerospace vehicle structures are needed to reduce noise impact on passengers and crew. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid dynamics techniques for aeroacoustic analysis, which can be adapted for design codes.
- Prediction of aerodynamic noise sources including those from engine and airframe as well as sources, which arise from significant interactions between airframe and propulsion systems.
- Efficient prediction tools for turbine and combustor aeroacoustics.
- Efficient high-fidelity computational fluid dynamics tools for assessing aeroacoustic performance of installed high and low speed single- and counter-rotation propellers.
- Innovative source identification techniques for engine (e.g., fan, jet, combustor, or turbine noise) and for airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise typical of jets, separated flow regions, vortices, shear layers, etc.
- Concepts for active and passive control of aeroacoustic noise sources for conventional and advanced aircraft configurations, including adaptive flow control technologies, smart structures for nozzles and inlets, advanced acoustic liners, and noise control technology and methods that are enabled by advanced aircraft configurations, including integrated airframe-propulsion control methodologies.
- Prediction of near field sound propagation including interaction between noise sources and the airframe and its flow field and far field sound propagation (including sonic booms) from the aircraft through a complex atmosphere to the ground.
- Computational and analytical structural acoustics prediction techniques for aircraft and advanced aerospace vehicle interior noise, particularly for use early in the airframe design process;
- Technologies and techniques for active and passive interior noise control for aircraft and advanced aerospace vehicle structures. Prediction and control of high-amplitude aeroacoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue.
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise, including sonic boom.

A2.04 Aeroelasticity
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

The NASA Fundamental Aeronautics program has the goal to develop system-level capabilities that will enable civilian and military designers to create revolutionary systems, in particular by integrating methods and technologies that incorporate multi-disciplinary solutions. Aeroelastic behavior of flight vehicles is a particularly challenging facet of that goal.

The program's work on aeroelasticity includes conduct of broad-based research and technology development to obtain a fundamental understanding of aeroelastic and unsteady-aerodynamic phenomena experienced by aerospace vehicles in subsonic, transonic, supersonic, and hypersonic speed regimes. The program content includes theoretical aeroelasticity, experimental aeroelasticity, and advanced aeroservoelastic concepts. Of interest are:

- Aeroelastic, aeroservoelastic, and unsteady aerodynamic analyses at the appropriate level of fidelity for the problem at hand.
- Aeroelastic, aeroservoelastic, and unsteady aerodynamic experiments to validate methodologies and to gain valuable insights available only through testing.
- Development of computational-fluid-dynamic, computational-aeroelastic, and computational-aeroservoelastic analysis tools that advance the state of the art in aeroelasticity through novel and creative application of aeroelastic knowledge.

The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for ensuring freedom from catastrophic aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the unsteady aerodynamic forces acting on the structure and at times, active systems controlling the flight vehicle. Complex unsteady aerodynamic flow phenomena, particularly at transonic Mach numbers, are also very important because this is the speed regime most critical to encountering aeroelastic instabilities. In addition, aeroelasticity is presently being exploited as a means for improving the capabilities of high performance aircraft through the use of innovative active control systems using both aerodynamic and smart material concepts. Work to develop analytical and experimental methodologies for reliably predicting the effects of aeroelasticity and their impact on aircraft performance, flight dynamics, and safety of flight are valuable. Subjects to be considered include:

- Development of design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of methods to predict aeroelastic phenomena and complex steady and unsteady aerodynamic flow phenomena, especially in the transonic speed range. Aeroelastic phenomena of interest include flutter, buffet, buzz, limit cycle oscillations, divergence, and gust response; flow phenomena of interest include viscous effects, vortex flows, separated flows, transonic nonlinearities, and unsteady shock motions.
- Development of efficient methods to generate mathematical models of wind-tunnel models and flight vehicles for performing vibration, aeroelastic, and aeroservoelastic studies. Examples include (a) CFD-based methods (reduced-order models) for aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, and flutter issues and (b) integrated tool sets for fully coupled modeling and simulation of aeroservothermoelasticity / flight dynamic (ASTE/FD) and propulsion effects.
- Development of physics-based models for turbomachinery aeroelasticity related to highly separated flows, shedding, rotating stall, and non-synchronous vibrations (NSV). This includes robust, fast-running, accelerated convergence, reduced-order CFD approaches to turbomachinery aeroelasticity for propulsion applications. Development of blade vibration measurement systems (including closely spaced modes, blade-to-blade variations (mistuning), and system identification) and blade damping systems for metallic and composite blades (including passive and active damping methods) are of interest.
- Development of aeroservoelasticity concepts and models, including unique control concepts and architectures that employ smart materials embedded in the structure and/or aerodynamic control surfaces for suppressing aeroelastic instabilities or for improving performance.
- Development of techniques that support simulations, ground testing, wind-tunnel tests, and flight experiments of aeroelastic phenomena.
- Investigation and development of techniques that incorporate structure-induced noise, stiffness and strength tailoring, propulsion-specific structures, data processing and interpretation methods, non-linear and time-varying methods development, unstructured grid methods, additional propulsion systems-specific methods, dampers, multistage effects, non-synchronous vibrations, coupling effects on blade vibration, probabilistic aerodynamics and aeroelastics, actively controlled propulsion system core components (e.g., fan and turbine blades, vanes), and advanced turbomachinery active damping concepts.
- Investigation and development of techniques that incorporate lightweight structures and flexible structures under aerodynamic loads, with emphasis on aeroelastic phenomena in the hypersonic domain. Investigation of high temperatures associated with high heating rates, resulting in additional complexities associated with

varying thermal expansion and temperature dependent structural coefficients. Acquisition of data to verify analysis tools with these complexities.

A2.05 Aerodynamics
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC, JSC, MSFC

The challenge of flight has at its foundation the understanding, prediction, and control of fluid flow around complex geometries - aerodynamics. Aerodynamic prediction is critical throughout the flight envelope for subsonic, supersonic, and hypersonic vehicles - driving outer mold line definition, providing loads to other disciplines, and enabling environmental impact assessments in areas such as emissions, noise, and aircraft spacing.

In turn, high confidence prediction enables high confidence development and assessment of innovative aerodynamic concepts. This subtopic seeks innovative physics-based models and novel aerodynamic concepts, with an emphasis on flow control, applicable in part or over the entire speed regime from subsonic through hypersonic flight.

All vehicle classes will experience subsonic flight conditions. The most fundamental issue is the prediction of flow separation onset and progression on smooth, curved surfaces, and the control of separation. Supersonic and hypersonic vehicles will experience supersonic flight conditions. Fundamental to this flight regime is the sonic boom, which to date has been a barrier issue for a viable civil vehicle. Addressing boom alone is not a sufficient mission enabler however, as low drag is a prerequisite for an economically viable vehicle, whether only passing through the supersonic regime, or cruising there. Atmospheric entry vehicles and space access vehicles will experience hypersonic flight conditions. Reentry capsules and vehicles deploy multiple parachutes during descent and landing. Predicting the physics of unsteady flows in supersonic and subsonic speeds is important for the design of these deceleration systems. The gas-dynamic performance of decelerators for vehicles entering the atmospheres of planets in the solar system is not well understood. Reusable hypersonic vehicles will be designed such that the lower body can be used as an integrated propulsion system in cruise condition. Their performance is likely to suffer in off-design conditions, particularly acutely at transonic speeds. Advanced flow control technologies are needed to alleviate the problem.

This solicitation seeks proposals to develop and validate:

- Turbulence models and advanced computational techniques such as detached eddy, large eddy, or direct numerical simulations that capture the physics of separation onset at Reynolds numbers relevant to flight, where relevant to flight is dependent on a targeted vehicle class and mission profile.
- Boundary-layer transition models suitable for direct integration with state-of-the-art flow solvers.
- Active flow control concepts targeted at separation control, shock wave manipulation, and/or viscous drag reduction with an emphasis on the development of novel, practical, lightweight, low-energy actuators.
- Innovative aerodynamic concepts targeted at vehicle efficiency or control, including but not limited to concepts targeted at turbulent boundary skin friction drag reduction.
- Physics-based models for simultaneous low boom/low drag prediction and design.
- Aerodynamic concepts enabling simultaneous low boom and low drag objectives.
- Innovative methods to validate both flow models and aerodynamic concepts with an emphasis on aft-shock effects, which are hindered by conventional wind tunnel model mounting approaches.
- Uncertainty quantification methods suitable for use with state-of-the-art flow solvers.
- Accurate aerodynamic analysis and multidisciplinary design tools for multi-body flexible structures in the atmospheres of planets and moons including the Earth, Mars, and Titan.
- Advanced flow control technologies to alleviate off-design performance penalties for reusable hypersonic vehicles.

A2.06 Aerothermodynamics
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

Development of hypersonic flight vehicles for airbreathing access to space and for planetary entry poses several design challenges. One of the primary obstacles is the large uncertainty in predictive capability of the aerothermal environment to which these vehicles are subjected. For airbreathing access to space vehicles, predictions of boundary layer transition to turbulence and shock boundary layer interactions in a turbulent flow regime are sources of large aerothermal uncertainty and require conservative assumptions. For planetary entry vehicles with either rigid or flexible thermal protection systems (TPS), sources of large aerothermal uncertainty in high enthalpy conditions also include the catalytic or ablative properties of the TPS. The fluid dynamic and thermochemical interactions of a rough ablating surface with the aerothermal environment leads to many poorly understood coupled phenomena such as early boundary layer transition, turbulent heating augmentation, catalytic heating, radiation absorption, etc. At high entry speeds and large vehicle sizes, shock layer radiation becomes a large component of the aeroheating, with an increasing fraction of the radiation produced in the poorly understood vacuum ultraviolet part of the spectrum. The low confidence in the predictive capability is apparent in high enthalpy flows that are often difficult to adequately reproduce in a ground test facility.

The model uncertainties require designers to resort to large margins, resulting in reduced mission capabilities and increased costs. Future science and human exploration missions to Mars and other planets will require dramatic improvements in our current capability to land large payloads safely on these worlds. Research in aerothermodynamics focuses on solving some of the most difficult challenges in hypersonic flight. These include the development of predictive models via experimental validation for shock layer radiation phenomena, non-equilibrium thermodynamic and transport properties, catalycity, transition and turbulence, and ablation phenomena, as well as the development of new experimental datasets, especially in high enthalpy flow that can be used to validate theoretical and computational models.

Proposals suggesting innovative approaches to any of these problems are encouraged; specific areas of interest include:

- Advancement of NASA boundary layer transition tools, especially including high enthalpy effects.
- Development of shock turbulent boundary layer interaction models and validation with an experimental program.
- Development of radiation models supported by experimental validation in a laboratory (using shock tube, plasma torch, etc.) simulating extreme entry environments at Earth, Mars, Titan, and the Giant Planets.
- Development of high enthalpy RANS level turbulence models in a rough, ablating environment using experimentation or use of high fidelity computational techniques such as DNS or LES.
- Development of instrumentation for use in high-enthalpy flows to measure pressure, shear, radiation intensity, and off body flow quantities with enhanced capability such as high frequency measurements and/or high temperature tolerance.
- Development of tools and techniques that enable remote thermal imaging of entry vehicles with high temperature and spatial resolution, and lower uncertainty than the state-of-the art.
- Development of numerical techniques and computational tools that advance the start-of-the-art in computations of unsteady, turbulent separated flows with reasonable computational efficiency.

A2.07 Flight and Propulsion Control and Dynamics
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

NASA is conducting fundamental aeronautic research to develop innovative ideas that can lead to next generation aircraft design concepts with improved aerodynamic efficiency, lower emissions, less fuel burn, and reduced noise and carbon footprints. To realize these potential benefits, innovative vehicle design concepts can exhibit many complex modes of interactions due to many different effects of flight physics such as aerodynamics, vehicle dynamics, propulsion, structural dynamics, and external environment in all three flight regimes. Advanced flight control strategies for innovative aircraft design concepts are seen as an enabling technology that can harvest potential benefits derived from these complex modes of interaction. The following technology areas are of particular interest:

Active Aeroelastic Wing Shape Tailoring for Aircraft Performance and Control
Modern aircraft are increasingly designed with light-weight, flexible airframe structures. By employing distributed flight control surfaces, a modern wing structure (which implies aircraft wing, horizontal stabilizer, and vertical stabilizer) can be strategically tailored in-flight by actively controlling the wing shape so as to bring about certain desired vehicle characteristics. For example, active aeroelastic wing shape tailoring can be employed to control the wash-out distribution and wing deflection in such a manner that could result in improved aerodynamic performance such as reduced drag during cruise or increased lift during take-off. Another novel use of active aeroelastic wing shape tailoring is for flight control. By actively controlling flexible aerodynamic surfaces differentially or collectively, the motion of an aircraft can be controlled in all three stability axes. In high speed supersonic or hypersonic vehicles, effects of airframe-propulsion-structure interactions can be significant. Thus, propulsion control can play an integral role with active aeroelastic wing shape tailoring control in high speed flight regimes.

Technology development of active aeroelastic wing shape tailoring may include, but are not limited to the following:

- Innovative aircraft concepts that can significantly improve aerodynamic, performance and control by leveraging active aeroelastic wing shape tailoring.
- Sensor technology that will enable in-flight wing twist and deflection static and dynamic measurements for control development.
- Actuation methods that include novel modes of operation and concepts of actuation for actively controlling wing shape in-flight.
- Vehicle dynamic modeling capability that includes effects of aero-propulsive-servo-elasticity for vehicle control and dynamics.
- Integrated approaches for active aeroelastic wing shape tailoring control with novel control effector concepts that will provide multi-objective advanced optimal or adaptive control strategies to achieve simultaneously aerodynamic performance such as trim drag reduction, aeroelastic stabilization or mode suppression, and load limiting.

Gust Load Alleviation Control
In a future NextGen operational concept, close separation between aircraft in super density operations could lead to more frequent wake vortex encounters. Airframe flexibility in modern aircraft will inherently lead to a potential increase in vehicle dynamic response to turbulence and wake vortices. Gust load alleviation control technology can improve ride qualities and reduce undesired structural dynamic loading on flexible airframes that could shorten aircraft service life. Gust load alleviation control technology can be either reactive or predictive. In a traditional reactive control framework, flight control systems can be designed to provide sufficient aerodynamic damping characteristics that suppress vehicle dynamic response as rapidly as possible upon a turbulence encounter. There is a trade off, however, between increased damping for mode suppression and command-following objectives of a flight control system. Large damping ratios, while desirable for mode suppression, may result in poor flight control performance.

Predictive control can provide a novel gust load alleviation strategy for future aircraft design with light-weight flexible structures. Novel look-ahead sensor technology can measure or estimate turbulent intensity to provide such information to a predictive gust load alleviation control system which in turn would dynamically reconfigure flight control surfaces as an aircraft enters a turbulent atmospheric region. Technology development of predictive gust load alleviation control may include, but are not limited to the following:

- Novel sensor methods for Optical Air Data Systems based on LIDAR or other novel detection methods that can measure near-field air turbulent velocity components directly in front of an aircraft in the order of one-body length scale to provide nearly instantaneous predictive capability to significantly improve the effectiveness of a gust load alleviation control system.
- Predictive gust load alleviation control approaches or other effective methods that can reliably reconfigure flight control surfaces dynamically based on the sensor information of the near-field turbulence to mitigate the vehicle structural dynamic response upon a turbulence encounter. The predictive control strategies should be cognizant of potential adverse effects due to potential latency issues that can counteract the objective of gust load alleviation, or potential structural mode interactions due to control input signals that may contain frequencies close to the natural frequencies of the airframe.

Advanced Control Concepts for Propulsion Systems
Enabling high performance “Intelligent Engines” will require advancement in the state of the art of propulsion system control. Engine control architectures/methods need to be developed that provide a tighter bound control on engine parameters for improved propulsion efficiency while maintaining safe operation. The ability of the controller to maintain its designed improvement of engine operation over the entire life and particular health condition of the propulsion system is critical. The controller needs to adapt to the specific health conditions of each engine to eventually allow for a “personalized” control, which will maintain the most efficient operation throughout the engine lifetime and increase the useful operating life. Possible advanced engine control concepts could include:

- Direct nonlinear control design such as predictive model based methods to directly control engine thrust while maintaining safety limits such as stall margins.
- Model-Based Multivariable control to allow direct control of quantities of interest such as thrust, temperature and stall margins while using all available actuators for feedback.
- Adaptive control schemes to maintain robust performance with changing engine condition with usage.

A2.08 Aircraft Systems Analysis, Design and Optimization
Lead Center: LaRC
Participating Center(s): ARC, GRC

One of the approaches to achieve the NASA Fundamental Aeronautics Program goals is to solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration. The needs to meet this approach can be defined by three general themes:

- Variable Fidelity, Physics-Based Design/Analysis Tools.
- Technology Assessment and Integration.
- Evaluation of Advanced Concepts.

Current interdisciplinary design/analysis involves a multitude of tools not necessarily developed to work together, hindering their application to complete system design/analysis studies. NASA has developed a capability that integrates several conceptual design/analysis tools and models in ModelCenter. In addition, development work is continuing on a python-based, open-source architecture (OpenMDAO) that should serve as the long term solution for a multi-fidelity, multi-disciplinary optimization framework. Solicited topics are targeted around these three themes that will support this NASA research area.

Variable Fidelity, Physics-Based Design/Analysis Tools
An integrated design process combines high-fidelity computational analyses from several disciplines with advanced numerical design procedures to simultaneously perform detailed Outer Mold Line (OML) shape optimization, structural sizing, active load alleviation control, multi-speed performance (e.g., low takeoff and landing speeds, but efficient transonic cruise), and/or other detailed-design tasks. Current practice still widely uses sequential, single-discipline optimization, at best coupling low-fidelity modeling of other relevant disciplines during the detailed design phase. Substantial performance improvements will be realized by developing closely integrated design

procedures coupled with highest-fidelity analyses for use during detailed-design. Design procedures must enable rapid determination of sensitivities (gradients) of a design objective with respect to all design variables and constraints, choose search directions through design space without violating constraints, and make appropriate changes to the vehicle shape (ideally both external OML shape and internal structural element size). Solicitations are for integrated design optimization tools that find combinations of design variables from more than one discipline and can vary synergistically to produce superior performance compared to the results of sequential, single-discipline optimization or repeated cut-and-try analysis.

Research challenges include the engineering details needed to numerically zoom (i.e., numerical analysis at various levels of detail) between multi-fidelity components of the same discipline, as well as, multi-discipline components of the same fidelity. A major computer science challenge is developing boundary objects that will be reused in a wide variety of simulations. Proposals will be considered that enable coupling differing disciplines, numerical zooming within a single discipline, deploying large simulations and assembling and controlling secure or non-secure simulations.

Technology Assessment and Integration

Improved analysis capability of integrated airframe and propulsion systems would allow more efficient designs to be created that would maximize efficiency and performance while minimizing both noise and emissions. Improved integrated system modeling should allow designers to consider trade-offs between various design and operating parameters to determine the optimum design for various classes of subsonic fixed wing aircraft ranging from personal aircraft to large transports. The modeling would also be beneficial if it had enough fidelity to enable it to analyze both conventional and unconventional systems. Current analysis tools capable of analyzing integrated systems are based on simplified physical and semi-empirical models that are not fully capable of analyzing aircraft and propulsion system parameters that would be required for new or unconventional systems.

Analysis tools are solicited that are capable of analyzing new and unconventional aircraft and propulsion integrated systems. These include:

- New combustor designs, alternate fuel operation, and the ability to estimate all emissions.
- Noise source models (e.g., fan, jet, turbine, core and airframe components). Analyses tools that are scalable, especially to small aircraft, are desired.

Evaluation of Advanced Concepts

Conceptual design and analysis of unconventional vehicle concepts and technologies is needed for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts. This capability will enable "virtual expeditions through the design space" for multi-mission trade studies and optimization. This will require an integrated variable fidelity concept design system. The aerospace flight vehicle conceptual design phase is, in contrast to the succeeding preliminary and detail design phases, the most important step in the product development sequence, because of its predefining function. However, the conceptual design phase is the least well understood part of the entire flight vehicle design process, owing to its high level of abstraction and associated risk, its multidisciplinary design complexity, its permanent shortage of available design information, and its chronic time pressure to find solutions. Currently, the important primary aerospace vehicle design decisions at the conceptual design level (e.g., overall configuration selection) are still made using extremely simple analyses and heuristics. An integrated, variable fidelity system would have large benefits. Higher fidelity tools enabling unconventional configurations to be addressed in the conceptual design process are solicited.

A2.09 Rotorcraft
Lead Center: ARC
Participating Center(s): GRC, LaRC

The challenge of the Subsonic Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop validated physics-based multidisciplinary design-analysis-optimization tools for rotorcraft, integrated with technology development, enabling rotorcraft with advanced capabilities to fly as designed for any mission. Technologies of particular interest are as follows:

Experimental Capabilities: Instrumentation and Techniques for Rotor Blade Measurements
Instrumentation and measurement techniques are encouraged for assessing scale rotor blade boundary layer state (e.g., laminar, transition, turbulent flow) in simulated hover and forward flight conditions, measurement systems for large-field rotor wake assessment, and fast-response pressure sensitive paints applicable to blade surfaces.

Acoustics: Interior and Exterior Rotorcraft Noise Generation, Propagation and Control
Interior noise topics of interest include, but are not limited to, prediction and/or experimental methods that enhance the understanding of noise generation and transmission mechanisms for cabin noise sources (e.g., power-train noise), active and combined active/passive methods to reduce cabin noise, and novel structural systems or materials to reduce cabin noise without an excessive weight penalty. Exterior noise topics of interest include, but are not limited to, noise prediction methods that address the understanding of issues such as noise generation, propagation, and control. These methods may address topics such as novel or drastically improved source noise prediction methods, novel or drastically improved noise propagation methods (e.g., through the atmosphere) to understand and/or control noise sources and their impact on the community. Methods should address one or more of the major noise components such as: harmonic noise, broadband noise, blade-vortex interaction noise, high-speed impulsive noise, interactional noise, and/or low frequency noise (e.g., propagation, psychoacoustic effects, etc).

Rotorcraft Power Train System Improvements
Health management of rotorcraft power trains is critical. Predictive, condition-based maintenance improves safety, decreases maintenance costs, and increases system availability. Topics of interest include algorithm development, software tools and innovative sensor technologies to detect and predict the health and usage of rotorcraft dynamic mechanical systems in the engine and drive system. Rotorcraft health management technologies can include tools to: increase fault detection coverage and decrease false alarm rates; detect onset of failure, isolate damage, and assess damage severity; predict remaining useful life and maintenance actions required; system models, material failure models and correlation of failure under bench fatigue, seeded fault test and fielded data; tools to correlate propulsion system operational parameters back to actual usage and component fatigue life; Also of interest are advanced gear technologies for rotorcraft transmissions.

Proposals on other rotorcraft technologies will also be considered as resources and priorities allow, but the primary emphasis of the solicitation will be on the above three identified technical areas.

A2.10 Propulsion Systems
Lead Center: GRC

This subtopic is divided into three parts. The first part is the Turbomachinery and Heat Transfer and the second part is Developments Needed in Turbulence Modeling for Propulsion Flowpaths and third is Propulsion System Integration:

Turbomachinery and Heat Transfer
There is a critical need for advanced turbomachinery and heat transfer concepts, methods and tools to enable NASA to reach its goals in the various Fundamental Aeronautics projects. These goals include dramatic reductions in aircraft fuel burn, noise, and emissions, as well as an ability to achieve mission requirements for Subsonic Rotary Wing, Subsonic Fixed Wing, Supersonics, and Hypersonics Project flight regimes. In the compression system,

advanced concepts and technologies are required to enable higher overall pressure ratio, high stage loading and wider operating range while maintaining or improving aerodynamic efficiency. Such improvements will enable reduced weight and part count, and will enable advanced variable cycle engines for various missions. In the turbine, the very high cycle temperatures demanded by advanced engine cycles place a premium on the cooling technologies required to ensure adequate life of the turbine component. Reduced cooling flow rates and/or increased cycle temperatures enabled by these technologies have a dramatic impact on the engine performance.

Proposals are sought in the turbomachinery and heat transfer area to provide the following specific items:

- Advanced instrumentation to enable time-accurate, detailed measurement of unsteady velocities, pressures and temperatures in three-dimensional flowfields such as found in turbomachinery components. This may include instrumentation and measurement systems capable of operating in conditions up to 900° F and in the presence of shock-blade row interactions, as well as in high speed, transonic cascades. The instrumentation methods may include measurement probes, non-intrusive optical methods and post-processing techniques that advance the state of the art in turbomachinery unsteady flowfield measurement for purposes of accurately resolving these complex flowfield.
- Advanced compressor flow control concepts to enable increased high stage loading in single and multi-stage axial compressors while maintaining or improving aerodynamic efficiency and operability. Technologies are sought that would reduce dependence on traditional range extending techniques (such as variable inlet guide vane and variable stator geometry) in compression systems. These may include flow control techniques near the compressor end walls and on the rotor and stator blade surfaces. Technologies are sought to reduce turbomachinery sensitivity to tip clearance leakage effects where clearance to chord ratios may be on the order of 5% or above.
- Novel turbine cooling concepts are sought to enable very high turbine cooling effectiveness especially considering the manufacturability of such concepts. These concepts may include film cooling concepts, internal cooling concepts, and innovative methods to couple the film and internal cooling designs. Concepts proposed should have the potential to be produced with current or forthcoming manufacturing techniques. The availability of advanced manufacturing techniques may actually enable improved cooling designs beyond the current state-of-the-art.

Developments Needed in Turbulence Modeling for Propulsion Flowpaths and Propulsion System Integration
Flowpaths within propulsion systems are characterized by several aerodynamic and thermodynamic features which are very difficult for currently available computational fluid dynamics (CFD) methods to calculate accurately. Experiments alone are limited in their ability to provide detailed insights to the complex flow physics which occur in advanced propulsion-airframe integrated systems for future subsonic, supersonic and hypersonic applications. Therefore, the continued need for competent CFD methods to be used in conjunction with experiments is high. The one CFD modeling area that has remained the most challenging, yet most critical to the success of integrated propulsion system simulations is turbulence modeling. The flow features specific to the propulsion system components that provide the greatest turbulence modeling challenges include separated flows whether they be from subsonic diffusion or turbulent shock wave-boundary layer interactions, inlet/vehicle forebody boundary layer transition, unsteady flowfields resulting from incorporation of active flow control, strongly three-dimensional and curved flows in turbomachinery, turbulent-chemistry interactions from subsonic combustors to scramjets, and heat transfer.

Propulsion system integration challenges are encountered across all of the speed regimes from subsonic “N+3” vehicle concepts (with projected fuel burn benefits from boundary layer ingestion or distributed propulsion systems, for example), to supersonic “N+2” vehicle concepts with low-boom, high-performance inlets and nozzles integrated with variable cycle engine systems, to hypersonic reusable air-breathing launch vehicle concepts which incorporate integrated combined-cycle propulsion systems.

Proposals suggesting innovative approaches to any of these problems are encouraged; specific areas of interest include:

- Advancement of turbulence modeling for shock wave-boundary layer interactions.
- Advancement of Reynolds-stress closure models for propulsion flowpath analyses, including application of LES and or DNS for model development and validation.
- Development of mid-level CFD models for the interaction of turbulence and chemical reaction that give superior results to the simple models (e.g., Magnussen), but which do not require the large computational expense of the very complex models (e.g., PDF evolution methods).
- Advancement of boundary layer transition models, especially in cases of low freestream turbulence levels that occur in actual flight.
- Incorporation of NASA high-order accurate numerical methods (e.g., Flux Reconstruction) into propulsion CFD tools using both structured as well as unstructured meshes.
- Development of methods and software tools to quantify uncertainty as part of the CFD solution procedure.

Development of meaningful metrics that quantify the difference between computed solutions and experimental data and use the metrics to validate the CFD codes. Development of tools to enable rapid post-processing and assessment of CFD solutions, especially from NASA in-house CFD tools such as Wind-US and VULCAN (e.g., automatically interpolating numerical solutions to the measurement locations, generating “metrics of goodness” for parameters of interest, etc.).

Propulsion integration topics:

- Development of methodologies that provide installed nozzle performance, specifically conceptual level design/analysis methods, capable of addressing conventional and unconventional geometries. Geometries should be valid for subsonic, supersonic, and/or hypersonic flight applications. Documentation of methodologies should include: underlying theory and mathematical models, computational solution methods, source-code, validation data, and limitations.
- Technologies and/or concepts to enable integrated, high-performance, light-weight supersonic inlets and nozzles that have minimal impact on an aircraft’s sonic boom signature.
- Development of supersonic inlet systems that are “Fail Safe” and require no net mass extraction (i.e., bleed) or mass injection to control the shock wave/boundary-layer separations that inevitably arise in any supersonic inlet.
- Shorter, accurate, robust inlet mass flow measurement systems to replace the classic cold pipe/mass flow plug and measure mass-flow with distorted inflow.

TOPIC: A3 Airspace Systems

NASA's Airspace Systems Program (ASP) is investing in the development, validation and transfer of advanced innovative concepts, technologies and procedures to support the development of the Next Generation Air Transportation System (NextGen). This investment includes partnerships with other government agencies represented in the Joint Planning and Development Office (JPDO), including the Federal Aviation Administration (FAA) and joint activities with the U.S. aeronautics industry and academia. As such, ASP will develop and demonstrate future concepts, capabilities, and technologies that will enable major increases in air traffic management effectiveness, flexibility, and efficiency, while maintaining safety, to meet capacity and mobility requirements of NextGen. ASP integrates the two projects NextGen Concepts and Technology Development (CTD) and NextGen Systems Analysis Integration and Evaluation (SAIE), to directly address the fundamental research needs of NextGen vision in partnership with the member agencies of the JPDO. The CTD develops and explores fundamental concepts, algorithms, and air-borne and ground-based technologies to increase capacity and throughput of the national airspace system, to address demand-capacity imbalances, and achieve high efficiency in the use of resources such as airports, en route and terminal airspace. The SAIE Project is responsible for facilitating the Research and Development maturation of integrated concepts through evaluation in relevant environments, providing integrated solutions, characterizing airspace system problem spaces, defining innovative approaches, and assessing the potential system impacts and design ramifications of the program's portfolio. Together, the projects will also focus NASA's technical expertise and world-class facilities to address the question of where, when, how and the extent to which automation can be applied to moving air traffic safely and efficiently through the NAS and technologies that address optimal allocation of ground and air technologies necessary for NextGen. Additionally, the roles and responsibilities of humans and automation influence in the ATM will be addressed by both projects. Key objectives of NASA's AS Program are to:

- Improve mobility, capacity, efficiency and access of the airspace system.
- Improve collaboration, predictability, and flexibility for the airspace users.
- Enable accurate modeling and simulation of air transportation systems.
- Accommodate operations of all classes of aircraft.
- Maintain system safety and environmental protection.

A3.01 Concepts and Technology Development (CTD)
Lead Center: ARC
Participating Center(s): DFRC, LaRC

The Concepts and Technology Development (CTD) Project supports NASA Airspace Systems Program objectives by developing gate-to-gate concepts and technologies intended to enable significant increases in the capacity and efficiency of the Next Generation Air Transportation System (NextGen), as defined by the Joint Planning and Development Office (JPDO).

The CTD project develops and explores fundamental concepts, algorithms, and technologies to increase throughput of the National Airspace System (NAS) and achieve high efficiency in the use of resources such as airports, en route and terminal airspace. The CTD research is concerned with conducting algorithm development, analyses and fast-time simulations, identifying and defining infrastructure requirements, field test requirements, and conducting field tests.

Innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's CTD effort. The general areas of primary interest are:

Traffic Flow Management
- Flow management to mitigate large-scale climate disruptions, such as volcanic ash, or other natural disaster phenomena.

Super Density Operations
- Environmental and traffic efficiency metrics and assessments to compare different super-density operations concepts and technologies.
- Application of environmental and traffic efficiency metrics specifically for congested airspace or mixed equipage scenarios.
- Cost-effective integration of advanced speed control capabilities into the cockpit to enable environmentally friendly super density operations.

Separation Assurance
- Develop and demonstrate a prototype capability to output real-time schedules (e.g., from Traffic Management Advisor [TMA]) from current operational en route computers (e.g., ERAM and/or Host) to an external system to support trajectory-based operations research and simulation.

Trajectory Design
- Trajectory design and conformance monitoring for surface, terminal area, and en route.
- Trajectory implementation/execution in flight deck automation and automated air traffic control.

- Innovative methods to improve individual aircraft (surface, climb, descent and cruise) trajectories and air traffic operations to reduce the environmental impact.

Dynamic Airspace Configuration
- Flexible/adaptable airspace boundaries for NextGen operations in both en route and terminal airspace.
- Generic-airspace operations, including airspace design attributes and human factors considerations such as procedures and decision support tools.
- Tubes-in-the-sky operational concept development, including air/ground equipage requirements and design of a dynamic tube network.
- Dynamic airspace allocation to facilitate operations of UAVs and/or commercial space vehicles in the national airspace system [note: unmanned aerial vehicles/systems and their capabilities have their own subtopic].

Human Factors
- Design considerations for Tower/surface controller tools.
- Graphical user-interface systems for air traffic management/flight deck and ground-based automation simulation and testing applications.

Weather
- Common situational awareness between flight deck and ground automation systems for weather avoidance (may be related to 4D weather cube)
- Integrating weather products into decision support tools
- Airspace capacity estimation in presence of weather
- Means for creating realistic, consistent 3-D weather objects/imagery across numerous automation systems (e.g., a flight simulator out-the-window scene, cockpit radar display, airline operations weather display, ground radar image of the same weather object).

Atmospheric Hazards
- Development of wake vortex detection and hazard metric tools.
- Wake modeling and sensing capabilities implemented into the flight deck for airborne aircraft separation and spacing.
- Development of enroute wake turbulence identification and mitigation tools, processes, and systems.
- Novel, compact, and field-deployable laser remote sensing technologies for measuring meteorological parameters (e.g., wind, temperature, pressure, and turbulence) at ranges >1km in support of characterization of aircraft generated wake vortices.

Methods and Methodologies
- Algorithms and methods to satisfy multi-criteria design needs in air traffic management.
- Integrated hardware/software tool for accelerating general optimization tasks.
- Applying novel computing concepts to ATM problems.
- Experimental methodology, including scenario development, for incorporating rare events in realistic and dynamic human-in-the-loop air traffic management research, and methods for analyzing cause and effect in post experiment data.
- Stand-alone graphical user interface capabilities for data collection and processing of meteorological remote sensing technologies.

Other
- Derived sensor information from both ground-based radar trackers and ADS-B information for derivation of airspeed and local wind information.

A3.02 Systems Analysis Integration Evaluation (SAIE)
Lead Center: LaRC
Participating Center(s): ARC, DFRC

SAIE will provide systems level analysis of the NAS characteristics, constraints, and demands such that a suite of capacity-increasing concepts and technologies for system solutions are enabled and facilitated, integrated, evaluated and demonstrated. SAIE is responsible for characterizing airspace system problem spaces, defining innovative approaches, assessing the potential system-level benefits, impacts and safety.

Specific innovative research topics being sought by SAIE include:

Airspace System Level Concepts Development
- NextGen airspace system safety assessment, graceful degradation, fault tolerant, and recovery concepts and methodologies.
- System level capacity and environmental (e.g., CO_2, NOx emissions and noise) improvement concepts and assessments and methodologies.
- System level NextGen assessments, concepts and methodologies that incorporate and/or inform future vehicle and fleet designs.
- Autonomous and distributed system concepts.
- Concepts that study system-wide effects of various functional allocations.
- Revolutionary airspace system concepts, designs and methodologies.

Trajectory Modeling and Uncertainty Prediction
- Analysis of growth of uncertainty as a function of look-ahead time on different phases of flight.
- Development of methods to determine, for a target concept/system, the TP accuracy needed to be able to achieve the minimum acceptable system/concept performance as well as identify sources of errors.
- Development of methods for managing/reducing trajectory uncertainty to meet specified performance requirements.
- Identify critical aircraft behavior data for exchange for interoperability.
- Innovative methods to improve individual aircraft (surface, climb, descent and cruise) trajectories and air traffic operations to reduce the environmental impact.

Roles and Responsibilities in NextGen
- Systems analysis concepts, assessments and methodologies to optimize air-ground and automation functional allocation for NextGen (e.g., functional allocation options between human/machine and among AOC, flight deck and service provider).
- Airspace systems-level concepts, assessments and methodologies using increasing levels of autonomy.

Modeling and Simulation (should be relevant to NASA Airspace Program objectives)
- Develop new methods that help in assessing and designing airspace to improve system level performance (e.g., increase capacity, reduce complexity, optimize or improve performance of the air transportation network architecture).
- Explicit methodologies relevant to applications can include:
  - Rigorous predictive modeling of uncertainty in various parts of the system and its propagation.
  - Multiobjective decision making algorithms for all aspects of decision making and optimization in the system.
  - Model/dimension reduction for improved computational tractability.
  - Methods for managing multiscale phenomena in the NAS.
  - Methods for quantifying and managing complexity and uncertainty.
  - Methods for assessing the necessary balance between predictability and flexibility in the system, especially in the presence of autonomy.

TOPIC: A4 Aeronautics Test Technologies

The Aeronautics Test Program (ATP) ensures the long term availability and health of NASA's major wind tunnels/ground test facilities and flight operations/test infrastructure that support NASA, DoD and U.S. industry research and development (R&D) and test and evaluation (T&E) requirements. Furthermore, ATP provides rate stability to the aforementioned user community. The ATP facilities are located at four NASA Centers made up of the Ames Research Center, Dryden Flight Research Center, Glenn Research Center and Langley Research Center. Classes of facilities within the ATP include low speed, transonic, supersonic, and hypersonic wind tunnels, hypersonic propulsion integration test facilities, air-breathing engine test facilities, the Western Aeronautical Test Range (WATR), support & test bed aircraft, and the simulation and loads laboratories. A key component of ensuring a test facility's long-term viability is to implement and continually improve on the efficiency and effectiveness of that facility's operations along with developing new technologies to address the nation's future aerospace challenges. To operate a facility in this manner requires the use of state-of-the-art test technologies and test techniques, creative facility performance capability enhancements, and novel means of acquiring test data. NASA is soliciting proposals in the areas of instrumentation, test measurement technology, test techniques and facility development that apply to the ATP facilities to help in achieving the ATP goals of sustaining and improving our test capabilities. Proposals that describe products or processes that are transportable across multiple facility classes are of special interest. The proposals will also be assessed for their ability to develop products that can be implemented across government-owned, industry and academic institution test facilities. Additional information: http://www.aeronautics.nasa.gov/atp/index.html.

A4.01 Ground Test Techniques and Measurement Technology
Lead Center: LaRC
Participating Center(s): ARC, GRC

NASA is seeking highly innovative and commercially viable test measurement technologies, test techniques, and facility performance technologies that would increase efficiency, capability, productivity for ground test facilities.
The types of technology solutions sought, but not limited to, are: skin friction measurement techniques; improved flow transition and quality detection methodologies; non-intrusive measurement technologies for velocity, pressure, temperature, and strain measurements; force balance measurement technology development; and improvement of current cutting edge technologies, such as Particle Based Velocimetry (LDV, PIV), Pressure Sensitive Paint (PSP), and focusing acoustic measurements that can be used more reliably in a production wind tunnel environment. Instrumentation solutions used to characterize ground test facility performance are being sought in the area of aerodynamics performance characterization (flow quality, turbulence intensity, mach number measurement, etc.). Of interest are subsonic, transonic, supersonic, and hypersonic speed regimes. Specialized areas may include cryogenic conditions, icing conditions, and rotating turbo machinery. Proposals that are applicable specifically to the ATP facilities (see http://www.aeronautics.nasa.gov/atp) and across multiple facility classes are especially important. The proposals will also be assessed for their ability to develop products that can be used in other aerospace ground test facilities.

A4.02 Flight Test Techniques and Measurement Technology
Lead Center: DFRC
Participating Center(s): ARC, GRC, LaRC

NASA's flight research and test facilities are reliant on a combination of both ground and flight research capabilities. By using state-of-the-art flight test techniques, measurement and data acquisition technologies, NASA will be able to operate its flight research facilities more effectively and also meet the challenges presented by NASA's cutting edge research and development programs. The Aeronautical Test Program pertains to a variety of flight regimes and vehicle types ranging from civil transports, low-speed, to high-altitude long-endurance to supersonic, to hypersonic and access-to-space.

The scope of this subtopic is broad. Flight research and test capabilities should address (but are not limited to) the following NASA aeronautical test facilities: Aeronautical Test Range, Aero-Structures Flight Loads Laboratory, Flight Research Simulation Laboratory, and Research Test Bed Aircraft. Proposals should address innovative methods and technologies to extend the health, maintainability and test capabilities of these flight research support facilities.

NASA is committed to improve the ATP effectiveness to support and conduct flight research. This includes developing test techniques that improve the control of both ground-based and in-flight test conditions, expanding measurement and analysis methodologies, and improving test data acquisition and management with sensors and systems that have fast response, low volume, minimal intrusion, and high accuracy and reliability.

NASA requires improved measurement and analysis techniques for acquisition of real-time, in-flight data used to determine aerodynamic, structural, flight control, and propulsion system performance characteristics. These data will also be used to provide test conductors the information to safely expand the flight and test envelopes of aerospace vehicles and components. This requirement includes the development of sensors to enhance the monitoring of test aircraft safety and atmospheric conditions during flight testing.

Areas of interest include:

- Multi-disciplinary nonlinear dynamic systems prediction, modeling, identification, simulation, and control of aerospace vehicles.
- Test techniques for conducting in-flight boundary layer flow visualization, shock wave propagation, Schlieren photography, near and far-field sonic boom determination, atmospheric modeling.
- Measurement technologies for steady & unsteady aerodynamic, aero-thermal dynamics, structural dynamics, stability & control, and propulsion system performance.
- Verification & Validation (V&V) of complex highly integrated flight systems including hardware-in-the-loop testing.
- Manufacturability, affordability, and performance of small upper-stage booster technologies for small- & nano-satellites.
- Innovative techniques that enable safer operations of aircraft (e.g., non destructive examination of composites through ultrasonic techniques).

Also of interest to NASA are innovative methods and analysis techniques to improve the correlation of data from ground test to flight test.

TOPIC: A5 Integrated System Research Project (ISRP)

The Integrated Systems Research Program (ISRP), a new program effort that began in FY10, will conduct research at an integrated system-level on promising concepts and technologies and explore, assess or demonstrate their benefits in a relevant environment. The integrated system-level research in this program will be coordinated with on-going long-term, foundational research within the three other research programs, as well as efforts within other Federal Government agencies. As the NextGen evolves to meet the projected growth in demand for air transportation, researchers must address the national challenges of mobility, capacity, safety, and energy and the environment in order to meet the expected growth in air traffic. In particular, the environmental impacts of noise and emissions are a growing concern and could limit the ability of the system to accommodate growth. ISRP will explore and assess new vehicle concepts and enabling technologies through system-level experimentation to simultaneously reduce fuel burn, noise and emissions, and will focus specifically on maturing and integrating technologies in major vehicle systems/subsystems for accelerated transition to practical application. ISRP is comprised of two projects - the Environmentally Responsible Aviation (ERA) Project and the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project. Environmentally Responsible Aviation

(ERA) The project's primary goal is to select vehicle concepts and technologies that can simultaneously reduce fuel burn, noise and emissions; it contains three subprojects: Airframe Technology, Propulsion Technology and Vehicle Systems Integration.

- Testing unconventional aircraft configurations that have higher lift to drag ratio, reduced drag and reduced noise around airports.
- Achieving drag reduction through laminar flow.
- Developing composite (nonmetallic) structural concepts to reduce weight and improve fuel burn; and
- Testing advanced, fuel-flexible combustor technologies that can reduce engine NOx emissions. The Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) The project's primary goal is to address technology development in several areas to reduce the technical barriers related to the safety and operational challenges of UAS routine operations in the NAS.
- Separation Assurance - Safely and seamlessly integrate UAS into NextGen separation assurance through demonstrate of 4DT applications that result in the same or fewer losses of separation as traditional separation services.
- Human Systems Integration - Demonstrate reduced workload of UAS pilots by advanced interface design and automation; Collect Human in the Loop (HITL) data to apply to computational model that provides for 100% situational awareness of aircraft within 5 nm and 1200 ft; and Develop at standard against which to assess UAS ground control stations.
- Communication - Demonstrate a secure UAS command and control datalink which meets communication confidentiality, availability and integrity requirements and which meets FAA communication latency requirements. Certification - Document applicability of possible certification method meeting airworthiness requirements for the full range of UAS and collect UAS-specific data in a civil context to support development of standards and regulations.
- Integrated Test and Evaluation - Creation of an appropriate test environment; Integration of the technical research to probe and evaluate the concepts; and Coordination and prioritization of facility and aircraft schedules.

A5.01 UAS Integration in the NAS
Lead Center: DFRC
Participating Center(s): ARC, GRC, LaRC

The following subtopic is in support of the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project under ISRP. There is an increasing need to fly UAS in the NAS to perform missions of vital importance to National Security and Defense, Emergency Management, Science, and to enable Commercial Applications. UAS are unable to routinely access the NAS today due to a lack of:

- Automated separation assurance integrated with collision avoidance systems.
- Robust communication technologies.
- Robust human systems integration.
- Standardized safety and certification.

The Federal Aviation Administration (FAA) regulations are built upon the condition of a pilot being in aircraft. There exist few, if any, regulations specifically addressing UAS today. The primary user of UAS to date has been the military. The technologies and procedures to enable seamless operation and integration of UAS in the NAS need to be developed, validated, and employed by the FAA through rule making and policy development. The Project goal is to develop capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine UAS access to the NAS. This goal will be accomplished through a two-phased approach based on development of system-level integration of key concepts, technologies and/or procedures, and demonstrations of integrated capabilities in an operationally relevant environment. The project is further broken down into five subprojects: Separation Assurance; Communications; Human Systems Integration; Certification; and

Integrated Test and Evaluation. The fifth sub-project, Integrated Test and Evaluation, integrates the other four subprojects. The Phase I technical objectives include:

- Developing a gap analysis between current state of the art and NextGen Concept of Operations.
- Validating the key technical elements identified by the project requirements.
- Initial modeling, simulation, and flight testing.
- Completion of subproject Phase I deliverables (Spectrum requirements, comparative analysis of certification methodologies, etc.) and continue Phase II preparation (infrastructure, tools, etc.).

The Phase II technical objectives include:

- Providing regulators with a methodology for developing airworthiness requirements for UAS, and data to support development of certifications standards and regulatory guidance.
- Providing systems-level, integrated testing of concepts and/or capabilities that address barriers to routine access to the NAS, through simulation and flight testing, address issues including separation assurance, communications requirements, and Human Systems Integration in operationally relevant environments.

This solicitation seeks proposals to develop:

- Desktop Simulation System for Rapid Collection of Human-in-the-Loop Simulation Data. Study, design and build a desktop human-in-the-loop simulation system that integrates UAS ground control stations, unmanned vehicles, manned aircraft, and controller interfaces to rapidly evaluate concepts for separation assurance, separation algorithms, procedures for off-nominal conditions, and other research questions. In addition, investigate training requirements and verification methods for the quality of the data, the types of tasks for which such a system could provide meaningful data, and the architecture required to ensure scalability. The simulation system could be based on the Multi Aircraft Control System (MACS), which already includes all those elements except the UAS ground control station. An initial implementation could include a single human operator with all other agents simulated, while advanced implementations would connect several instances of the simulator to capture interactions between human controllers, pilots and UAS operators.
- UAS Model Construction from Real-time Surveillance Data. In order to improve trajectory predictions for aircraft types without detailed models, a real-time system identification process is needed to automatically construct propulsion and aerodynamics models from available Air Traffic Control (ATC) surveillance data (primary or secondary radar, ADS-B, etc.) while the aircraft is in flight. Initial work would establish what real-time surveillance data is required for a model of sufficient fidelity to reliably predict aircraft trajectories ten or more minutes into the future and over tens of thousands of vertical feet, and what types of aircraft maneuvers would provide maximum observability of the unknown parameters (e.g., the vehicle's response to commanded doublets in altitude at max climb/descent speed or step changes in commanded aircraft velocity as observed by radar or ADS-B). These maneuvers would be commanded of the UAS by ATC to improve a poorly understood vehicle model in real-time. Model construction could also be done with archived surveillance data as a first step, but real-time construction is the preferred ultimate outcome.
- Certified control and non-payload communications (CNPC) system. Current civil UAS operations are significantly constrained by the lack of a standardized, certified control and non-payload communications (CNPC) system. The UAS CNPC system is to provide communications functions between the Unmanned Aircraft (UA) and the UA ground control station for such applications as: telecommands; non-payload telemetry; navigation aid data; air traffic control (ATC) voice relay; air traffic services (ATS) data relay; sense and avoid data relay; airborne weather radar data; and non-payload situational awareness video. New and innovative approaches to providing terrestrial and space-based high-bandwidth CNPC systems that are inexpensive, small, low latency, reliable, and secure offer opportunities for quantum jumps in UAS utility and capabilities. Of particular interest are technologies for the enhancement/improvement of CNPC performance for UAS operations in urban locations, taking into account the propagation, reflection/refraction and shadowing/blockage environment encountered in the urban environment.

- System for Rapid Automated UAS Mission Planning. UAS mission planning is currently a very cumbersome and time-consuming activity that involves a highly manual process. In order to provide better UAS integration in the NAS, an automated mission planning system is required with the following capabilities:
  - During the pre-flight mission phase, automation is needed to identify emergency landing sites, ditch sites, and develop UAS responses to contingency events at all points along the route commensurate with UAS platform performance.
  - During the in-flight mission phase, automation is needed to assess and integrate real-time weather information, such as that provided via Flight Information Services – Broadcast (FIS-B), to dynamically re-plan the route for safe navigation. This includes fuel planning and weather assessment capabilities to select and fly to appropriate alternate destination airfields.
  - During the in-flight mission phase, automation is needed to assess real-time route deviations/changes imposed by Air Traffic Control (ATC). The assessment would consider fuel, weather and emergency landing/ditch site constraints to verify the route change is supportable and safe.

9.1.2 EXPLORATION SYSTEMS

The Exploration Systems Mission Directorate (ESMD) develops capabilities and supporting research and technologies that will make sustained human and robotic exploration possible. The directorate also focuses on the human element of exploration by conducting research to ensure astronaut explorers are safe, healthy and can perform their work during long-duration space exploration.

ESMD focuses on technologies and capabilities enabling human spaceflight, ultimately expanding a human presence throughout the solar system. Missions will venture beyond low-Earth orbit to multiple destinations, including the moon, near-Earth objects, Lagrange points, and Mars and its moons.

To create the new capabilities and contribute to the knowledge that is required for humans to explore to these destinations ESMD is responsible for several key areas including:

- Conducting technology development and demonstrations to reduce cost and prove required capabilities for future human exploration
- Developing exploration precursor robotic missions to multiple destinations to cost-effectively scout human exploration targets
- Increasing investments in human research to prepare for long journeys beyond Earth
- Developing U.S. commercial human spaceflight capabilities.

More information is available at: http://www.nasa.gov/exploration.

With this solicitation, ESMD seeks advancements in technologies in the following areas:

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TOPIC: X1 In Situ Resource Utilization

The purpose of In-Situ Resource Utilization (ISRU) is to harness and utilize resources at the site of exploration to create products and services which can enable and significantly reduce the mass, cost, and risk of near-term and long-term space exploration. The ability to make propellants, life support consumables, fuel cell reagents, and radiation shielding can significantly reduce the cost, mass, and risk of sustained human activities beyond Earth. The ability to modify the landscape for safer landing and transfer of payloads, creation of habitat and power infrastructure, and extraction of resources for construction, power, and in-situ manufacturing can also enable long-term, sustainable exploration of the solar system. Since ISRU can be performed wherever resources may exist, both natural and discarded, ISRU systems will need to operate in a variety of environments and gravitations. Also, because ISRU systems and operations have never been demonstrated before in missions, it is important that ISRU concepts and technologies be evaluated under relevant conditions (gravity, environment, and vacuum) as well as anchored through modeling to regolith/soil and environmental conditions. While the discipline of ISRU can encompass a large variety of different concept areas, resources, and products, the ISRU Topic will focus on technologies and capabilities associated with solid in-situ material handling and processing along with atmospheric and trash/waste processing.

X1.01 In-Situ Resource Characterization, Extraction, Transfer, and Processing
Lead Center: JSC
Participating Center(s): GRC, KSC, MSFC

The ability to characterize, collect, transfer, and process resources at the site of exploration on the Moon, Mars, and Near Earth Objects (NEOs)/Phobos can completely change robotic and human mission architectures. The subtopic seeks proposals for the design and subsequent build of hardware and technologies that perform critical functions and operations for characterization, collection, transfer, and processing operations that can be inserted for integration into on-going and future system-level development and demonstration efforts. The technologies and hardware must utilize local materials with the minimum Earth-supplied feedstock possible. There are three main areas of interest:

Extraterrestrial Material-Based ISRU

- Methods for collection and transfer of NEO/Phobos material under micro-gravity conditions under vacuum/space environmental conditions. Proposals must state and explain material properties and water content considered in the design.
- Methods for the transfer of Mars surface material containing water at 1 to 5 kg/hr under Mars surface environmental conditions. Proposals must state and explain material properties and water content considered in the design, and locations on Mars where the method proposed is applicable
- Use of ionic liquids for processing and extracting oxygen and metals from extraterrestrial material at temperatures below 200 C at 0.2 kg/hr. Proposals must include methods for product separation and ionic liquid reagent regeneration for subsequent processing.
- Development of reactors with dust tolerant gas-tight seals and valving to extract and collect of water and other potential volatiles from extraterrestrial materials at 0.5 to 5 kg/hr of material processing rate. Proposals must state and explain material properties, water content, mixing technique, and gravity conditions considered in the design. Proposals may combine material transfer with water/volatile processing to minimize mass and power. Proposals for processing reactor systems should focus on highly effective approaches to energy utilization, including internal heat and mass transport enhancements and/or other physical or operational characteristics. Proposals that cover more than one material for consideration are of particular interest.
- Development of a compact, lightweight gas chromatograph – mass spectrometer (GC-MS) instrument that can quantify volatile gases released by sample heating below atomic number 70 (of particular interest H_2, He (and isotopes), CO, CO_2, CH_4, H_2O, N_2, O_2, Ar, NH_3, HCN, H_2S, SO_2). The instrument should be designed to be able to withstand exposure to the release of HF, HCl, or Hg that may result from heating regolith samples to high temperatures. The instrument should be capable of detecting 1000 ppm to 100% concentration of the volatiles in the gas phase. The instrument should have a clear path to flight with a

flight instrument design with a mass of less than 5 kg not including any vacuum components required to operate in the laboratory environment.

Extraterrestrial Atmosphere Based ISRU

- Devices that collect and separate Mars atmospheric argon and nitrogen using a standalone device or as part of carbon dioxide collection concepts at carbon dioxide collection rates (0.5 to 2 kg CO_2/hr rate and supply pressure at >15 psi for subsequent processing).
- Micro-channel reactor and heat exchanger concepts for efficient processing of carbon monoxide and carbon dioxide into water and/or methane with hydrogen at 0.5 to 2 kg/hr rate.

Discarded Material-Based ISRU

- Trash processing reactor concepts for production of carbon monoxide, carbon dioxide, water, and methane from plastic trash and dried crew solid waste. Proposals must define use of solar or electrical energy during processing, and any reagents/consumables. Recycling schemes for reactants/reagents used in the processing should be included. Highly efficient, compact water vapor removal/separation devices from product gas streams is also of interest.

Proposals must consider the physical/abrasive, mineral, and volatile/water properties and characteristics of the material/resource of interest, and the gravity environment in which collection, transfer, and processing will occur. Concepts that can operate in micro & low-gravity (1/6-g & 3/8-g), as well as multiple resources are of greater interest. Designs that are compatible for subsequent analog, micro/low-g flight experiments, and ground vacuum experiments are also of greater interest. Proposals that utilize rotating gears and actuators must be designed for abrasive/dusty environmental conditions. Proposals will be evaluated against state-of-the-art capabilities with respect to mass, power, and process efficiency. Figures of merit include consumable production rate (kg/hr), production energy efficiency (kg produced/ hr per KWe), and extraction/reactant recovery efficiency.

TOPIC: X2 Propulsion

Human Exploration requires advances in propulsion for transport to the moon, Mars, and beyond. A major thrust of this research and development activity will be related to space launch and in-space propulsion technologies. These efforts will include earth-to-orbit propulsion, in-space chemical propulsion, in-space nuclear propulsion, and in-space electric propulsion development and demonstrations. NASA is interested in making propulsion systems more capable and less expensive. NASA is interested in technologies for advanced in-space propulsion systems to support exploration, reduce travel time, reduce acquisition costs, and reduce operational costs.

X2.01 Low Cost Heavy Lift Propulsion
Lead Center: MSFC
Participating Center(s): GRC, KSC

Heavy lift launch vehicles envisioned for exploration beyond LEO will require large first stage propulsion systems. Total thrust at lift-off in will probably exceed 6 million pounds. There are available, in-production, practical propulsion options for such a vehicle. However, the cost for outfitting the booster with the required propulsion systems is in the hundreds of millions of dollars (2011 $). This cost severely limits what missions NASA can perform. Low cost design concepts and manufacturing techniques are needed to make future exploration affordable.

Objectives include:

Development of propulsion concepts whose cost is less than 50% of currently available heavy-lift propulsion options but with similar performance (i.e., reduced parts count, increased robustness to allow less expensive manufacturing techniques, less complex parts to maximize vendor competition, maximization of common parts, etc.) - both solid and liquid options are desired.

Development and demonstration of low-cost manufacturing techniques (i.e., use of rapid prototype techniques for metallic parts, application of nano-technology for manufacturing of near net shape manufacturing, etc.).

X2.02 High Thrust In-Space Propulsion
Lead Center: GRC
Participating Center(s): JSC, MSFC

This solicitation intends to examine a range of key technology options associated with cryogenic, non-toxic storable, and solid core nuclear thermal propulsion (NTP) systems for use in future exploration missions. Non-toxic engine technology, including new mono and bi-propellants, is desired for use in lieu of the currently operational NTO/MMH engine technology. Handling and safety concerns with toxic chemical propellants can lead to more costly propulsion systems. For future short round trip missions to Mars, NTP systems using nuclear fission reactors may be enabling by helping to reduce launch mass to reasonable values and by also increasing the payload delivered for Mars exploration missions. Non-toxic and cryogenic engine technologies could range from pump fed or pressure fed reaction control engines of 25-1000 lbf up to 60,000 lbf primary propulsion engines. Pump fed NTP engines in the 15,000-25,000 lbf class, used individually or in clusters, would be used for primary propulsion.

Specific technologies of interest to meet proposed engine requirements include:

- Non-toxic bipropellant or monopropellants that meet performance targets (as indicated by high specific impulse and high specific impulse density) while improving safety and reducing handling operations as compared to current state-of-the-art storable propellants.
- High temperature, low burn-up carbide- and ceramic-metallic (cermet)-based nuclear fuels with improved coatings and /or claddings to maximize hydrogen propellant heating and to reduce fission product gas release into the engine's hydrogen exhaust stream.
- Low-mass propellant injectors that provide stable, uniform combustion over a wide range of propellant inlet temperature and pressure conditions.
- High temperature materials, coatings and/or ablatives or injectors, combustion chambers, nozzles, and nozzle extensions.
- High temperature and cryogenic radiation tolerant instrumentation and avionics for engine health monitoring. Non-invasive designs for measuring neutron flux (outside of reactor), chamber temperature, operating pressure, and liquid hydrogen propellant flow rates over wide range of temperatures are desired. Sensors need to operate for months/years instead of hours.
- Combustion chamber thermal control technologies such as regenerative, transpiration, swirl or other cooling methods, which offer improved performance and adequate chamber life.
- Long life, lightweight, reliable turbopump designs and technologies include seals, bearing and fluid system components. Hydrogen technologies are of particular interest.
- Highly-reliable, long-life, fast-acting propellant valves that tolerate long duration space mission environments with reduced volume, mass, and power requirements is also desirable.
- Radiation tolerant materials compatible with above engine subsystem applications and operating environments.

Note to Proposer: Subtopic S3.04 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.04.

X2.03 Electric Propulsion Systems
Lead Center: GRC
Participating Center(s): JPL, MSFC

The goal of this subtopic is to develop innovative technologies for high-power (100 kW to MW-class) electric propulsion systems. High-power (high-thrust) electric propulsion may enable dramatic mass and cost savings for lunar and Mars cargo missions, including Earth escape and near-Earth space maneuvers. At very high power levels, electric propulsion may enable piloted exploration missions as well. Improved performance of propulsion systems that are integrated with associated power and thermal management systems and that exhibit minimal adverse spacecraft-thruster interaction effects are of interest. Innovations are sought that increase system efficiency, increase system and/or component life, increase system and/or component durability, reduce system and/or component mass, reduce system complexity, reduce development issues, or provide other definable benefits. Desired specific impulses range from a value of 2000 s for Earth-orbit transfers to over 6000 s for planetary missions. System efficiencies in excess of 50% and system lifetimes of at least 5 years (total impulse > 1 x 107 N-sec) are desired. Specific technologies of interest in addressing these challenges include:

- Long-life, high-current cathodes (100,000 hours).
- Electric propulsion designs employing alternate fuels (ISRU, more storable).
- Electrode thermal management technologies.
- Innovative plasma neutralization concepts.
- Metal propellant management systems and components, and cathodes.
- Low-mass, high-efficiency power electronics for RF and DC discharges.
- Lightweight, low-cost, high-efficiency power processing units (PPUs).
- PPUs that accept variable input voltages of greater than 200V and vary by a factor of 2-to-1.
- Direct drive power processing units.
- Low-voltage, high-temperature wire for electromagnets.
- High-temperature permanent magnets and/or electromagnets.
- Application of advanced materials for electrodes and wiring.
- Highly accurate propellant control devices/schemes.
- Miniature propellant flow meters.
- Lightweight, long-life storage systems for krypton and/or hydrogen.
- Fast-acting, very long-life valves and switches for pulsed inductive thrusters.
- Superconducting magnets.
- Lightweight thrust vector control for high-power thrusters.
- Fast-starting cathodes.
- Propellantless cathodes.
- High temperature electronics for power processing units.

Note to Proposer: Subtopic S3.04 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.04.

TOPIC: X3 Life Support and Habitation Systems

Life support and habitation encompasses the process technologies and equipment necessary to provide and maintain a livable environment within the pressurized cabin of crewed spacecraft. Functional areas of interest to this solicitation include thermal control and ventilation, atmosphere resource management and particulate control, water recovery systems, solid waste management, habitation systems, food production, environmental monitoring and fire protection systems. Technologies must be directed at long duration missions in microgravity, including earth orbit and planetary transit. Requirements include operation in microgravity and compatibility with cabin atmospheres of up to 34% oxygen by volume and pressures ranging from 1 atmosphere to as low as 7.6 psi (52.4 kPa). Special emphasis is placed on developing technologies that will fill existing gaps, reduce requirements for consumables and other resources including mass, power, volume and crew time, and which will increase safety and reliability with respect to the state-of-the-art. Non-venting processes may be of interest for technologies that have future applicability to planetary protection. Technology solutions involving both physicochemical and biological approaches are sought. Results of a Phase I contract should demonstrate proof of concept and feasibility of the technical approach. A resulting Phase II contract should lead to development, evaluation and delivery of prototype hardware. Specific technologies of interest to this solicitation are addressed in each subtopic.

X3.01 Enabling Technologies for Biological Life Support
Lead Center: KSC
Participating Center(s): ARC, JSC, MSFC

Biochemical Systems for CO_2 Removal and Processing to Useful Products
NASA is interested in biochemical or biological systems and supporting hardware suitable for purifying the atmosphere in confined spaces such as crewed spacecraft or space habitat cabins. Of special interest is the removal and fixation of CO_2 from a cabin atmosphere via biochemical pathways or autotrophic organisms (plants, algae, cyanobacteria, etc) to produce oxygen and other useful products, including food. Processes considering photosynthesis must address how quantum and/or radiation use efficiency will be improved. Systems should consider minimizing power, mass, consumables and biologically produced waste, while maximizing reliability and efficiency.

Biochemical Systems for Wastewater Treatment
NASA is interested in biological or biochemical approaches to assist in purifying and recycling wastewater in confined spaces such as crewed spacecraft or space habitat cabins. Of special interest are novel approaches for removing carbon, nitrogen and phosphorus to potable or near potable concentrations, and reduction of biosolids. Systems should consider operating with low power, low consumables, low volume, high reliability and rapid deployment, as well as addressing multi-phase flow issues for reduced gravity.

X3.02 Crew Accommodations and Waste Processing for Long Duration Missions
Lead Center: ARC
Participating Center(s): GRC, JSC, KSC, MSFC

Critical gaps exist with respect to interfaces between human accommodations and life support systems for long duration human missions beyond low Earth orbit. New technologies are needed for management and processing of human fecal waste and for clothing and laundry. Proposals should explicitly describe the weight, power, volume, and microgravity performance advantages.

Human Fecal Waste Management
Microgravity technology is needed to collect, stabilize, safen, recover useful materials, and store human feces or its processed residuals. Simple low energy systems that recover water and sterilize/sanitize feces or mineralize it to minimal residuals (and perhaps gases or fuels) are desired. Complete systems are desired that include consideration of preprocessing, processing, and venting or containment for storage of the resultant residuals and/or recovered materials.

Clothing and Laundry Systems
The requirements for crew clothing are balanced between appearance, comfort, wear, flammability and toxicity. Ideally, crew clothing should have durable flame resistance in a 34% O_2 (by volume) enriched environment. Fabrics must enable multiple crew wear cycles before cleaning/disposal.

The laundry system should remove or stabilize the combined contamination from perspiration salts, organics, dander and dust, preserve flame resistance properties, and use cleaning agents compatible with water recovery technologies, including both physiochemical and biological processes. Proposals using water for cleaning should use significantly less than 10 kg of water per kg of clothing cleaned.

X3.03 Environmental Monitoring and Fire Protection for Spacecraft Autonomy
Lead Center: JPL
Participating Center(s): ARC, GRC, JSC, KSC, MSFC

Environmental Monitoring
Monitoring technologies to ensure that the chemical and microbial content of the air and water environment of the crew habitat falls within acceptable limits, and life support system is functioning properly and efficiently, are sought. Required technology characteristics: 2-year shelf-life; functionality in microgravity, low pressure and elevated oxygen cabin environments. Significant improvements in miniaturization, operational reliability, life-time, self-calibration, and reduction of expendables should be demonstrated. Proposals should focus on one of the following areas:

- Process control monitors for life support. Improved reliability for closed-loop feedback control system.
- Trace toxic metals, trace organics in water.
- Monitoring trace contaminants in both air and water with one instrument.
- Microbial monitoring for water and surfaces using minimal consumables.
- Optimal system control methods. Operate the life support system with optimal efficiency and reliability, using a carefully chose suite of feedback and health monitors, and the associated control system.
- Sensor suites. Determine, with robust technical analysis, the optimal number and location of sensors for the information that is needed, and efficient extraction of data from the suite of sensors.

Fire Protection
Spacecraft fire protection technologies to detect the overheating or combustion of spacecraft materials by their particulate and/or gaseous signatures are also sought. These must be of suitable size, mass, and volume for a distributed sensor array. Technologies that detect smoke particulates and identify characteristics (mean particulate sizes or distribution) would also be useful. Catalytic or sorbent technologies suitable for the rapid removal of gases, especially CO, and particulate during a contingency response are desired.

X3.04 Spacecraft Cabin Ventilation and Thermal Control
Lead Center: JSC
Participating Center(s): GRC, GSFC, JPL, LaRC, MSFC

Future spacecraft will require quieter fans, better cabin air filtration, and advanced active thermal control systems.

Small Fan Aero-Acoustics
Procedures and non-intrusive apparatus to measure the sound pressure levels in the inlet and exhaust duct of a candidate spacecraft ventilation fan are requested. Details of the aerodynamic design and the predicted aerodynamic performance of the candidate spacecraft cabin ventilation fan are reported in NASA CR-2010-216329, "Aerodynamic Design and Computational Analysis of a Spacecraft Cabin Ventilation Fan". The duct diameter for this fan (89 mm) falls below the minimum diameter required (150 mm) by ASHRAE Standard 68. The pressure rise at design point for this fan (925 Pa) exceeds the maximum recommended (750 Pa) in ISO 10302. The procedure that is requested to be developed should apply to fans of similar size and capacity (or greater) as the identified candidate spacecraft ventilation fan. The procedure developed should overcome the deficiencies in the standards by providing plots of overall sound power levels as a function of fan flow rate (from full flow to fully throttled conditions) along lines of constant fan rotational speed in the inlet and exhaust ducts. Values of the radial and circumferential duct mode sound power levels calculated from the pressure measurement should be recorded and made available for subsequent examination at all tested conditions. It also must be shown that the flow-induced microphone self-noise, if any, does not contribute significantly to the measured fan sound pressure levels or sound power levels. Validation of the measured fan sound power levels must be shown for a sub-set of the performance range using an alternate technique.

Methods of Particulate Separation and Filtration from Air
Methods of particulate air filtration and/or separation targeting a range of particle sizes from tens of micron down to submicron in conjunction with efficient methods of regeneration are sought. The proposed technical solutions should reduce crew maintenance time and eliminate the need for consumable filter elements. These units should be able to handle large surges of particles and operate over very long periods. They should also be self-cleaning in-place (preferable) or off-line. Targeted technologies should be compact and lightweight, easily integrated with the spacecraft life support system, and provide viable methods for disposing of collected particulate matter while minimizing or eliminating direct contact by the crew.

Active Thermal Control Systems
Thermal control systems will be required that can dissipate a wide range of heat loads with widely varying environments while using fewer of the limited spacecraft mass, volume and power resources. The thermal control system designs must accommodate high input heat fluxes at the heat acquisition source and harsh thermal environments at the heat rejection sink. Advances are sought for microgravity thermal control in the areas of:

- Innovative Thermal Components and System Architectures that are capable of operating over a wide range of heat loads in varying environments (for example, a 10:1 heat load range in environments ranging from 0 to 275K).
- Two-phase Heat Transfer Components and System Architectures for nuclear propulsion that will allow the acquisition, transport, and rejection of waste heat on the order of megawatts,.
- Heat rejection hardware for transient, cyclical applications using either phase change material heat exchangers or efficient evaporative heat sinks.
- Smaller, lighter high performance heat exchangers and coldplates.
- Low temperature external working fluids (a temperature limit of less than 150K with favorable thermophysical properties – e. g., viscosity and specific heat).
- Internal working fluids that are non-toxic, have favorable thermophysical properties, and are compatible with aluminum tubing (i.e., no corrosion for up to 10 years).
- Low mass, high conductance ratio thermal switches.
- Long-life, lightweight, efficient single-phase thermal control loop pumps capable of producing relatively high-pressure head (~4 atm).
- Dust tolerant long-life radiators.
- Variable area radiators (e. g., variable capacity heat pipe radiators or drainable radiators).
- Radiators compatible with inflatable volumes.
- Thermal systems and/or components to extend operational times for spacecraft under the extreme planetary environments, for example: the Venusian surface at approximately 460C and 98 atm.
- Flexible heat pipes.
- Methods to predict the performance of cryogenic multi-layer insulation blankets at 1 atmosphere and during ascent venting.
- Advanced thermal analysis tools that utilize stream processing to improve computational speed over conventional approaches. Possible candidates are: view factor calculation via ray tracing, orbital heating rate calculations, and thermal environment modeling.
- Inflatable/deployable shades to enhance reduce boiloff of cryogenic propellants in long-term storage in low earth orbit.

TOPIC: X4 Extra-Vehicular Activity Technology

Advanced Extra -Vehicular Activity (EVA) systems are necessary for the successful support of the International Space Station (ISS) beyond 2020 and future human space exploration missions for in-space microgravity EVA and for planetary surface exploration. Advanced EVA systems include the space suit pressure garment, airlocks, the Portable Life Support System (PLSS), Avionics and Displays, and EVA Integrated Systems. Future human space exploration missions will require innovative approaches for maximizing human productivity and for providing the capability to perform useful tasks safely, such as assembling and servicing large in-space systems and exploring surfaces of the Moon, Mars, and small bodies. Top-level requirements include reduction of system weight and volume, low or non-consuming systems, increased hardware reliability, durability, operating life, increased human comfort, and less restrictive work performance in the space environment. All proposed Phase I research must lead to specific Phase II experimental development that could be integrated into a functional EVA system.

X4.01 Space Suit Pressure Garment and Airlock Technologies
Lead Center: JSC
Participating Center(s): GRC

Advanced space suit pressure garment and airlock technologies are necessary for the successful support of the International Space Station (ISS) and future human space exploration missions for in-space microgravity EVA and planetary surface operations.

Research is needed in the following space suit pressure garment areas:

- The space suit pressure garment requires innovative technologies that increase the life, comfort, mobility, and durability of gloves, self sealing materials to minimize the effects of small punctures or tears, and materials that are resistant to abrasion.
- Innovative garments that provide direct thermal control to crew member that minimize consumables are needed as well as materials for helmets that are scratch resistant or prevent fogging
- Technologies for space suit flexible thermal insulation suitable for use in vacuum and low ambient pressure are also needed.
- Light Weight Bearings for use in mobility joints in the pressure garment are needed.
- Advanced cooling garments that are highly efficient in removing metabolic heat and are low power consuming are needed.
- Advanced suit materials that provide radiation protection and reduce risks associated with electrical charging and shock.

Due to the expected large number of space walks that will be performed on the ISS beyond 2020 and future human space exploration missions, innovative technologies and designs for both microgravity and surface airlocks will also be needed.

Research is needed in the following space suit airlock area:

Technology development is needed for minimum gas loss airlocks providing quick exit and entry that can accommodate an incapacitated crew member, suit port/suit lock systems for docking a space suit to a dust mitigating entry/hatch in order for the space suit to remain in the airlock and prevent dust from entering the habitable environment.

X4.02 Space Suit Life Support Systems
Lead Center: JSC
Participating Center(s): GRC

Advanced space suit life support systems are necessary for the successful support of the International Space Station (ISS) and future human space exploration missions for in-space microgravity EVA and planetary surface operations. Exploration missions will require a robust, lightweight, and maintainable Primary Life Support System (PLSS). The PLSS attaches to the space suit pressure garment and provides approximately an 8 hour supply of oxygen for breathing, suit pressurization, ventilation and CO_2 removal, and a thermal control system for crew member metabolic heat rejection. Innovative technologies are needed for high-pressure O_2 delivery, crewmember cooling, heat rejection, and removal of expired CO_2 and water vapor.

Focused research is needed in the following space suit life support system areas:

Feedwater Supply Bladder for PLSS - Focused research is needed to develop a shallow, translucent water bladder that will serve to pressurize the water loop for the new PLSS by using the suit pressure to compress the flexible bladder material. The unique aspect of this bladder includes a detection system to indicate via a signal that the remaining usable feed water is approximately .5 kg. Some additional requirements are: Usable capacity => 4.5 kg, Chemically inert to avoid chemical reactions with the feed water which may be DI water to potable standards, Approximate shape is a semi-circle with a diameter of 16 in (40.6 cm), Configuration is similar to an accumulator with a single inlet, 1/8in hose barb, and the Maximum Allowable Working Pressure => 20 psid (138 kPa differential).

$PPCO_2$-H_2O-O_2 Sensor for PLSS - Focused research is needed for a PLSS sensor that is able to measure critical life support constituents in a single combined flow-through sensor configuration. Free water tolerance is an important feature. Test and Shuttle/ISS space suit experience has shown this to be a real possibility that the sensor should tolerate.

X4.03 Space Suit Radio, Sensors, Displays, Cameras, and Audio
Lead Center: GRC
Participating Center(s): JSC

Future EVAs need advances in radio technologies, including antennas, tunable RF front-ends, and power amplifiers; low-power cameras; more accurate, reliable, and packaged core temperature, CO_2, and biomedical sensors; user-friendly, minimally invasive crewmember information displays; and technologies that provide improvements in speech quality, listening quality and listening effort for in-helmet aural and vocal communications. Progress in these technologies will help ensure reliable communications, crew safety and comfort, and work efficiency and autonomy. The focus of this subtopic is to advance future EVA lightweight, compact, low-power technologies in five primary areas: radios, sensors, displays, cameras, and suit audio. The expectation for all of these EVA areas is that a report demonstrating the concept, requirements, design, and technical feasibility will be delivered at the end of Phase I, and that a working and fully functional device will be delivered at the end of Phase II.

The next-generation EVA radio needs to fulfill multiple functions while satisfying stringent requirements on size, weight and power (SWaP) consumption in the ISM S-band (2.4 - 2.483 GHz) and Ka-band (approximately 26 GHz). Ideally, eventual radio SwAP reductions would result in approximately 115 cubic inches, 3.5 – 5.5 pounds, and 15 watts total power consumption, respectively. Next-generation EVA radios will need to support multiple comm loops and point-to-point EVA comm., receive caution and warning messages from the vehicle and other EVA crew, receive, store, and display voice/text messaging to handle comm delays. Moreover, next-generation EVA antenna systems that effectively present uniform coverage around the suit are needed. Likewise, the next-generation EVA radio needs RF front-end architectures capable of presenting baseband or IF signals to waveform processing hardware in multiple bands. Radiation-hardened-by-design transceiver technologies improving upon current Single Event Upset tolerant approaches, along with cognitive technologies, are needed for future EVA exploration to Near Earth Asteroids and beyond.

In addition, advances in tunable technology that permit high Q factor, minimum insertion losses, and excellent linearity are desirable at the given S- and Ka-band Gigahertz frequencies for agility. The next-generation EVA radios will need to support voice, telemetry, and standard/high definition video data flows (up to 20 Mbps); ensure rapid upgrades via scalable, open, and modular architectures; and, advance power aware technologies to optimize efficiency, conserve EVA battery lifetime power, and prolong duration of EVA operations. Finally, no matter what type of transceiver architecture is used in the next-generation EVA radio, the power amplifier is always a key component to enable new functionality, and to minimize the power consumption of the whole radio. Current amplifiers suffer from one or many of the following drawbacks: a) insufficient power added efficiency, b) insufficient linearity performance and incompatibility with modern modulation signals, and c) incompatible with silicon CMOS technology. Most of the commercial PAs are based on III-V GaAs material system, which is more expensive compared to the CMOS fabrication processes. Additionally, the incompatibility with silicon CMOS technology makes it impossible to realize a fully integrated radio-on-a-chip system. Consequently, the implemented radio with the existing power amplifiers requires much more SwAP and higher fabrication costs. Advances are needed in the efficiency and linearity of power amplifiers for next-generation EVA radio applications.

Crew health and suit monitoring require advancement of lightweight CO_2, biomedical (heart rate, blood OX, EKG) and core temperature sensors with reduced size, increased reliability, and greater packaging flexibility. Consequently, technologies are needed to provide high accuracy, low mass, and low-power sensors that measure flow rate, pressure, temperature, and relative humidity or dew point. All sensors must operate in a low pressure 100% O_2 environment with high humidity and may be exposed to liquid condensate.

Because missions must be designed with appropriate radiation shielding and adjusted to keep the radiation doses within tolerable limits, real-time, accurate, instantaneous and integrated radiation dose measurements and readout are needed such as novel dosimeter sensors. Given sufficient warning, astronauts can move to a more shielded part of the space vehicle and lessen dose impact. As cosmic rays impinge upon the vehicle leaving the magnetosphere, sensors are needed to determine the type of radiation and dose as well as reduce the potential risk of biological tissue damage.

Future EVAs need a user-friendly and minimally invasive crewmember information display device that provides significant task efficiency improvement for a broad range of EVA tasks. Current Head-Mounted Display and Near-to-Eye display technologies are a non-starter for EVA, because the display must be mechanically decoupled from the user's head in order to improve crew safety, comfort, and prevent display misalignment. This in turn makes for more difficult specifications for the eyebox (tolerance to misalignment before image goes out of focus), field of view (angle of the image created by the optics), and eye relief (working distance from the eye to the last optical element). Additionally, current Helmet-Mounted Display technologies are challenged in EVA applications due to geometric constraints within the helmet, and future display technologies must ensure suit displays can operate outside the suit protection in thermal, radiation, and vacuum environments as well as internally without imposing ignition hazards due to 100% oxygen environment. Key performance parameters (targets) include: Graphical Data Presentation: SXGA @ 40 deg FOV (possibly biocular); Decoupled from User's Head – Large Eyebox: 100 mm x 100mm x 50mm (D); Sunlight Readability: 500 fL inside visor, 1800 fL outside visor (>10 to 1 contrast).

Future EVAs need to support high definition motion and high resolution imagery with ultra compact, low-power HD cameras and low loss compressed digital data output for RF transmissions and/or IP networks. Hemispherical and dynamic cameras are desired, where hemispherical cameras take video views of a crewmember (360 degrees), distorting those views thru optics and then undistorting those views via software on the ground to pan/zoom for total situational awareness. Dynamic cameras can take stills and motion in variable bandwidths, capture image based on link quality, change frame rates, interfaced to gigabit Ethernet and in a rad-tolerant package with dynamically reconfigure compression core(s) and common 'back-end' interfaces.

The space suit environment presents a unique challenge for capturing and transmitting speech communications to and from a crewmember. The in-suit acoustic environment is characterized by highly reflective surfaces, causing high levels of reverberation, as well as spacesuit-unique noise fields; and wide swings of static pressure levels. Due to these factors, the quality of speech delivered to and from the inside of a spacesuit helmet can be low and can have a negative effect on inbound and outbound speech intelligibility. The traditional approach to overcome the challenges of the spacesuit acoustic environment is to use a skullcap-based system of microphones and speakers. Cap-based systems are less successful, however, in attenuating high noise levels generated outside the spacesuit, and many logistical issues exist for head-mounted caps (e.g., crewmembers are not able to adjust the skullcap, headset or microphone booms during EVA operations, interference between the protuberances of the cap and other devices, comfort, hygiene, proper positioning and dislocation, and wire fatigue and blind mating of the connectors, multiple cap sizes to accommodate anthropometric variations in crew heads).

NASA is seeking technologies in support of improvements in speech intelligibility, speech quality, listening quality and listening effort for in-helmet aural and vocal communications. The specific focus of this SBIR subtopic is on improving the interface between crewmember and the acoustic pickup (microphones) and generation (speaker) systems. Devices are sought to improve or resolve acoustic, physical and technical problems (listed above) that have been associated with skullcap-mounted speakers and microphones, or allow for the elimination of skullcap-mounted speakers and microphones. In particular, voice communications systems are sought that have provided crewmembers with adequate speech intelligibility over background noise within, and external to, the spacesuit. Overall system performance must provide Mean Opinion Score (MOS) for Listening Quality (Lq) and Listening Effort (Le) of 3.9 or greater, or Articulation Index (AI) of .7 or better or 90% Intelligibility in the crewmember's native language for both inbound and outbound speech communication. Specific technologies of interest include, but are not limited to: acoustic modeling of the in-suit acoustic environment, including the ability to model structure-borne vibration in helmet and suit structures as well as transduction to and from the acoustic medium; low-mass, low-volume, low-distortion, space-qualified speakers with low variation in sensitivity with static pressure. Changes in speaker sensitivity should be less than 2 dB over the speech band with changes in static pressure between 3 and 18 psia; low-mass, ultra-low-volume (< 1mm^3), low-distortion low noise microphones that are capable of being space-qualified noise canceling microphones with low variation in sensitivity with static pressure. Changes in microphone sensitivity should be less than 2 dB over the speech band with changes in static pressure between 3 and 18 psia; and, attenuation of external noise by passive hearing protection that is comfortable for crewmembers during extended use.

TOPIC: X5 Lightweight Spacecraft Materials and Structures

The SBIR topic area of Lightweight Spacecraft Materials and Structures centers on developing lightweight inflatable structures, advanced manufacturing technologies for metallic and composite materials, structural sensoring techniques, and in-situ non-destructive evaluation systems. Applications are expected to include space exploration vehicles including launch vehicles, crewed vehicles, and surface and habitat systems. The area of expandable structures solicits innovative concepts to support the development of lightweight-structure technologies that would be viable solutions to high packaging efficiency and increasing the usable primary pressurized volume in habitats, airlocks, and other crewed vessels. Technologies are needed to minimize launch mass, size and costs, while maintaining the required structural performance for loads and environments. Advanced fabrication and manufacturing of lightweight structures focuses on the development of metallic alloys and hybrid materials, processing and fabrication technologies related to near-net shape forming. The goal is to reduce structural weight, assembly steps, and minimize welds, resulting in increased reliability and reduced cost. Research should evaluate material compatibility with forming methods and establish fundamental microstructure/processing/property correlations to guide full-scale fabrication. Laboratory scale test methods are needed to accurately simulate the deformation modes experienced in large-scale manufacturing. Polymer matrix composite (PMC) materials have been identified as a critical need for launch and in-space vehicles. The reduction of structural mass translates directly to additional performance, increased payload mass and reduced cost. PMC materials are also critical for other structures, such as cryogenic propellant tanks. Advances in PMC materials, automated manufacturing processes, non-autoclave curing methods, advances in damage-tolerant/repairable structures, and PMC materials with high resistance to microcracking at cryogenic temperatures are sought. The objective is to advance technology readiness levels of PMC materials and manufacturing for launch vehicle and in-space applications resulting in structures having affordable, reliable, and predictable performance. Practical modular structural sensor systems and NDE technologies are sought for spaceflight missions. Smart, lightweight, low-volume, and stand-alone sensor systems should reduce the complexities of standard wires and connectors and enable sensing in locations not normally accessible. NDE sensor system technology should include modular, low-volume systems and have the ability to perform inspections with minimal human interaction. Systems need to provide the location and extent of damage with the minimal data transfer between the flight system and Earth. Mission application areas include space transportation vehicles, pressure vessels, ISS modules, inflatable structures, EVA suits, MMOD shields, and thermal protection structures. Research under this topic should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a full-scale demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X5.01 Expandable Structures
Lead Center: LaRC
Participating Center(s): JSC

The SBIR subtopic area of Lightweight Inflatable Structures solicits innovative concepts to support the development of primary pressurized expandable habitat and storage modules for space exploration environments. Inflatable concepts should illustrate small efficient launch volumes and large deployment volumes. Concepts should also illustrate simple designs, efficient deployment techniques, lightweight materials, and potential for integrated hard points. Robustness, damage tolerance, and minor repair capabilities should also be considered in concept submittals. Airlock and window integration into the inflatable should also be considered.

Lightweight secondary structures for internal outfitting of the inflatable structure after deployment are also solicited. Lightweight concepts of interest include walkways, storage facilities, and hard points for utility or operational subsystems. Secondary structures should be packing and mass efficient, stiff-post deployment, redundant, modular, and multi-functional.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of a Phase II contract.

X5.02 Advanced Fabrication and Manufacturing of Metallic and Polymer Matrix Composite Materials for Lightweight Structures
Lead Center: LaRC
Participating Center(s): GRC, KSC, MSFC

The objective of the subtopic is to advance technology readiness levels of lightweight structures for launch vehicles and in-space applications, by using advanced materials and manufacturing techniques, resulting in structures having affordable, reliable, predictable performance with reduced costs. Performance metrics include: achieving adequate structural and weight performance; manufacturing and life cycle affordability analysis; verifiable practices for scale-up; validation of confidence in design, materials performance, and manufacturing processes; and quantitative risk reduction capability. Research should be conducted to demonstrate novel approaches, technical feasibility, and basic performance characterization during Phase I, and show a path toward a Phase II design allowables and prototype demonstration. Emphasis should be on demonstrable materials/manufacturing technology combinations that can be scaled up for very large structures.

Materials topics should focus on lightweight monolithic metallic materials or Polymer Matrix Composites (PMC) that, in combination with design modifications, can significantly reduce structural mass. Research should include assessment of the material response to forming and joining methods and verification of post-forming properties. Also of interest are high temperature PMC materials for high performance composite structures (high temperature applications), particularly those which are compatible with current composite manufacturing techniques. High temperature PMCs should enable reduction of vehicle mass through elimination or reduction of thermal protection systems. Another area of interest covers development of lightweight damage-tolerant materials that are compatible with forming methods that can significantly reduce structural mass. Proposals to each area will be considered separately.

Fabrication technology topics should focus on near-net-shape and automated manufacturing methods, which can reduce structural weight, processing, and assembly steps, and minimize joints, resulting in increased reliability and reduced cost, and characterization of material response to forming and joining methods. Other interests include development of laboratory scale test methods to accurately simulate large scale manufacturing for use in screening material behavior. Research should include computational modeling and simulation of material behavior and testing to characterize material properties and validate manufacturing methods.

X5.03 Spaceflight Structural Sensor Systems and NDE
Lead Center: LaRC
Participating Center(s): JSC, MSFC

There is a growing use for modular/low mass-volume, low power, low maintenance systems, that reduce or eliminate wiring, stand-alone smart sensor systems that provide answers as close to the sensor as practical and systems that are flexible in their applicability. The systems should allow for additions or changes in instrumentation late in the design/development process and enable relocation or upgrade on orbit. They reduce the complexities of standard wires and connectors and enable sensing functions in locations not normally accessible with previous technologies. They allow NASA to gain insight into performance and safety of NASA vehicles as well as commercial launchers, vehicles and payloads supporting NASA missions.

There is also a need for modular/low mass/volume smart NDE sensors systems and associated software that enable effective use with minimum crew training or re-familiarization after extended periods of no use. Systems should include ability to perform inspections with minimal human interaction. These systems need to provide reliable assessments of the location and extent of damage with the minimal data transfer between vehicle and Earth. Methods are desired to perform inspections in areas with difficult access in pressurized habitable compartments and external environments. Many applications require the ability to see through conductive and/or thermal insulating materials without contacting the surface. Sensors that can dynamically and accurately determine position and orientation of the NDE sensor are needed to automatically register NDE results to precise locations on the structure. Structural design and material configurations are sought that can enhance NDE and monitoring. Advanced processing and displays are needed to reduce the complexity of operations for astronaut crews who may only use the NDE tool infrequently.

TOPIC: X6 Autonomous Systems and Avionics

NASA invests in the development of autonomy and automation software, advanced avionics, integrated system health management, and robust software technology capabilities for the purpose of enabling complex missions and technology demonstrations. The software and avionics elements requested within this topic are critical to enhancing flight system functionality, reducing system vulnerability to extreme radiation and thermal environments, reducing system risk, and increasing autonomy and system reliability through processes, operations, and system management. As a game-changing and cross-cutting technology area, autonomous software and avionics are applicable to broad areas of technology emphasis, including heavy lift launch vehicle technologies, robotic precursor platforms, utilization of the International Space Station, and spacecraft technology demonstrations performed to enable long duration space missions. All of these flight applications will require unique advances in software technologies and avionics such as integrated systems health management, autonomous systems for the crew and mission operations, radiation hardened, multi-core processors, and reliable, dependable software. The exploration of space requires the best of the nation's technical community to step up to providing the technologies, engineering, and systems to explore the beyond LEO, visit asteroids and the Moon, and to extend our reach to Mars.

X6.01 Spacecraft Autonomy and Space Mission Automation
Lead Center: ARC
Participating Center(s): JPL, JSC

Future human spaceflight missions will place crews at large distances and light-time delays from Earth, requiring novel capabilities for crews and ground to manage spacecraft consumables such as power, water, propellant and life support systems to prevent Loss of Mission (LOM) or Loss of Crew (LOC). This capability is necessary to handle events such as leaks or failures leading to unexpected expenditure of consumables coupled with lack of communications. If crews in the spacecraft must manage, plan and operate much of the mission themselves, NASA must migrate operations functionality from the flight control room to the vehicle for use by the crew. Migrating flight controller tools and procedures to the crew on-board the spacecraft would, even if technically possible, overburden the crew. Enabling these same monitoring, tracking, and management capabilities on-board the spacecraft for a small crew to use will require significant automation and decision support software. Required capabilities to enable future human spaceflight to distant destinations include:

- Enable on-board crew management of vehicle consumables that are currently flight controller responsibilities.
- Increase the onboard capability to detect and respond to unexpected consumables-management related events and faults without dependence on ground.
- Reduce up-front and recurring software costs to produce flight-critical software.
- Provide more efficient and cost effective ground based operations through automation of consumables management processes, and up-front and recurring mission operations software costs.

The same capabilities for enabling human spaceflight missions are directly applicable to efforts to automate the operation of unmanned aircraft flying in the National Airspace (NAS) and robotic planetary explorers.

Mission Operations Automation
Peer-to-peer mission operations planning
Mixed initiative planning systems
Elicitation of mission planning constraints and preferences
Planning system software integration

Space Vehicle Automation
Autonomous rendezvous and docking software
Integrated discrete and continuous control software
Long-duration high-reliability autonomous system
Power aware computing

Robotic Systems Automation
Mutli-agent autonomous systems for mapping
Uncertainty management for mapping system
Uncertainty management for grasping robotic system
Uncertainty management for path planning and traversing

Emphasis of proposed efforts:

- Software proposals only, but emphasize hardware and operating systems the proposed software will run on (e.g., processors, sensors).
- In-space or Terrestrial applications (e.g., UAV mission management) are acceptable.
- Proposals must demonstrate mission operations cost reduction by use of standards, open source software, staff reduction, and/or decrease of software integration costs.
- Proposals must demonstrate autonomy software cost reduction by use of standards, demonstration of capability especially on long-duration missions, system integration, and/or open source software.

X6.02 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors
Lead Center: MSFC
Participating Center(s): GSFC, JPL

Exploration flight projects, robotic precursors, and technology demonstrators that are designed to operate beyond low-earth orbit require avionic systems, components, and controllers that are capable of enduring the extreme temperature and radiation environments of deep space, the lunar surface, and eventually the Martian surface.

Spacecraft vehicle electronics will be required to operate across a wide temperature range and must be capable of enduring frequent (and often rapid) thermal-cycling. Packaging for these electronics must be able to accommodate the mechanical stress and fatigue associated with the thermal cycling. Spacecraft vehicle electronics must be radiation hardened for the target environment. They must be capable of operating through a minimum total ionizing dose (TID) of 300 krads (Si), provide fewer Single Event Upsets (SEUs) than 10-10 to 10-11errors/bit-day, and provide single event latchup (SEL) immunity at linear energy transfer (LET) levels of 100 MeV cm^2/mg (Si) or more. All three characteristics for radiation hardened electronics of TID, SEU and SEL are needed. Electronics hardened for thermal cycling and extreme temperature ranges should perform beyond the standard military specification range of -55°C to 125°C, running as low as -230°C or as high as 350°C.

Considering these target environment performance parameters for thermal and radiation extremes, proposals are sought in the following specific areas:

- Low power, high efficiency, radiation-hardened processor technologies.
- Technologies and techniques for environmentally hardened Field Programmable Gate Array (FPGA).
- Innovative radiation hardened volatile and nonvolatile memory technologies.
- Tightly-integrated electronic sensor and actuator modules that include power, command and control, and processing.
- Radiation hardened analog application specific integrated circuits (ASICs) for spacecraft power management and other applications.
- Radiation hardened DC-to-DC converters and point-of-load power distribution circuits.
- Computer Aided Design (CAD) tools for predicting the electrical performance, reliability, and life cycle for low-temperature and wide-temperature electronic systems and components.
- Physics-based device models valid at temperature ranging from -230°C to +130°C to enable design, verification and fabrication of custom mixed-signal and analog circuits.
- Circuit design and layout methodologies/techniques that facilitate improved radiation hardness and low-temperature (-230°C) analog and mixed-signal circuit performance.
- Packaging capable of surviving numerous thermal cycles and tolerant of the extreme temperatures on the Moon and Mars. This includes the use of appropriate materials including substrates, die-attach, encapsulants, thermal compounds, etc.

X6.03 Integrated System Health Management for Flexible Exploration
Lead Center: ARC
Participating Center(s): JPL, JSC, KSC, MSFC

Novel integrated system health management technologies will enable NASA’s pursuit of a more sustainable and affordable approach to spaceflight. New heavy lift launch systems will incorporate new engines, propellants, materials, and combustion processes and will increase NASA’s capabilities and significantly lower operations costs. Health management is essential for the safe and reliable operation of these complex systems. Innovative health management technologies are also essential for long-duration robotic precursor missions. Projects may focus on one or more relevant subsystems such as rocket engines, liquid propulsion systems, structures and mechanisms, thermal protection systems, power, avionics, life support, communications, and software. Specific technical areas of interest are methods and tools for:

- Early-stage design of health management functionality during the development of space systems, including failure detection methods, sensor types and locations that enable fault detection to line replaceable units.
- Sensor validation and robust state estimation in the presence of inherently unreliable sensors. Focus on data analysis and interpretation using legacy sensors.
- Model-based fault detection and isolation based on existing sensor suites that enables fault detection within time ranges to allow mission abort.

- Automatic construction of models used in model-based diagnostic strategies, limiting model construction times to 60% of the time required using manual methods.
- Prognostic techniques able to anticipate system degradation before loss of critical functions and enable further improvements in mission success probability, operational effectiveness, and automated recovery of function.
- Techniques that address the particular constraints of maintaining long-duration systems health of structures, mechanical parts, electronics, and software systems are also of interest.

TOPIC: X7 Human-Robotic Systems

This call for technology development is in direct support of the Exploration Systems Mission Directorate (ESMD). The purpose of this research is to develop component and subsystem level technologies to support robotic precursor exploration missions. To that end, it is the intent of this Topic to capitalize on advanced technologies that allow humans and robots to interact seamlessly and significantly increase their efficiency and productivity in space. The objective is to produce new technologies that will reduce the total mass-volume-power of equipment and materials required to support both short and long duration planetary missions. The proposals must focus on component and subsystem level technologies in order to maximize the return from current SBIR funding levels and timelines. Doing so increases the likelihood of successfully producing a technology that can be readily infused into existing robotic system designs. This research focuses on technology development for the critical functions that will ultimately enable surface exploration for the advancement of scientific research. Surface exploration begins with short duration missions to establish a foundation, which leads to extensible functional capabilities. Successive buildup missions establish a continuous operational platform from which to conduct scientific research while on the planetary surface. Reducing risk and ensuring mission success depends on the coordinated interaction of many functional surface systems including power, communications infrastructure, and mobility and ground operations. This topic addresses technology needs within three subtopic areas:

- Mobility systems.
- Dexterous manipulation.
- The interfaces that facilitate productive and seamless interaction between humans and robots.

X7.01 Human Robotic Systems - Human Robot Interfaces
Lead Center: ARC
Participating Center(s): JPL, JSC

The objective of this subtopic is to create human-robot interfaces that improve the human exploration of space. Robots can perform tasks to assist and off-load work from astronauts. Robots may perform this work before, in support of, or after humans. Ground controllers and astronauts will remotely operate robots using a range of control modes, over multiple distances (shared-space, line-of-sight, in orbit, and interplanetary), and with a range of time-delay and communications bandwidth.

This subtopic seeks to develop new technologies that enable crew and ground controllers to better operate, monitor and supervise semi-autonomous robots. Of particular interest is software that improves robot operator productivity, situational awareness, and effectiveness.

Proposals are sought that address the following technology needs:

- Crew telerobotic interfaces. User interfaces that enable crew to remotely operate and monitor robots from inside a flight vehicle, habitat and/or during an extra-vehicular activity (EVA). User interfaces must be appropriate and relevant for use with near-term flight systems.

- Robot performance monitoring software. Software tools that enable remote monitoring of robot performance, detection of anomalies and contingencies, assessment of robot utilization and situational awareness of remote robot operations.
- Robot tactical planning software. Software tools that enable efficient, rapid handling of contingencies during robot tactical operations. This may involve a combination of embedded and user interface modules.
- Robot ground data systems. Systems and software for robot command planning and sequencing, telemetry processing, sensor/instrument data management, and automating ground control functions.

This subtopic does not solicit proposals for direct teleoperation (e.g., joystick-based rate control), telepresence, or immersive virtual reality subsystems or systems.

X7.02 Human-Robotic Systems - Mobility Subsystems
Lead Center: JSC
Participating Center(s): ARC, JPL

The objective of this subtopic is to create human-robotic technologies (hardware and software) to improve the exploration of space. Robots can perform tasks to assist and off-load work from astronauts. Robots may perform this work before, in support of, or after humans.

Ground controllers and astronauts will remotely operate robots using a range of control modes (teleoperation to supervised autonomy), over multiple spatial ranges (shared-space, line-of-sight, in orbit, and interplanetary), and with a range of time-delay and communications bandwidth.

Proposals are sought that address the following technology needs:

- Subsystems to improve the transport of crew, instruments, and payloads on planetary surfaces, asteroids, in-space; and improve handling and maintenance of payloads and assets. This includes hazard detection sensors/perception, active suspension, grappling/anchoring, legged locomotion, robot navigation, and infrastructure-free localization. As well as, tactile sensors, human-safe actuation, active structures, dexterous grasping, modular “plug and play” mechanisms for deployment and setup, small/lightweight excavation/drilling devices to enable subsurface access, and novel manipulation methods.

TOPIC: X8 High-Efficiency Space Power Systems

This topic solicits technology development for high-efficiency power systems to be used for the human exploration of space. Technologies applicable to both space exploration and clean and renewable energy for terrestrial applications are of particular importance. Power system needs include: electric energy generation and storage for human-rated vehicles, electrical energy generation for in-space propulsion systems, and electric energy generation, storage, and transmission for planetary and lunar surface applications. Technology development is sought in: Fuel cells and electrolyzers including both proton exchange membrane and solid oxide technologies; Battery technology including components for improved performance and safety; Nuclear power systems including fission and radioisotope power generation; Photovoltaic power generation including solar cell, blanket and array technology; reliable, radiation tolerant electronic devices; and robust high voltage electronics.

X8.01 Fuel Cells and Electrolyzers
Lead Center: GRC
Participating Center(s): JPL, JSC

Advanced primary fuel cell and regenerative fuel cell energy storage systems are enabling for various aspects of future Exploration missions. Proposals that address technology advances related to the following issues for PEM fuel cell, electrolysis, and regenerative fuel cell systems are desired.

Proton Exchange Membrane (PEM) Fuel Cells and Electrolyzers
Proposals that address technology advances related to the following issues for PEM fuel cell, electrolysis, and regenerative fuel cell systems are desired.

Oxidation Resistant Gas Diffusion Layer (GDL)
GDLs are integral to PEM fuel cell membrane-electrode-assemblies (MEAs). Traditional carbon or graphite based GDLs are very susceptible to oxidation under certain operating conditions in the pure oxygen environment of space fuel cell systems. This results in MEA degradation and shortened life. Proposals addressing the development of oxidation resistant GDLs that remain stable to oxidation in a pure oxygen environment, and provide improved performance and longer life are desired.

Deionizing Water Treatment for High Pressure, High Temperature Water Electrolyzers
Ultra high purity water is needed for NASA's high pressure, high temperature water electrolyzers. Technology is needed to remove ions within the water that is circulated over the catalyzed electrodes of the electrolyzer. Ions need to be reduced below TBD ppm prior to entering the water electrolyzer. The deionizer must function in flowing water at 2000 psi and 80°C.

High System Pressure water Pump
A water pump is needed to circulate water through a high-pressure water electrolyzer. The pump must meet the following criteria:

- Operating System pressure of >2000 psia.
- Minimum developed differential pressure of 30 psid.
- Operating temperature 20-90°C.
- Minimum liquid flow rate of 30 LPM.
- Chemically tolerant to water saturated with dissolved oxygen at 2000 psia, 90°C.
- Tolerant to two-phase mixtures of gaseous oxygen and liquid water without losing pumping effectiveness.
- Mass ≤ 2 kg.
- Volume ≤ 0.75 liters.
- Power Consumption ≤ 120 watts.

Instrumentation, Control, Health Monitoring, and Data Handling
Highly reliable voltage monitors for batteries, fuel cells, electrolyzers, and regenerative fuel cells are needed having low mass and low parasitic power consumption. Up to 48 differential voltages (0-5 VDC) with a minimum of 120 VDC common mode rejection must be monitored for system health management over an operating temperature range of -20 to +40°C, and the system must be capable of being upgraded to meet a Grade-1 EEE reliability

Solid Oxide Fuel Cells and Electrolyzers
Advanced primary Solid Oxide Fuel Cells (SOFC) and Electrolyzers offer notable advantages in certain space applications when integrated with, respectively, CH_4/O_2 propulsion systems and systems for producing oxygen from planetary resources. In contrast to most terrestrial/commercial applications, solid oxide devices for spacecraft will operate on pure oxygen and clean fuel streams (e.g., pure methane.) New materials are required to enable their use in these applications. These devices typically operate at high temperatures (800-1000°C) and are expected to undergo on/off cycling in aerospace applications. Technology advances are sought that reduce the time required to get to operating temperature, enable hundreds of rapid start-up/shut-down cycles, and enable systems to accommodate large load swings without leakage or deposition of elemental carbon. Spacecraft solid oxide devices that operate with minimal active cooling are needed. Low recurring costs are not a priority for spacecraft fuel cell materials. Technology advances that reduce the weight and volume, improve the efficiency, life, safety, system simplicity and reliability of Solid Oxide Fuel Cells and Electrolyzers are desired. Proposals are sought which address the following areas:

Advanced Primary SOFC Systems
Their high temperature heat rejection and high efficiency power generation from methane and oxygen make primary SOFC's attractive for application to spacecraft with CH_4/O_2 propulsion systems. Research directed towards improving the durability, efficiency, and reliability of SOFC systems fed by propellant-grade methane and oxygen is desired. Primary SOFC components and systems of interest:

- Have power outputs in the 1 to 3 kW range.
- Offer thermodynamic efficiencies of at least 70% (fuel source-to-DC output) when operating at the current draw corresponding to optimized specific power.
- Operate as specified after at least 300 start-up cycles (from cold to operating temperature within 5 minutes) and 300 shut-down cycles (from operating temperature to cold within 5 minutes).
- Operate as specified after at least 2500 hours of steady state operation on propellant-grade methane and oxygen.
- Are cooled by way of conduction through the stack to a radiator exposed to space and/or by anode exhaust flow.

Advanced Solid Oxide Electrolyzers
Their high temperature heat rejection and operation, along with high efficiency, make solid oxide electrolyzers attractive as the final step of producing oxygen from Lunar or Martian regolith by way of hydrogen or carbothermal reduction. They are also attractive components for Sabatier reactors producing methane from the Martian atmosphere. Research directed towards improving the durability, efficiency, and reliability of solid oxide electrolyzers is desired. Solid oxide electrolysis systems of interest:

- Require power inputs in the 1 to 3 kW range.
- Operate as specified after 10,000 hours of operation fed by water with mild contamination.
- Operate as specified after 100 start-up cycles (from cold to operating temperature within 5 minutes) and 100 shut-down cycles (from operating temperature to cold within 5 minutes).
- Offer thermodynamic efficiencies of at least 70% (DC-input to Lower Heating Value H_2 output) when operating at the current feed corresponding to rated power.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X8.02 Space-Rated Batteries
Lead Center: GRC
Participating Center(s): JPL, JSC

Advanced battery systems are sought for future NASA Exploration missions to address requirements for safe, human-rated, high specific energy, high energy density, and high efficiency power systems. Possible applications include extravehicular activities, landers, and rovers. Areas of emphasis include advanced cell chemistries with aggressive weight and volume performance improvements and safety advancements over state-of-the-art lithium-based systems. Novel rechargeable battery chemistries with advanced non-toxic anode and cathode materials and nonflammable electrolytes are of particular interest. Priority will be given to efforts addressing novel cathode materials that can be paired with advanced silicon anodes.

The focus of this solicitation is on advanced concepts and cell components that provide weight and volume improvements and safety advancements that contribute to the following cell level metric goals:

- Specific energy >350 Wh/kg at C/2 (Fully charged or discharged in 2 hours).
- Energy density > 650 Wh/l at C/2.
- Tolerance to abuse such as overcharge, external short-circuit, and over temperature.

- Calendar life >10 years.
- Cycle life >250 cycles at 100% depth of discharge.

Systems that combine all of the above characteristics and demonstrate a high degree of safety and radiation tolerance are desired. Cell safety devices such as shutdown separators, current limiting devices that inhibit thermal runaway, venting, and eliminate flame or fire; autonomous safety features that include safe, non-flammable, non-hazardous operation especially for human-rated applications are of particular interest.

Proposals should include analysis that demonstrates the potential of the proposed technology to meet the projected performance parameters. Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II breadboard demonstration, and when possible, deliver a prototype/ demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X8.03 Space Nuclear Power Systems
Lead Center: GRC
Participating Center(s): JPL, JSC, MSFC

NASA is developing fission power system technology for future space transportation and surface power applications using a stepwise approach. Early systems are envisioned in the 10 to 100 kWe range that utilize a 900 K liquid metal cooled reactor, dynamic power conversion, and water-based heat rejection. The anticipated design life is 8 to 15 years with no maintenance. Candidate mission applications include initial power sources for human outposts on the moon or Mars, and nuclear electric propulsion systems (NEP) for Mars cargo transport. A non-nuclear system ground test in thermal-vacuum is planned by NASA to validate technologies required to transfer reactor heat, convert the heat into electricity, reject waste heat, process the electrical output, and demonstrate overall system performance.

The primary goals for the early systems are low cost, high reliability, and long life. Proposals are solicited that could help supplement or augment the planned NASA system test. Specific areas for development include:

- 900 K NaK heat transport loops, including pumps and accumulators.
- 10 kWe-class Stirling and Brayton power conversion devices.
- 450 K water heat rejection loops, including pumps and accumulators.
- Composite radiator panels with embedded water heat pipes.
- Radiator deployment mechanisms and structures.
- Radiation tolerant materials and components.
- 120 V - 1k V power management and distribution (PMAD) for high power DC and AC systems, 1 kW to 100 kW respectively.

The NASA system test is expected to provide the foundation for later systems in the multi-hundred kilowatt or megawatt range that utilize higher operating temperatures, alternative materials, and advanced components to improve system performance. For the later systems, specific power will be a key performance metric with goals of 30 kg/kWe at 100 kWe and 10 kg/kWe at 1 MWe. Possible mission applications include large NEP cargo vehicles, NEP piloted vehicles, and surface-based resource production plants. In addition to low cost, high reliability, and long life, the later systems should address the low system specific mass goal. Proposals are solicited that identify novel system concepts and methods to reduce mass and increase power output. Specific areas for development include:

- High temperature reactor fuels and structural materials.
- Reactor heat transport technologies for 1100 K and above.
- 100 kWe-class Brayton and Rankine power conversion devices.
- Waste heat rejection technologies for 500 K and above.

X8.04 Advanced Photovoltaic Systems
Lead Center: GRC
Participating Center(s): JPL, JSC

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought for improvements in capability and reliability of PV power generation for space exploration missions. Power levels for PV applications may reach 100s of kWe. System and component technologies are sought that can deliver efficiency, cost, reliability, mass and volume improvements under various operating conditions.

PV technologies must enable or enhance the ability to provide low-cost, low mass and higher efficiency for power systems with particular emphasis on high power arrays to support solar electric propulsion missions. Examples of PV technology areas:

- Very large solar array concepts (>300kW) operating at high voltage (>200V).
- High voltage electronics for use in solar electric propulsion vehicles operating at bus voltages >200 VDC.
- Advanced concepts for array packaging, deployment and retraction.
- Advanced PV blanket and component technology/designs.
- Array concepts and module/component technologies that emphasize cost reduction (in materials, fabrication and testing).
- Automated/modular fabrication methods.
- Component and material availability/ high volume production capability.
- Ground testability/ space qualification for large array structures.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. A major focus will be on the demonstration of dual-use technologies that address exploration mission needs but also benefit clean/ renewable energy for terrestrial applications.

TOPIC: X9 Entry, Descent, and Landing (EDL) Technology

The Entry, Descent, and Landing (EDL) Technology includes developments in Thermal Protection Systems (TPS) and Supersonic Retropropulsion (SRP). The Thermal Protection System (TPS) protects a spacecraft from the severe heating encountered during hypersonic flight through a planetary atmosphere. Supersonic Retropropulsion has been identified in past studies to be enabling for putting human-scale payloads on the surface of Mars. Thermal Protection Systems: In general, there are two classes of TPS: reusable and ablative. Typically, reusable TPS applications are limited to relatively mild entry environments like that of Space Shuttle. No change in the mass or properties of the TPS material results from entry; a significant amount of energy is re-radiated from the heated surface and the remainder is conducted into the TPS material. Ablative TPS materials, in contrast, accommodate high heating rates and heat loads through phase change and mass loss. All NASA planetary entry probes to date have used ablative TPS. Most ablative TPS materials are reinforced composites employing organic resins as binders. In comparison to reusable TPS materials, the interaction of ablative TPS materials with the surrounding gas environment is much more complex as there are many more mechanisms to accommodate the entry heating. Better performing ablative TPS is needed to satisfy requirements of the most severe missions, e.g., Mars Landing from 8 km/s entry and Mars Sample Return with 12-15 km/s Earth entry. Beyond the improvement needed in ablative TPS materials, more demanding future missions such as large payload missions to Mars will require novel entry system designs that consider different vehicle shapes, deployable or inflatable configurations and integrated approaches of TPS materials with the entry system sub-structure. Supersonic Retropropulsion: When decelerating a vehicle to land on a body with an atmosphere, it is generally more mass-effective to take advantage of the natural environment and use atmospheric drag to its full potential, rather than use a propulsion system. This approach works well at Earth where the atmosphere is dense, but the trade is less conclusive at Mars. Recent studies for landing human-scale payloads on Mars (40-60 mt) have shown that using Supersonic Retropropulsion is probably enabling for this challenge. The scale of an aerodynamic decelerator employed in this flight regime would be very large, and presents issues with payload extraction and deployment in the short time available. Since a terminal propulsion system is already needed for these large landers, starting the engines earlier in the descent profile is an attractive solution. Aerodynamic challenges with this approach center around the interaction of the engine plumes with the oncoming supersonic flowfield, and what instabilities this causes for the system. Controlled wind tunnel testing with high-fidelity instrumentation and subsequent modeling of these complex flowfields is key to predicting system behavior. The SRP system will also need to be flight-tested in a relevant environment as part of the technology maturation. Cost-effective, feasible concepts and vehicle configurations for Earth flight tests are needed, to prove feasibility in the near term.

X9.01 Ablative Thermal Protection Systems
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, LaRC

The technologies described below support the goal of developing higher performance ablative TPS materials for future Exploration missions. Developments are sought for ablative TPS materials and heat shield systems that exhibit maximum robustness, reliability and survivability while maintaining minimum mass requirements, and are capable of enduring severe combined convective and radiative heating, including: development of acreage (main body, non-leading edge) materials, adhesives, joints, penetrations, and seals. Three classes of materials will be required:

- One class of materials, for Mars aerocapture and entry for a rigid mid L/D (lift to drag ratio) shaped vehicle, will need to survive a dual heating exposure, with the first at heat fluxes of 400-500 W/cm^2 (primarily convective) and integrated heat loads of up to 55 kJ/cm^2, and the second at heat fluxes of 100-200 W/cm^2 and integrated heat loads of up to 25 kJ/cm^2. These materials or material systems must improve on the current state-of-the-art recession rates of 0.25 mm/s at heating rates of 200 W/cm^2 and pressures of 0.3 atm and improve on the state-of-the-art areal mass of 1.0 g/cm^2 required to maintain a bondline temperature below 250ºC
- The second class of materials, for Mars aerocapture and entry for a hypersonic deployable aerodynamic decelerator, will need to survive a dual heating exposure, with the first at heat fluxes of 100-200 W/cm^2 (primarily convective) and integrated heat loads of 10 kJ/cm^2 and the second at heat fluxes of 30-50 W/cm^2 and heat loads of 5 kJ/cm^2. These materials may be either flexible or deployable.
- The third class of materials, for Mars return, will need to survive heat fluxes of 1500-2500 W/cm^2, with radiation contributing up to 75% of that flux, and integrated heat loads from 75-150 kJ/cm^2. These materials, or material systems must improve on the current state-of-the-art recession rates of 1.00 mm/s at heating rates of 200 W/cm^2 and pressures of 0.3 atm and improve on the state-of-the-art areal mass of 4.0 g/cm^2, required to maintain a bondline temperature below 250ºC.

In-situ heat flux sensors and surface recession diagnostics tools are needed for flight systems to provide better traceability from the modeling and design tools to actual performance. The resultant data will lead to higher fidelity design tools, risk reduction, decreased heat shield mass and increases in direct payload. The heat flux sensors should be accurate within 20%, surface recession diagnostic sensors should be accurate within 10%, and any temperature sensors should be accurate within 5% of actual values.

Non Destructive Evaluation (NDE) tools are sought to verify design requirements are met during manufacturing and assembly of the heat shield, e.g., verifying that anisotropic materials have been installed in their proper orientation, that the bondline as well as the TPS materials have the proper integrity and are free of voids or defects. Void and/or defect detection requirements will depend upon the materials being inspected. Typical internal void detection requirements are on the order of 6-mm, and bondline defect detection requirements are on the order of 25.4-mm by 25.4-mm by the thickness of the adhesive.

Advances are sought in ablation modeling, including radiation, convection, gas surface interactions, pyrolysis, coking, and charring. There is a specific need for improved models for low and mid density as well as multi-layered charring ablators (with different chemical composition in each layer). Consideration of the non-equilibrium states of the pyrolysis gases and the surface thermochemistry, as well as the potential to couple the resulting models to a computational fluid dynamics solver, should be included in the modeling efforts.

Technology Readiness Levels (TRL) of 2-3 or higher are sought.

X9.02 Advanced Integrated Hypersonic Entry Systems
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, LaRC

The technologies below support the goal of developing advanced integrated hypersonic entry systems that meet the longer-term goals of realizing larger payload masses for future Exploration missions.

Advanced integrated thermal protection systems are sought that address:

- Thermal performance efficiency (i.e., ablation vs. conduction).
- In-depth thermal insulation performance (i.e., material thermal conductivity and heat capacity vs. areal density).
- Systems thermal-structural performance.
- System integration and integrity.

Such integrated systems would not necessarily separate the ablative TPS material system from the underlying sub-structure, as is the case for most current NASA heat shield solutions. Instead, such integrated solutions may show benefits of technologies such as hot structures and/or multi-layer systems to improve the overall robustness of the integrated heat shield while reducing its overall mass. The primary performance metrics for concepts in this class are increased reliability, reduced areal mass, and/or reduced life cycle costs over the current state of the art.

Advanced multi-purpose TPS solutions are sought that not only serve to protect the entry vehicle during primary planetary entry, but also show significant added benefits to protect from other natural or induced environments including: MMOD, solar radiation, cosmic radiation, passive thermal insulation, dual pulse heating (e.g., aero capture followed by entry). Such multi-purpose materials or systems must show significant additional secondary benefits relative to current TPS materials and systems while maintaining the primary thermal protection efficiencies of current materials/systems. The primary performance metrics for concepts in this class are reduced areal mass for the combined functions over the current state of the art.

Integrated entry vehicle conceptual development is sought that allow for very high mass (> 20 mT) payloads for Earth and Mars entry applications. Such concepts will require an integrated solution approach that considers: TPS, structures, aerodynamic performance (e.g., L/D), controllability, deployment, packaging efficiency, system robustness/reliability, and practical constraints (e.g., launch shroud limits, ballistic coefficients, EDL sequence requirements, mass efficiency). Such novel system designs may include slender or winged bodies, deployable or inflatable entry systems as well as dual use strategies (e.g., combined launch shroud and entry vehicle). New concepts are enabling for this class of vehicle. Key perormance metrics for the overall design are system mass, reliability, complexity, and life cycle cost.

Advances in Multidisciplinary Design Optimization (MDO) are sought specifically in application to address combined aerothermal environments, material response, vehicle thermal-structural performance, vehicle shape, vehicle size, aerodynamic stability, mass, vehicle entry trajectory/GN&C (Guidance, Navigation and Control), and cross-range, characterizing the entry vehicle design problem.

Technology Readiness Levels (TRL) of 2-3 or higher are sought.

TOPIC: X10 Cryogenic Propellant Storage and Transfer

The Exploration Systems architecture presents cryogenic storage, distribution, and fluid handling challenges that require new technologies to be developed. Reliable knowledge of low-gravity cryogenic fluid management behavior is lacking and yet is critical for future manned and robotic exploration in the areas of storage, distribution, and low-gravity propellant management. Additionally, Earth-based and planetary surface missions will require success in storing and transferring liquid and gas commodities in applications. Some of the technology challenges are for long-term space use cryogenic propellant storage and distribution; cryogenic fluid processing and fluid conditioning; liquid hydrogen and liquid oxygen liquefaction processes. Furthermore, specific technologies are required in valves, regulators, instrumentation, modeling, mass gauging, cryocoolers, and passive and active thermal control techniques. The technical focus for component technologies are for accuracy, reduced mass, minimal heat leak, minimal leakage, and minimal power consumption. The anticipated technologies proposed are expected to increase safety, reliability, economic efficiency over current state-of-the-art cryogenic system performance, and are capable of being made flight qualified and/or certified for the flight systems and dates to meet Exploration Systems mission requirements.

X10.01 Cryogenic Fluid Management Technologies
Lead Center: GRC
Participating Center(s): ARC, GSFC, JSC, KSC

This topic solicits technologies related to cryogenic propellant storage, transfer, and instrumentation to support NASA's exploration goals. Proposed technologies should feature enhanced safety, reliability, long-term space use, economic efficiency over current state-of-the-art, or enabling technologies to allow NASA to meet future space exploration goals. This includes a wide range of applications, scales, and environments consistent with future NASA missions. Specifically:

- Innovative concepts for cryogenic fluid instrumentation are solicited to enable accurate measurement of propellant mass in low-gravity storage tanks, sensors to detect in-space and on-pad leaks from the storage system, minimally invasive cryogenic liquid mass flow measurement sensors, including cryogenic two-phase flow.
- Passive thermal control for Zero Boil-Off (ZBO) storage of cryogens for both long term (>200 days) and short term (~14 days) in all mission environments. Insulation systems that can also serve as Micrometeoroid/orbital debris (MMOD) protection and are self-healing are also desired.
- Active thermal control for long term ZBO storage for space applications. Technologies include 20K cryocoolers and integration techniques, heat exchangers, distributed cooling, and circulators.
- Zero gravity cryogenic control devices including thermodynamic vent systems, spray bars, mixers, and liquid acquisition devices.
- Advanced spacecraft valve actuators using piezoelectric ceramics. Actuators that can reduce the size and power while minimizing heat leak and increasing reliability.
- Large scale propellant conditioning and densification technologies for zero loss propellant storage and transfer. Specific component technologies include compact, efficient and economical cryogenic compressors, cryocoolers and integration techniques, Joule-Thompson orifices, vapor shielded transfer lines, and heat exchangers.
- Liquefaction of oxygen for in space resource utilization applications. This includes passive cooling with low temperature radiators, cryocooler liquefaction, or open cycle systems that work with HP electrolysis.
- Processes or components/instrumentation that can reduce or eliminate helium usage. This includes real time purge gas concentration visibility, helium capture and purification technology, and alternatives to helium use such as hydrogen gas purges or advanced insulation systems.

TOPIC: X11 Radiation Protection

The SBIR topic area of Radiation Protection focuses on the development and testing of mitigation concepts to protect astronaut crews and exploration vehicles from the harmful effects of space radiation, both in Low Earth Orbit (LEO) and while conducting long-duration missions beyond LEO. Advances are needed in mitigation schema for the next generation of exploration vehicles inclusive of radiation shielding materials and structures technologies to protect humans from the hazards of space radiation during NASA missions. As NASA continues to form plans for long duration exploration, it has also become increasingly clear that the ability to mitigate the risks posed to both crews and vehicle systems by the space weather environment are also of central importance. This Radiation Protection Topic will have two sub-topics consisting of:

- Radiation Shielding.
- Alert and Warning Systems.

This first area of interest for the 2011 solicitation is radiation shielding materials systems for long-duration Galactic Cosmic Ray (GCR) and Solar Particle Event (SPE) protection capable of providing structural integrity for architectural element design, while also providing sufficient radiation protection. These material systems should likely possess other multi-functional properties such as thermal and/or MMOD protection, etc., therefore negating the need for the addition of parasitic shield mass. Neutron protection and high-energy electron protection are also of interest. Research should be conducted to demonstrate technical feasibility during Phase I and to show a path forward to Phase II technology demonstration. Physical, mechanical, structural, and/or other relevant characterization data to validate and qualify multifunctional radiation shielding materials and structures should be demonstrated. Advances are needed in:

- Innovative tailored materials for lightweight radiation shielding of humans and electronics for NASA missions.
- Innovative, multifunctional, integrated, or multipurpose structures (primary or secondary structure) for lightweight radiation shielding of humans and electronics for NASA missions.

Applications are expected to include space exploration vehicles including launch vehicles, crewed vehicles, and surface and habitat systems. Another area of interest in which SBIR-developed technologies can contribute to NASA’s overall mission requirements are advances in the understanding and predictability of space weather science. Current operational space weather support utilizes both inter- and extra-agency assets to maintain situational awareness and mitigate radiation risks associated with agency missions. Operational space weather support consists in the most basic terms of maintaining situational awareness of both the state of the Sun as a physical system and the radiation environment and its dynamics within the Heliosphere, and altering in real-time, a mission in order to minimize their effects. Therefore, advances are needed in the development of scientific research products for real-time operational forecasting tools to mitigate mission risk. Research under this topic should be conducted to demonstrate technical feasibility during Phase I and show a path forward to Phase II hardware demonstration, and when possible, deliver a full-scale demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X11.01 Radiation Shielding Materials Systems
Lead Center: LaRC
Participating Center(s): MSFC

Advances in radiation shielding materials technologies and systems are needed to protect humans from the hazards of space radiation during NASA missions. The primary areas of interest for this 2011 solicitation are radiation shielding materials systems for long-duration galactic cosmic radiation (GCR) and solar energetic particles (SEP) protection. Neutron protection and high-energy electron protection are also of interest. Research should be conducted to demonstrate technical feasibility during Phase I and to show a path toward a Phase II technology demonstration.

Physical, mechanical, structural, and/or other relevant characterization data to validate and qualify multifunctional radiation shielding materials should be demonstrated. Specific areas in which SBIR-developed technologies can contribute to NASA's overall mission requirements include the following:

- Innovative tailored materials for lightweight radiation shielding of humans.
- Innovative, multifunctional, integrated, or multipurpose structures (primary or secondary structures) for lightweight radiation shielding of humans.
- Innovative processes for developing radiation shielding materials.
- Smart, or sensing, radiation shielding materials.
- Radiation shielding materials demonstration experiments for MISSE (Materials International Space Station Experiment) or other ISS experiments.

X11.02 Integrated Advanced Alert/Warning Systems for Solar Proton Events
Lead Center: JSC

Advances are needed in alerts/warnings and risk assessment models that give mission planners, flight control teams and crews sufficient advanced warning of impending Solar Proton Event impact. Research and development should be targeted which leverages modeling techniques used throughout terrestrial weather for extreme event assessment. There is particular interest in development of models capable of delivering the probability of no SPE occurrence in a 24-hour time period, i.e., an "All-Clear" forecast.

Forecast techniques should utilize the historical record of archived SPEs to characterize model forecast validity in terms accepted metrics, i.e., skill score, false alarm rates, etc. Specific areas in which SBIR-developed technologies can contribute to NASA's overall mission requirements include the following:

Innovative forecasting solutions that leverage model development in other areas such as ensemble forecasting of hurricane tracks, flooding, financial market behavior, and earthquake prediction.

Innovative methods that integrate historical trending, real-time data, and fundamental physics-based models into advance warning and detection systems.

TOPIC: X12 Exploration Crew Health Capabilities

Human space flight is associated with losses in muscle strength, bone mineral density and aerobic capacity. Crewmembers returning from the International Space Station (ISS) can lose as much as 10-20% of their strength in weight bearing and postural muscles. Likewise, bone mineral density is decreased at a rate of ~1% per month. During future exploration missions such physiologic decrements represent the potential for a significant loss of human performance which could lead to mission failure and/or a threat to crewmember health and safety. NASA is conducting research to enhance and optimize exercise countermeasure hardware and protocols for these missions. In this solicitation, we are seeking portable technologies to collect foot ground reaction force data from current exercise hardware deployed on the International Space Station to be analyzed by research teams on the ground, as well as compact, low mass, low power, high life-cycle, force-generating components for application to future crew exercise concepts.

X12.01 Crew Exercise Systems
Lead Center: GRC
Participating Center(s): JSC

NASA seeks compact, low mass, low power, hi life-cycle, force-generating components for application to future crew exercise equipment – capable of providing aerobic and resistive (>700 lbs) loads over a range of load increments of 5 lbs. for each load setting <100 lbs., of 10 lbs. for each load setting >100 lbs., and with adjustable stroke range up to 70 inches, while providing return: pull stroke load ratios of 0.9:1.0 or greater (e.g., 1.0:1.0 better, or 1.1:1.0 best) over the entire range of motion.

Phase I Deliverable: Fully developed concept complete with feasibility and top-level drawings/computational methodology as applicable. A breadboard or prototype system is highly desired.

X12.02 Portable Load Sensing Systems
Lead Center: GRC
Participating Center(s): JSC

NASA seeks a portable, force/load measurement system capable of being integrated into existing International Space Station (ISS) exercise systems. During long duration spaceflight, exercise countermeasures are prescribed to mitigate bone and muscle loss. However, advancement of these exercise prescriptions may require biomechanical analysis of exercise on orbit. Output parameters from the proposed device must operate in the bandwidth from 0-100Hz and be able to be synchronized with existing analog data systems. Vertical and shear forces are required and the portable system should be low-maintenance, durable, easy to set-up and calibrate, non-disruptive to exercise form (e.g., running, squat, dead lift, and calf raises), reliable, accurate (<1% error for static and dynamic loads), low mass, and require minimal power.

Phase I Deliverable: Fully developed concept complete with feasibility and top-level drawings/computational methodology as applicable. A breadboard or prototype system is highly desired.

TOPIC: X13 Exploration Medical Capability

Further human exploration of the solar system will present significant new challenges to crew health including hazards created by traversing the terrain of asteroids or planetary surfaces and the effects of variable gravity environments. The limited communications with ground-based personnel for diagnosis and consultation of medical events creates additional challenges. Providing health care capabilities for exploration missions will require the definition of new medical requirements and development of technologies to ensure the safety and success of Exploration missions, pre-, in-, and post-flight. This SBIR Topic addresses some key medical technology and gaps that NASA will need to solve in order to proceed with exploration missions.

X13.01 Smart Phone Driven Blood-Based Diagnostics
Lead Center: JSC
Participating Center(s): ARC

As user applications pervade the field of telemedicine, smart phones provide a robust, reconfigurable platform capable of communications, computations and various functions (i.e., imaging, video, power source, signal processing) that will continue to expand at an accelerated pace. By leveraging this technology, NASA seeks to exploit the smart phone for blood-based diagnostics to develop an analytical device that can determine basic metabolic (Chem8), blood gas (PaO_2, $PaCO_2$, SaO_2, HCO_3, pH), cardiac (troponin I, CK-MB, total cholesterol, HDL, LDL, VDL, triglyecerides and lipoproteins) and liver/renal (total bilirubin, direct bilirubin, ALP, ALT, AST) panels. These panels are representative of the operational and research requirements for space exploration related point of care diagnostics.

The diagnostic device must interface to a smart phone that will drive the device's electronics and/or optics; or use the built-in features of the phone to interrogate the diagnostic device. The described diagnostic component is to be no larger than the phone itself. The microfluidic device must also be reusable or extremely compact if disposable, and minimize reagent consumption. Other requirements to consider are analytical times in two minutes or less, strategies for operational capability up to 144 hours on battery power and a long shelf-life (> 36 months).

The Phase I effort will seek to demonstrate the feasibility of one diagnostic panel in the smart phone format. The Phase II effort will demonstrate at least two of the above stated panels in an analytical component that interfaces to a cell phone, and provides a path towards FDA approval or similar.

NASA Deliverable: Functional Diagnostic System

X13.02 Non-Wet Prep Electrodes
Lead Center: JSC
Participating Center(s): ARC

Although physiological monitoring has been conducted since the earliest human flights, there has not been substantial improvement in the technology of the sensors used in space since those early years. The current systems on the International Space Station (ISS) are still using wet-prep electrodes - which are time consuming and inconvenient, requiring shaving, application of electrodes, signal checks, and management of lead wires. Skin irritation sometimes develops from the electrode's interactions with roughened skin. And the signals are still subject to noise, corruption, and loss.

NASA desires a non-wet prep sensor system that:

- Is easy to don/doff (requires no shaving or skin prep), has no disposables, and can be worn comfortably for 48 hours.
- Maintains signal integrity at clinical quality (meets or exceeds ANSI/AAMI EC11 Standard for Diagnostic Electrocardiographic Devices) during rigorous exercise.
- Solutions that partially involve software (as opposed to strictly hardware) are acceptable, but any developed software code must be easily integrated into the ECG software system(s) used by NASA and not just into the given company's proprietary and/or standalone product.

NASA Deliverable: Functioning sensor system

TOPIC: X14 Behavioral Health and Performance

The Behavioral Health and Performance topic is interested in developing strategies, tools, and technologies to mitigate Behavioral Health and Performance risks. The Behavioral Health and Performance topic is seeking tools and technologies to prevent performance degradation, human errors, or failures during critical operations resulting from: fatigue or work overload; deterioration of morale and motivation; interpersonal conflicts or lack of team cohesion, coordination, and communication; team and individual decision-making; performance readiness factors (fatigue, cognition, and emotional readiness); and behavioral health disorders. For 2011, the Behavioral Health and Performance topic is interested in the following technologies: Virtual reality and world technologies for team training approaches.

X14.01 Virtual Reality and World Technologies for Team Training Approaches
Lead Center: JSC

This subtopic is to develop a virtual reality training environment to support pre-mission and just-in-time training for exploration crews and controllers. The training should encompass individual interactions with other team members as well as with the environment.

NASA wishes to identify how virtual reality and world technologies could be used to train crews and controllers on topics such as cross-cultural interactions, leadership, psychological support, and effective interactions with other team members or artificial intelligent agents while attempting to complete complicated, multi-agent (human or robotic) tasks.

The proposal should provide a framework describing:

- The virtual environment to be developed.
- Platform in which training will be experienced.
- How the training will allow the interaction with others (multi-player online or artificial intelligent agents), specific suggestions as to how to evaluate the training module's effectiveness and prediction of team performance and other important team outcomes and an assessment to determine the feasibility of the proposed training modules in the technical skill domains.

NASA Deliverables: Phase I deliverable should yield a proof of concept which includes both a literature review that encompasses an assessment of current knowledge of virtual reality technologies and its use in team training. In addition, the following deliverables will be required:

- A requirements document for such a training module.
- An evaluation plan for assessing the effectiveness of the training module on team outcomes.

The subsequent Phase II deliverable would provide a prototype of specific training modules that can demonstrate improved team performance (including task performance metrics) by utilizing these training technologies.

TOPIC: X15 Space Human Factors and Food Systems

The emphasis on developing new, innovative technologies to enable future space exploration encompasses a need for new approaches in the areas of Space Human Factors and Food Systems. Operations in confined, isolated, and resource-constrained environments can lead to suboptimal human performance. Research and development activities in this topic address challenges that are fundamental to design, development, and operation of the next generation crewed space vehicles. These challenges include:

- Development of a software tool that automatically processes crew motion and interaction, either on orbit or on the ground, from video footage taken with a single conventional 2D camera to enable unobtrusive and non-invasive measurement of task performance and crew behavioral health.
- A need to develop a technology or system capable to prevent vitamin degradation of naturally-occurring and supplemented vitamins within a food substrate stored at ambient temperatures for five years. (http://humanresearchroadmap.nasa.gov/evidence/, http://www.nasa.gov/centers/johnson/slsd/about/divisions/hefd/index.html)

X15.01 A New Technique for Automated Analyses of Raw Operational Videos
Lead Center: JSC
Participating Center(s): ARC

Develop a software tool that automatically processes raw motion video footage (from a single conventional 2D camera) of a crew (spacecraft or ground) during a space mission.

Such a tool is needed to address vehicle/habitat design issues, as well as crew-to-crew interaction issues, on the ground. For example, unprocessed space mission operational videos down linked from a spacecraft that involve humans as the subjects of interest need to be analyzed on the ground for their motion and behavioral health information.

Requirements:

- The raw video data shall be video footages from a single conventional 2D camera and with no special lighting or fiduciary markers.
- The processed data shall contain the subjects' geometric information (position, movement, acceleration) relative to their operational environment and crewmates.
- A "tool chest" shall be available for visualization aids, velocity computations, etc. For visualization aids, the tool chest shall enable the user to specify areas or actions of interest. The software shall then locate, mark, count, etc. to indicate how many times the crew accessed a piece of hardware, traversed a path, reached above their heads, etc.

Desirable: 3D information extraction - ability to extract 3D information from the raw video to enable high-precision human motion analyses using the software's tool chest.

Phase I Deliverable: Algorithm

Phase II Deliverable: Functional software prototype

X15.02 Advanced Food Technologies
Lead Center: JSC

The purpose of the NASA Advanced Food Technology Project is to develop, evaluate and deliver food technologies for human centered spacecraft that will support crews on long duration missions beyond low-Earth orbit. Safe, nutritious, acceptable, and varied shelf-stable foods with a shelf life of 3 - 5 years will be required to support the crew during these exploration missions. Concurrently, the food system must efficiently balance appropriate vehicle resources such as mass, volume, water, air, waste, power, and crew time.

Refrigeration and freezing require dispensable resource utilization, so NASA provisions consist solely of shelf stable foods. Stability is achieved by thermal or irradiative processing to kill the microorganisms in the food or drying to prevent viability of the microorganisms. These methods do impact the micronutrients within the food substrate. Environmental factors (such as moisture ingress and oxidation) are also capable of compromising the nutrient content over the shelf life of the food. Since the food system is the designated source of nutrition to the crew, a significant loss in nutrient availability could significantly jeopardize the health and performance of the crew. Optimal nutritional content of the food for up to five years will ensure that the food can support crew performance and help protect their bodies from deficiencies that cause disease.

Vitamin content in NASA foods, such as Vitamin C, Vitamin A, thiamin, and folic acid, is degraded during processing and as the product ages in storage. The goal is to develop a system that protects the vitamins from this degradation at ambient temperatures over a five year duration. Possible technologies that could be investigated to protect food ingredients from biological and chemical degradation of components over time include nanoscale technologies (e.g., encapsulation), biosensors, novel food ingredients, and controlled-release systems. Technologies or systems that could aid in increasing the bioavailability of the nutrients should also be considered.

Phase I Requirements: Phase I should concentrate on the scientific, technical, and commercial merit and feasibility of the proposed innovation resulting in a feasibility report and concept, complete with analyses.

NASA Deliverable: A system which will result in higher nutrient content in shelf stable foods.

TOPIC: X16 Space Radiation

The goal of the NASA Space Radiation Research Program is to assure that we can safely live and work in the space radiation environment, anywhere, any time. Space radiation is different from forms of radiation encountered on Earth. Radiation in space consists of high-energy protons, heavy ions and secondary products created when the protons and heavy ions interact with matter such as a spacecraft, surface of a planet, moon, asteroid, or even the astronauts themselves. NASA requires instruments that can reliably measure these radiations. NASA has a need for compact active radiation detection systems that can meet stringent size, power, and performance requirements. These include real-time personal monitors and area monitors that can be used on the International Space Station (ISS) as well as on future missions beyond low-Earth orbit (LEO). Ending the Space Shuttle program will increase the need to replace the current passive monitoring technologies on the ISS with active ones to reduce up and down mass. Also, as missions extend beyond LEO there will be further premium on reduced size, mass, and power for radiation detection technologies. To achieve such reductions, there will be an increasing need for reliable miniaturized components such as sensors, photomultipliers, data processors, power supplies, and the like that can be used to enhance radiation detection technologies as they develop. Advanced technologies up to technology readiness level (TRL) 4 are requested in these and related areas.

X16.01 Radiation Measurement Technologies
Lead Center: ARC

NASA has a need for compact active radiation detection systems that can meet stringent size, power, and performance requirements. These include real-time personal monitors and area monitors that can be used on the ISS as well as on future missions beyond LEO. Ending the Space Shuttle program will increase the need to replace the current passive monitoring technologies on the ISS with active ones to reduce up and down mass. Also, as missions extend beyond LEO there will be further premium on reduced size, mass, and power for radiation detection technologies. To achieve such reductions, there will be an increasing need for reliable miniaturized components such as sensors, photomultipliers, data processors, power supplies, and the like that can be used to enhance radiation detection technologies as they develop. Advanced technologies up to technology readiness level (TRL) 4 are requested in these and related areas useful to NASA. Also, such advances would likely have potential customers outside NASA and in the commercial sector.

Metric and desired performance range:

Personal Monitors
Sensitive to charged particles with LET of 0.2 to 500 keV/µm and detect charged particles (including protons) with energies 30 MeV/n to 1000 MeV/n. Design goals for mass should be 0.25 kg and for volume, 250 cm^3. The monitor should be able to measure dose rate and dose-equivalent rate at both ambient conditions in space (0.01 mGy/hr) and during a large solar particle event (100 mGy/hr). Total power requirement should be in the 1 W range. Monitors shall perform data reduction internally and display dosimetry data in real time.

Area Monitors
Same as Personal Monitors but extend LET to 1000 keV/µm and must also detect neutrons between 0.5 MeV and 150 MeV. Design goals for mass should be 1 kg and for volume should be 1000 cm^3. Total power requirement should be less than 2 W. Monitors shall perform data reduction internally and display dosimetry data in real time.

Components
These may include but are not limited to compact sensors with excellent response to space radiation (e.g., novel scintillation crystals, organic semiconductors, photodiodes), compact low-noise solid state photomultipliers that require less than 0.5 W of power, data processors not to exceed 0.2 W that can perform multi-channel analysis, low noise power supplies that require less than 0.3 W of power.

Phase I Deliverables: Proof of concept of the technologies requested.

Phase II Deliverables: Prototypes or components of the monitoring technologies meeting the requirements indicated.

TOPIC: X17 Inflight Biological Sample Preservation and Analysis

The Human Research Program (HRP) is an applied research and technology program aimed at providing human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. HRP's specific objectives include development of technologies that serve to reduce human systems resource requirements, such as mass, volume, and power to maximize utilization of spaceflight platforms to perform the essential research and technology development tasks that can only be accomplished during a space mission. Addressing multiple HRP human health and performance risks and knowledge gaps across various disciplines requires collection, preservation and analysis of biological samples from human subjects during a space mission, a common practice in clinical diagnostic medicine. However, the spaceflight environment affords unique challenges for the processing, storage and transport of biological specimens, due to highly constrained resources, such as limited conditioned stowage (mass and volume requiring storage in refrigerators or freezers) available. This topic aims to mitigate those space mission constraints by means of innovative approaches for the collection, long duration ambient temperature preservation, and low-resource small-footprint in situ analysis of human biospecimens, such as blood and urine, for a wide array of biomedically significant analytes.

X17.01 Alternative Methods for Ambient Preservation of Human Biological Samples During Extended Spaceflight and Planetary Operations
Lead Center: JSC

Addressing multiple Human Research Program (HRP) human health and performance risks and knowledge gaps across various disciplines requires collection, preservation and analysis of biological samples from human subjects during a space mission, a common practice in clinical diagnostic medicine. However, the spaceflight environment affords unique challenges for the processing, storage and transport of biological specimens, due to highly constrained resources, such as very limited conditioned stowage (mass and volume requiring storage in refrigerators or freezers) to keep and return the biospecimens. This subtopic aims to mitigate those space mission constraints by means of innovative approaches for the long duration ambient temperature preservation of human biological samples, particularly blood and urine, while maintaining the integrity of a wide array of biomedically significant molecular markers for subsequent post-mission processing and analysis.

This subtopic seeks proposals for novel approaches to preserve analytes of clinical and research interest in human blood and urine samples for a minimum of one year at ambient temperature. Target blood analytes to be preserved include those in the Comprehensive Metabolic Panel: glucose, calcium, albumin, total protein, electrolytes (sodium, potassium, bicarbonate, chloride), kidney tests (blood urea nitrogen, creatinine), and liver tests (bilirubin, alkaline phosphatase, alanine amino transferase, aspartate amino transferase). Additional blood markers to be preserved include N-telopeptide, sulfate, highly specific C-reactive protein, tumor necrosis factor, interleukin-1, interleukin-6, 8-hydroxy-2-deoxy-guanosine, vitamin D, homocysteine, and selenium. For urine samples, the following analytes should be preserved: creatinine, cortisol, N- and C-telopeptides, hydroxyproline, 4-pyridoxic acid, 3-methylhistidine, G-carboxyglutamic acid, 8-hydroxy-2-deoxy-guanosine, uric acid, phosphorus, citrate, sulfate, oxalate, calcium, sodium, potassium, magnesium, and chloride. The proposed technology should be low-resource, low-footprint, and should involve a low volume of supplies/consumables, which do not require refrigeration or freezing for storage.

NASA Deliverable: Prototype functional system for long duration room temperature preservation of human blood and/or urine biospecimens, demonstrating integrity for a subset of the target analytes (in Phase I).

9.1.3 SCIENCE

NASA leads the nation on a great journey of discovery, seeking new knowledge and understanding of our planet Earth, our Sun and solar system, and the universe out to its farthest reaches and back to its earliest moments of existence. NASA's Science Mission Directorate (SMD) and the nation's science community use space observatories to conduct scientific studies of the Earth from space, to visit and return samples from other bodies in the solar system, and to peer out into our Galaxy and beyond.

NASA's science program seeks answers to profound questions that touch us all:

- How are Earth's climate and the environment changing?
- How and why does the Sun vary and affect Earth and the rest of the solar system?
- How do planets and life originate?
- How does the universe work, and what are the origin and destiny of the universe?
- Are we alone?

For more information on SMD, visit: http://science.nasa.gov/.

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TOPIC: S1 Sensors, Detectors and Instruments

NASA's Science Mission Directorate (SMD) (http://nasascience.nasa.gov/) encompasses research in the areas of Astrophysics (http://nasascience.nasa.gov/astrophysics/), Earth Science (http://nasascience.nasa.gov/earth-science/), Heliophysics (http://nasascience.nasa.gov/heliophysics/), and Planetary Science (http://nasascience.nasa.gov/planetary-science/). A major objective of SMD instrument development programs is to implement science measurement capabilities with smaller or more affordable spacecraft so development programs can meet multiple mission needs and therefore make the best use of limited resources. The rapid development of small, low-cost remote sensing and in situ instruments is essential to achieving this objective. For Earth Science needs, in particular, the subtopics reflect a focus on instrument development for airborne and Unmanned Aerial Vehicle (UAV) platforms. Astrophysics has a critical need for sensitive detector arrays with imaging, spectroscopy, and polarimetric capabilities, which can be demonstrated on ground, airborne, balloon, or suborbital rocket instruments. Heliophysics, which focuses on measurements of the sun and its interaction with the Earth and the other planets in the solar system, needs a significant reduction in the size, mass, power, and cost for instruments to fly on smaller spacecraft. Planetary Science has a critical need for miniaturized instruments with in situ sensors that can be deployed on surface landers, rovers, and airborne platforms. For planetary missions, planetary protection requirements vary by planetary destination, and additional backward contamination requirements apply to hardware with the potential to return to Earth (e.g., as part of a sample return mission). Technologies intended for use at/around Mars, Europa (Jupiter), and Enceladus (Saturn) must be developed so as to ensure compliance with relevant planetary protection requirements. Constraints could include surface cleaning with alcohol or water, and/or sterilization treatments such as dry heat (approved specification in NPR 8020.12; exposure of hours at 115C or higher, non-functioning); penetrating radiation (requirements not yet established); or vapor-phase hydrogen peroxide (specification pending). For the 2011 program year, we are encouraging proposals for two new subtopics, S1.10 for technologies in support of atomic interferometry to enable precise targeting, pointing, and tracking and S1.11 for technologies in support of the specific needs of planetary orbital remote sensing instruments. A key objective of this SBIR topic is to develop and demonstrate instrument component and subsystem technologies that reduce the risk, cost, size, and development time of SMD observing instruments and to enable new measurements. Proposals are sought for development components that can be used in planned missions or a current technology program. Research should be conducted to demonstrate feasibility during Phase I and show a path towards a Phase II prototype demonstration. The following subtopics are concomitant with these objectives and are organized by technology.

S1.01 Lidar and Laser System Components
Lead Center: LaRC
Participating Center(s): GSFC, JPL

Accurate measurements of atmospheric parameters with high spatial resolution from ground, airborne, and space-based platforms require advances in the state-of-the-art lidar technology with emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar component technologies that directly address the measurements of the atmosphere and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Frequency-stabilized lasers for a number of lidar applications such as CO_2 concentration measurements as well as for highly accurate measurements of the distance between spacecraft for gravitational wave astronomy and gravitational field planetary science are among technologies of interest. Single longitudinal mode lasers and optical filter technologies for high spectral resolution lidars are also of interest. Proposals relevant to the development of components that can be used in planned missions or current technology programs are highly encouraged. Examples of planned missions and technology programs are: Laser Interferometer Space Antenna (LISA), Doppler Wind Lidar, Lidar for Surface Topography (LIST), Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS), and Aerosols-Clouds-Ecosystems (ACE). In addition, innovative technologies relevant to the NASA sub-orbital programs, such as Unmanned Aircraft Systems (UAS) and Venture-class focusing on the studies of the Earth climate, carbon cycle, weather, and atmospheric composition, are being sought.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II prototype demonstration. For the PY11 SBIR Program, we are soliciting only the specific component technologies described below:

- Highly efficient solid state laser transmitter operating in the 1.0 µm – 1.7 µm range with wall-plug efficiency of greater than 25%. The proposed laser must show path in maturing to space applications. The laser transmitter must be capable of single frequency with narrow spectral width capable of generating transform-limited pulses, and M2 beam quality < 1.5. We are interested in two different regimes of repetition rate and output energy: in one case, repetition rate from 5 kHz to 20 kHz with pulse energy from 2 - 10 mJ, and in the second case, repetition rate 20 Hz to 2 kHz with pulse energy from 30 - 300 mJ. In addition, development of non-traditional optical amplifier architectures that yield optical efficiency of >70% are of interest. Although amplifiers such as planar waveguide or grazing incidence have been shown to generate optical efficiencies >50%, much higher efficiency is needed for space applications. Proposed solutions should incorporate electronics packages suitable for use in aircraft demonstration (i.e., small, well packaged, low power).
- Narrow linewidth laser transmitters and receiver components (seeds, fiber amplifiers, modulators, drivers, etc.) supporting laser absorption spectroscopy applications in the 1.3, 1.5 and 2.0 micron wavelength regimes. The lasers and components should be tunable by several nm, support amplitude modulation at frequencies from 50 KHz to 10 MHz, have frequency stability of less than 3 MHz, and be capable of mixing and simultaneous transmission of multiple lines for differential absorption measurements without introducing non-linear mixing effects. Techniques for cloud and aerosol discrimination are also sought.
- Efficient and compact single mode solid state or fiber lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for direct detection differential absorption lidar (DIAL) and coherent lidar applications. These lasers must meet the following general requirements: pulse energy 0.5 mJ to 50 mJ, repetition rate 10 Hz to 10 kHz, and pulse duration of either 10 nsec or 200 nsec regimes.
- Low noise detectors operating in 1.5 to 2.0 micron wavelength for use in differential absorption lidar (DIAL) instruments measuring CO_2 concentration. Large area (>250 micron dia.) detectors with high quantum efficiency (>75%), noise equivalent power of less than 2x 10-14 W/Hz1/2, and bandwidth greater than 50 MHZ are being sought. Additionally, arrays of 4x4 PIN detectors for coherent detection and avalanche photodiodes with a minimum gain of 10 are of interest. Other detectors relevant to NASA programs are low-noise, high quantum efficiency devices operating at 355 nm, 532 nm, and 1064 nm with gain greater than or equal to 100. These detectors must be linear or correctable for incident power levels ranging from 0.1 pW to 50 nW and have bandwidths exceeding 200 MHz with excellent transient recovery.
- Novel compact solid-state UV laser for Ozone DIAL measurements from surface and airborne UAS science platforms that also enables technology demonstrations for future spaceborne measurements are needed. New and novel technology developments that enable solid-state UV lasers operating within the 280 nm - 320 nm wavelength range (305-320 nm for the spaceborne lasers) generating laser pulses of up to 1 KHz rate and average output power greater than 1 Watt. Operation at two distinct wavelengths separated by 10 nm to 15 nm is required for the Ozone measurements. Scalability of the laser design to power levels greater than 10 W for space deployment is important.
- Novel scanning telescope capable of scanning over 360 degrees in azimuth with nadir angle fixed in the range of 30 to 45 degrees. Clear apertures scalable to 1 m, good optical performance (although diffraction limited performance is not necessary), and high optical efficiency are desired, as is ability to operate at multiple wavelengths from 1064 nm to 355 nm. Optical materials (e.g., substrates and coatings) and components should be space qualifiable. Phase II should result in a prototype unit capable of demonstration in a high-altitude aircraft environment, with aperture on the order 8 inches. Due to issues with spacecraft momentum compensation and previous investments, concepts for large articulating telescopes will not be considered responsive to this request, nor will holographic substrates.
- Flash Lidar Receiver for planetary landing application with at least 128X128 pixels capable of generating 3-dimensional images and detection of hazardous terrain features, such a as rocks, craters and steep slopes from at least 1 km distance. The receiver must include real-time image processing capability with 30 Hz frame rate. Embedded image enhancement and classification algorithms are highly desirable. Proposals

for low noise Avalanche Photodiode (APD) arrays with 256x256 pixels format suitable for use in Flash Lidar receiver will be also considered. The detector array must operate in the 1.06 to 1.57 micron region and be able to detect laser pulses with 6 nsec in duration. The array needs to achieve greater than 90% fill factor with a pitch size of 50 to 100 microns with provisions for hybridization with an Integrated Readout Circuit (ROIC).

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S1.02 Active Microwave Technologies
Lead Center: JPL
Participating Center(s): GSFC, LaRC

NASA employs active sensors (radars) for a wide range of remote sensing applications (for example, see: http://www.nap.edu/catalog/11820.html). These sensors include low frequency (less than 10 MHz) sounders to G-band (160 GHz) radars for measuring precipitation and clouds and for planetary landing. We are seeking proposals for the development of innovative technologies to support future radar missions and applications. The areas of interest for this call are listed below:

Low-Loss, Dual-Polarized W-band Radiator Array With MMIC Integration

- Frequency: 94 GHz.
- Radiation Efficiency: >70%.
- Polarization isolation = 25 dB.
- Interconnect loss: <0.05 dB.
- No dielectric materials.

These radiator and interconnect technologies are critical to achieving the density and RF signal performance required for scanning millimeter-wave array radars.

High Performance W-band Millimeter-wave Transmit/Receive MMICs

- Frequency: 94 GHz.
- Transmit Power: >1W, TX PAE: >25%.
- TX Gain >20 dB.
- RX NF: <4 dB.
- RX Gain: > 20 dB.
- RX input power tolerance >250mW
- Monolithic integration of TR function is required to meet space constraints for high-density arrays and to reduce assembly costs.

Low-Cost mm-wave Beamforming MMIC Receiver

- Frequencies: 35.6, 94 GHz.
- Input Channels: 16.
- Phase shifter: 360 deg.
- 5-bits, Output IF: 1 channel @ < 2 GHz.
- Bandwidth: >100 MHz.
- Serial phase update rate: >10kHz for all channels.

Millimeter-wave phased arrays require integration of a large number of phase shifters in a small space, leading to impossible interconnect requirements. Integrating many channels vastly reduces the number of interconnects required, achieving the needed array density.

High-Speed Radar Distributed Target Simulator

Given model inputs of radar parameters, radar/target geometries and distributed target properties, generates simulated radar echo signals. For some missions, a single scene would take approximately a year to simulate on a single processor and global simulations are not feasible. It is critical to reduce simulation time for global validation of on-board processor. The simulator should be able to produce and store simulated returns for a product of 40 billion targets and pulses per second.

Low-Jitter Programmable Delay/Divide Clock Distribution IC

- Total Jitter: <15.
- Fanout: >=10.
- Prog. Delay: up to 192 ns.
- Delay Resolution: 2 ps.
- Divide by: 2 or 3.
- Temp. range: -40 to +80C.
- Implemented in radiation-hard technology.

This part is critical to high-speed real-time digital beamforming and processing required for next generation of Earth and space based high-resolution sensors.

L-band Array Antennas

- Compact, lightweight arrays (< 7 kg/m^2) with 50 – 60% bandwidth using electronic frequency hopping and tuning capabilities.
- Dual-polarization.
- High polarization isolation (> 25 dB) for airborne and spaceborne radar applications.

High Power, High Speed RF Switch

- W-band (94 GHz).
- Ka-band (35GHz).
- Low loss (< 0.5 dB).
- High speed (transition time < 500 ns) switch for radar front end.
- Peak power >= 1.5 kW.
- Average power >= 75 W.
- Isolation >= 25 dB.

Fast Turn on and Turn Off Power Amplifiers

To increase solid state radar sensitivity NASA requires compact and high efficiency (> 50%) power amplifiers (> 25 W peak.) in P, L, and X-bands that can be switched off during the receive period to prevent noise leakage. Switch on and switch off times under 1 μs, stable amplitude (< 0.1dB) and phase (< 1º) are required.

Small Radar Packaging Concepts for Unmanned Aerial Systems (UAV)

Miniaturization of radar and radiometer components while maintaining power and performance is a requirement for UAV science. Seeking high isolation switched filters and phase shifters for interleaved radar/radiometer operation at multiple channels, LNAs, stable noise sources, circulators, and solid-state power amplifiers for operation at L-, C-X-, and Ku-Bands.

Real Time Adaptive Waveform-Agile Radars for Very Weak Targets Detection in Strong Clutter/Noise Environment for Remote Sensing

NASA seeks novel ideas in advancing software and hardware technology of real time adaptive waveform-agile radars for detection and exploration of weak targets hidden behind strong targets (such as sub-surface planetary surfaces). -25 dB signal-to-clutter, range resolution < 10 m. Frequency Range: 3 MHz-100MHz, L-band

S1.03 Passive Microwave Technologies
Lead Center: GSFC
Participating Center(s): JPL

NASA employs passive microwave and millimeter-wave instruments for a wide range of remote sensing applications from measurements of the Earth's surface and atmosphere (http://www.nap.edu/catalog.php?record_id=11820) to cosmic background emission. Proposals are sought for the development of innovative technology to support future science and exploration missions employing 450 MHz to 5 THz sensors. Technology innovations should either enhance measurement capabilities (e.g., improve spatial, temporal, or spectral resolution, or improve calibration accuracy) or ease implementation in spaceborne missions (e.g., reduce size, weight, or power, improve reliability, or lower cost). While other concepts will be entertained, specific technology innovations of interest are listed below for missions including decadal survey missions (http://www.nap.edu/catalog/11820.html) such as PATH, SCLP, and GACM and the Beyond Einstein Inflation Probe (Inflation Probe - cosmic microwave background, http://science.gsfc.nasa.gov/660/research/):

- High emissivity (>40 dB return loss) surfaces/structures for use as onboard calibration targets that will reduce the weight of aluminum core targets, while reliably improving the uniformity and knowledge of the calibration target temperature. Earth Science Decadal survey missions which apply: SCLP and PATH.
- Room temperature LNAs for 165 to 193 GHz with low 1/f noise, and a noise figure of 6.0 dB or better; and cryogenic LNAs for 180 to 270 GHz with noise temperatures of less than 150K. Earth Science Decadal Survey missions that apply: PATH, GACM and future Earth Venture Class low cost millimeter wave instruments.
- Low noise amplifiers, MMIC or discrete transistor, at frequencies below 2 GHz, operating at room temperature or thermoelectrically cooled, and giving noise figures below 0.25 dB (17K noise temperature). Amplifier should have S11 < -10dB, S21>25 dB, over an octave band, and be stable for any generator impedance at any frequency. For highly red shifted hydrogen spectroscopy for early universe cosmology.
- Local Oscillator technologies for 2nd generation instruments for SOFIA, next generation HIFI, and suborbital instruments (GUSSTO). This can include: GaN based frequency multipliers that can work in the 200-400 GHz range (output frequency) with input powers up to 1 W. Graphene based devices that can work as frequency multipliers in the frequency range of 1-3 THz.
- Enabling technology for ultra-stable microwave noise references (three or more) embedded in switched network with reference stability (after temperature correction) to within 0.01K/year. Applies to: PATH, SCLP, GACM, SWOT.
- RFI mitigation approaches employing channelizers for broadband (>100MHz) radiometers at frequencies between 1 and 40 GHz. These systems should demonstrate both detection and removal approaches for mitigating RFI. Earth Science Decadal Survey missions that apply: SCLP, SWOT.
- Multi-Frequency and/or multi-Beam Focal Plane Arrays (FPA) as a primary feed for reflector antennas. Earth Science Decadal Survey missions that apply: PATH, SCLP, SWOT.
- In addition to the technologies listed above, proposals for innovative passive microwave instruments for a wide range of remote sensing applications from measurements of the Earth's surface and atmosphere to cosmic background emission would also be welcome.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S1.04 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter
Lead Center: JPL
Participating Center(s): ARC, GSFC, KSC, LaRC

NASA is seeking new technologies or improvements to existing technologies to meet the detector needs of future missions, as described in the most recent decadal surveys for Earth science (http://www.nap.edu/catalog/11820.html), planetary science (http://www.nap.edu/catalog/10432.html), and astronomy and astrophysics (http://www.nap.edu/books/0309070317/html/).

The following technologies are of interest for the Scanning Microwave Limb Sounder (http://mls.jpl.nasa.gov/index-cameo.php) on the Global Atmospheric Composition Mission, Single Aperture Far Infrared (SAFIR) Observatory (http://safir.jpl.nasa.gov/technologies.shtml), the SOFIA (Stratospheric Observatory for Infrared Astronomy) airborne observatory (http://www.sofia.usra.edu/), and Inflation Probe (cosmic microwave background, http://science.gsfc.nasa.gov/660/research/):

- Radiation tolerant digital polyphase filterbank back ends for sideband separating microwave spectrometers. Requirements are >5GHz instantaneous bandwidth per sideband, 2 MHz resolution, low power (<5 W/GHz), and 4 bits or higher digitization.
- Improved submillimeter mixers for frequencies >2 THz are needed for heterodyne receivers to fly on SOFIA. Minimum noise temperatures for cyrogenic operation and instantaneous bandwidths >5 GHz are key parameters.
- Large format (megapixel) broadband detector arrays in the 30 to 300 micron wavelength range are needed for SAFIR. These should offer background limited operation with cooled (5 K) telescope optics, and have minimal power dissipation at low temperatures. Low power frequency multiplexers are also of interest for readout of submm bolometer arrays for SAFIR and Inflation Probe.

High performance sensors and detectors that can operate with low noise under the severe radiation environment (high-energy electrons, =1 megarad total dose) anticipated during the Europa Jupiter System Mission (EJSM) are of interest (see the Jupiter Europa Orbiter Mission Study 2008: Final Report, http://opfm.jpl.nasa.gov/library/). Notional instruments include visible and infrared cameras and spectrometers, a thermal imager and laser altimeter. Devices can be radiation hardened by design and/or process:

- Hardened visible imaging arrays with low dark currents even in harsh radiation environments, line or framing arrays suitable for use in pushbroom and framing cameras. Detectors include CCDs (n or p-channel), CMOS imagers, PIN photodiode hybrids, etc.
- Hardened infrared imaging arrays with a spectral range of 400 to 5000 nm with high quantum efficiency and low dark current, as well as compatible radiation hardened CMOS readouts. These devices could include substrate removed HgCdTe hybrid focal plane arrays responsive from 400 to 2500 nm and IR only focal plane arrays responsive from 2500 nm to 5000 nm.
- High-speed radiation hardened avalanche photodiodes that respond to a 1.06 micron laser beam suitable for use in time of flight laser rangefinders. Devices should have high and stable gain with lower dark current in harsh radiation environments.
- Radiation hardened detectors suitable for use in uncooled thermal imagers that respond to spectral bands ranging from 8 to 100 microns. Detectors could include thermopile or microbolometer small line arrays.

Technologies are needed for active and passive wave front and amplitude control, and relevant missions include Extra solar Planetary Imaging Coronagraph (EPIC), and other coronagraphic missions such as Terrestrial Planet Finder (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) and Stellar Imager (http://hires.gsfc.nasa.gov/si/):

- Spatial Filter Array (SFA) consisting of a monolithic array of up to 1200 coherent, polarization preserving, single mode fibers, or custom waveguides, that operate with minimal coupling losses over a large fraction of the spectral range from 0.4 - 1.0 microns. The SFA should have input and output lenslet with each pair mapped to a single fiber or waveguide and such that the lenslets maintain path length uniformity to < 100 nm. Uniformity of both output intensity and wave front phase, and high throughput is desired and fiber-to-fiber placement accuracies of < 1.0 microns are required with < 0.5 microns desired.
- MEMS based segmented deformable mirrors consisting of arrays of up to 1200 hexagonal packed segments with strokes over the range of 0 to 1.0 microns, quantized with 16-bit electronics with segment level

stabilities of 0.015 nm rms (1-bit) over 1 hour intervals. Segments should be flat to 2 nm rms or better and the substrate flat to 125 nm or better and high uniformity of coatings (1% rms).

Thermal imaging, LANDSAT, all IR Earth observing missions:

- Development of uncooled or passively cooled detectors with NEΔT<20mK and QE>30% in the 6-14 µm infrared wavelength region. Formats ~ 640 x 512 with a goal to exceed 3,000 pixel linear dimension. Also, work in promising new technologies such as InAs/GaSb type-II strain layer superlattices.

The Geo-CAPE Mission

Wide Field 0.26-15um and Narrow Field 0.35-2.1µm. PanFTS 60µm pixel pitch, 256 X 256 format with in-pixel ADC digitization ROIC, 16-bit precision, 16kHz frame rate.

S1.05 Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments
Lead Center: GSFC
Participating Center(s): JPL, MSFC

This subtopic covers detector requirements for a broad range of wavelengths from UV through to gamma ray for applications in Astrophysics, Earth science, Heliophysics, and Planetary science. Requirements across the board are for greater numbers of readout pixels, lower power, faster readout rates, greater quantum efficiency, and enhanced energy resolution.

The proposed efforts must be directly linked to a requirement for a NASA mission. These include Explorers, Discovery, Cosmic Origins, Physics of the Cosmos, Vision Missions, and Earth Science Decadal Survey missions. Details of these can be found at the following URLs:

- General Information on Future NASA Missions: http://www.nasa.gov/missions
- Specific mission pages: IXO: http://htxs.gsfc.nasa.gov/index.html, future planet ary programs: http://nasascience.nasa.gov/planetary-science/mission_list, Earth Science Decadal missions: http://www.nap.edu/catalog/11820.html.
- Helio Probes: http://nasascience.nasa.gov/heliophysics/mission_list.

Specific technology areas are listed below:

- Significant improvement in wide band gap semiconductor materials, such as AlGaN, ZnMgO and SiC, individual detectors, and detector arrays for operation at room temperature or higher for missions such as Geo-CAPE, NWO, ATALAST and planetary science composition measurements.
- Highly integrated, low noise (< 300 electrons rms with interconnects), low power (< 100 uW/channel) mixed signal ASIC readout electronics as well as charge amplifier ASIC readouts with tunable capacitive inputs to match detector pixel capacitance. See needs of National Research Council's Earth Science Decadal Survey (NRC, 2007): Future Missions include GEOCape, HyspIRI, GACM, future GOES and SOHO programs and planetary science composition measurements.
- Large format UV and X-ray focal plane detector arrays: micro-channel plates, CCDs, and active pixel sensors (>50% QE, 100 Megapixels, <0.1 W/Megapixel, 30 Hz). Improved micro-channel plate detectors, including improvements to the plates themselves (smaller pores, greater lifetimes, lower ion feedback alternative fabrication technologies, e.g., silicon), as well as improvements to the associated electronic readout systems (spatial resolution, signal-to-noise capability, and dynamic range), and in sealed tube fabrication yield. Possible future mission applications are the International X-ray Observatory and Advanced Technology Large Aperture Space Telescope (ATLAST).
- Advanced Charged Couple Device (CCD) detectors, including improvements in UV quantum efficiency and read noise, to increase the limiting sensitivity in long exposures and improved radiation tolerance.

Electron-bombarded CCD and CMOS detectors, including improvements in efficiency, resolution, and global and local count rate capability. In the X-ray, we seek to extend the response to lower energies in some CCDs, and to higher, perhaps up to 50 keV, in others. Possible missions are future GOES missions and International X-ray Observatory.

- Wide band gap semiconductor, radiation hard, visible and solar blind large format imagers for next generation hyperspectral Earth remote sensing experiments. Need larger formats (>1Kx1K), much higher resolution (<18µm pixel size), high fill factor and low read noise (<60 electrons). See needs of National Research Council's Earth Science Decadal Survey (NRC, 2007): Future missions include GEOCape, HyspIRI, GACM.
- Solar blind, compact, low-noise, radiation hard, EUV and soft X-ray detectors are required. Both single pixels (up to 1cm x 1cm) and large format 1D and 2D arrays are required to span the 0.05nm to 150nm spectral wavelength range. Future GOES missions post-GOES R and T.
- Visible-blind SiC Avalanche Photodiodes (APDs) for EUV photon counting are required. The APDs must show a linear mode gain >1E6 at a breakdown reverse voltage between 80 and 100V. The APD's must demonstrate detection capability of better than 6 photons/pixel/s at near 135nm spectral wavelength. See needs of National Research Council's Earth Science Decadal Survey (NRC, 2007): Tropospheric ozone.
- Imaging from low-Earth orbit of air fluorescence, UV light generated by giant air showers by ultra-high energy (E >10E19 eV) cosmic rays require the development of high sensitivity and efficiency detection of 300-400 nm UV photons to measure signals at the few photon (single photo-electron) level. A secondary goal minimizes the sensitivity to photons with a wavelength greater than 400 nm. High electronic gain (~106), low noise, fast time response (<10 ns), minimal dead time (<5% dead time at 10 ns response time), high segmentation with low dead area (<20% nominal, <5% goal), and the ability to tailor pixel size to match that dictated by the imaging optics. Optical designs under consideration dictate a pixel size ranging from approximately 2 x 2 mm^2 to 10 x 10 mm^2. Focal plane mass must be minimized (2 g/cm^2 goal). Individual pixel readout is required. The entire focal plane detector can be formed from smaller, individual sub-arrays.
- Large area (3 m^2) photon counting near-UV detectors with 3 mm pixels and able to count at 10 MHz. Array with high active area fraction (>85%), 0.5 Megapixels and readout less than 1 mW/channel. Future instruments are JEM-EUSO and OWL.
- Large area (m^2) X-ray detectors with <1mm pixels and high active area fraction (>85%).
- Improve beyond CdZnTe detectors using micro-calorimeter arrays at hard X-ray, low gamma-ray bands (above 10 keV and Below 80 keV).
- Improvement of spatial resolution for the hard x-ray band up to 10 and ultimately to 5 arcsecond resolution.

Future instrument is a Phased-Fresnel X-ray Imager.

S1.06 Particles and Field Sensors and Instrument Enabling Technologies
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC, MSFC

Advanced sensors for the detection of elementary particles (atoms, molecules and their ions) and electric and magnetic fields in space and associated instrument technologies are often critical for enabling transformational science from the study of the sun's outer corona, to the solar wind, to the trapped radiation in Earth's and other planetary magnetic fields, and to the atmospheric composition of the planets and their moons. Improvements in particles and fields sensors and associated instrument technologies enable further scientific advancement for upcoming NASA missions such as Solar Orbiter, Solar Probe Plus, ONEP, SEPAT, INCA, CISR, DGC, HMag and planetary exploration missions. Technology developments that result in a reduction in size, mass, power, and cost will enable these missions to proceed. Of interest are advanced magnetometers, electric field booms, ion/atom/molecule detectors, and associated support electronics and materials. Specific areas of interest include:

- Self-calibrating scalar-vector magnetometer for future Earth and space science missions. Performance goals: dynamic range: ±100,000 nT, accuracy with self-calibration: 1 nT, sensitivity: 5 pT • $Hz^{-1/2}$ (max), max sensor unit size: 6 x 6 x 12 cm, max sensor mass: 0.6 kg, max electronics unit size: 8 x 13 x 5 cm, max electronics mass: 1 kg, and max power: 5 W operation, 0.5 W standby, including, but not limited to "sensors on a chip".
- High-magnetic-field sensor that measures magnetic field magnitudes to 16 Gauss with an accuracy of 1 part in 105.
- Strong, lightweight, thin, compactly-stowed electric field booms possibly using composite materials that deploy sensors to distances of 10-m or more.
- Cooled (-60ºC) solid state ion detector capable of operating at a floating potential of -15 kV relative to ground.
- Low noise magnetic materials for advanced magnetometer sensors with performance equal to or better than those in the 6-81.3 Mo-Permalloy family.
- Radiation hardened ASIC spectrum analyzer module that determines mass spectra using fast algorithm deconvolution to produce ion counts for specific ion species.
- Low-cost, low-power, fast-stepping (≤ 50-μs), high-voltage power supplies 5-15 kV.
- Low-cost, efficient low-power power supplies (5-10 V).
- Low-power charge sensitive preamplifiers on a chip.
- High efficiency (5% or greater) conversion surfaces for low energy neutral atom conversion to ions possibly based on nanotechnology.
- Miniature low-power, high efficiency, thermionic cathodes, capable of 1-mA electron emission per 100-mW heater power with emission surface area of 1-mm^2 and expected lifetime of 20,000 hours.
- Long wire boom (≥ 50 m) deployment systems for the deployment of very lightweight tethers or antennae on spinning spacecraft.
- Systems to determine the orthogonality of a deployed electric/magnetic field boom system in flight (for use with three-axis rigid 10-m booms) accurate to 0.10° dynamic.
- Die-level optical interferometer, micro-sized, for measuring Fabry-Perot plate spacing with 0.1-nm accuracy.
- Diffractive optics (photon sieves) of 0.1-m aperture or larger with micron-sized outer Fresnel zones for high-resolution EUV imaging.

Developing near-real time data-assimilative models and tools, for both solar quiet and active times, which allow for precise specification and forecasts of the space environment, beginning with solar eruptions and propagation, and including ionospheric electron density specification.

S1.07 Cryogenic Systems for Sensors and Detectors
Lead Center: GSFC
Participating Center(s): ARC, JPL, MSFC

Cryogenic cooling systems often serve as enabling technologies for detectors and sensors flown on scientific instruments as well as advanced telescopes and observatories. As such, technological improvements to cryogenic systems (as well as components) further advance the mission goals of NASA through enabling performance (and ultimately science gathering) capabilities of flight detectors and sensors. Presently, there are six potential investment areas that NASA is seeking to expand state of the art capabilities in for possible use on future programs such as GEOID, SPICA, WFirst (http://wfirst.gsfc.nasa.gov/), Space Infrared Interferometric Telescope (SPIRIT), Submillimeter Probe of the Evolution of Cosmic Structure (SPECS), as well as, the Planetary and Europa Science missions (http://www.nasa.gov/multimedia/podcasting/jpl-europa20090218.html). The topic areas are as follows:

- Extremely Low Vibration Cooling Systems - Examples of such systems include Joule Thompson, pulse tube and turbo Brayton cycles. Desired cooling capabilities sought are on the order of 40 mW at 4K or 1 W at 50K. Present state of the art capabilities display < 100 mN vibration at operational frequencies of 30-70 Hz. Proposed systems should either satisfy or improve upon this benchmark.

- Advanced Magnetic Cooler Components - An example of an advanced magnetic cooler might be Adiabatic Demagnetization Refrigeration systems. Specific components sought include:
  - Low current superconducting magnets.
  - Active/Passive magnetic shielding (3-4 Tesla magnets).
  - Single or Polycrystalline magnetocaloric materials (< 1 cm^3).
  - Superconducting leads (10K - 90K) capable of 10 amp operation with 1 mW conduction.
  - 10 mK scale thermometry.
- Continuous Flow Distributed Cooling Systems - Distributed cooling provides increased lifetime of cryogen fluids for applications on both the ground and spaceborne platforms. This has impacts on payload mass and volume for flight systems which translate into costs (either on the ground, during launch or in flight). Cooling systems that provide continuous distributed flow are a cost effective alternative to present techniques/methodologies. Cooling systems that can be used with large loads and/or deployable structures are presently being sought after.

S1.08 In Situ Airborne, Surface, and Submersible Instruments for Earth Science
Lead Center: GSFC
Participating Center(s): ARC, JPL, KSC, LaRC, MSFC, SSC

New, innovative, high risk/high payoff approaches to miniaturized and low cost instrument systems are needed to enhance Earth science research capabilities. Sensor systems for a variety of platforms are desired, including those designed for remotely operated robotic aircraft, surface craft, submersible vehicles, balloon-based systems (tethered or free), and kites. Global deployment of numerous sensors is an important objective, therefore cost and platform adaptability are key factors.

Novel methods to minimize the operational labor requirements and improve reliability are desired. Long endurance (days/weeks/months) autonomous/unattended instruments with self/remote diagnostics, self/remote maintenance, capable of maintaining calibration for long periods, and remote control are important. Use of data systems that collect geospatial, inertial, temporal information, and synchronize multiple sensor platforms are also of interest.

Priorities include:

- Atmospheric measurements in the troposphere and lower stratosphere: Aerosol Optical and Microphysical Properties, Cloud Properties and Particles, Water, Chemical Composition, i.e., Carbon Dioxide ($12CO^2$ and $13CO^2$), Carbon Monoxide, Methane, Nitrogen Dioxide, Hydrogen Peroxide, Formaldehyde, Bromine Oxides, Ozone, and Three-dimensional Winds and Turbulence.
- Oceanic, coastal, and fresh water measurements including inherent and apparent optical properties, temperature, salinity, currents, chemical and particle composition, sediment, and biological components such as nutrient distribution, phytoplankton, harmful algal blooms, fish or aquatic plants.
- Hyperspectral radiometers for above water (340 -1400 nm) and shallow water (340 – 900 nm) profiling: high frequency measurements of sky-radiance, sun irradiance, water leaving radiance, and bidirectional reflectance, with solar-tracking and autonomous operation.
- Instrument systems for hazardous environments such as volcanoes and severe storms, including measurements of Sulfur Dioxide, Particles, and Precipitation.
- Land Surface characterization geopotential field sensors, such as gravity, geomagnetic, electric, and electromagnetic.
- Urban air-quality profiler: ground based, compact, inexpensive, (laser based) systems suited for unattended measurement (e.g., ozone) profiles of the troposphere.

Instrument systems to support satellite measurement calibration and validation observations, as well as field studies of fundamental processes are of interest. A priority is applicability to NASA's research activities such as the

Atmospheric Composition and Radiation Sciences programs, including Airborne Science support thereof, as well as the Applied Sciences, and Ocean Biology and Biogeochemistry programs. Support of algorithm development for the Geostationary Coastal and Air Pollution Events (Geo-CAPE) mission is also a priority. Development of instruments that will provide near-term benefit to the NASA science community is a priority – working prototypes delivered by the completion of Phase II are desired.

S1.09 In Situ Sensors and Sensor Systems for Lunar and Planetary Science
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC, JSC, KSC, LaRC, MSFC

This subtopic solicits development of advanced instrument technologies and components suitable for deployment on planetary and lunar missions. These technologies must be capable of withstanding operation in space and planetary environments, including the expected pressures, radiation levels, launch and impact stresses, and range of survival and operational temperatures. Technologies that reduce mass, power, volume, and data rates for instruments and instrument components without loss of scientific capability are of particular importance. In addition, technologies that can increase instrument resolution and sensitivity or achieve new & innovative scientific measurements are solicited. For example missions, see http://science.hq.nasa.gov/missions. For details of the specific requirements see the National Research Council's, Vision and Voyages for Planetary Science in the Decade 2013-2022 http://solarsystem.nasa.gov/2013decadal/. Technologies which support NASA's Planetary Flagship mission candidates (Mars 2018, JEO, & Uranus Orbiter & Probe Mission), New Frontiers Mission candidates (Comet Surface Sample Return, Lunar South Pole-Aitken Basin Sample Return, Saturn Probe, Trojan Tour & Rendezvous, Venus In-Situ Explorer, Io Observer, and the Lunar Geophysical Network) and Discovery missions to various planetary bodies are of top priority.

In situ technologies are being sought to achieve much higher resolution and sensitivity with significant improvements over existing technologies. Orbital sensors and technologies that can provide significant improvements over previous orbital missions are also sought. Specifically, this subtopic solicits instrument development that provides significant advances in the following areas, broken out by planetary body:

- Mars: Sub-systems relevant to current in situ instrument needs (e.g., lasers and other light sources from UV to microwave, X-ray and ion sources, detectors, mixers, mass analyzers, etc.) or electronics technologies (e.g., FPGA and ASIC implementations, advanced array readouts, miniature high voltage power supplies). Technologies that support high precision in situ measurements of elemental, mineralogical, and organic composition of planetary materials are sought. Conceptually simple, low risk technologies for in situ sample extraction and/or manipulation including fluid and gas storage, pumping, and chemical labeling to support analytical instrumentation. Seismometers, mass analyzers, technologies for heat flow probes, and atmospheric trace gas detectors. Improved robustness and g-force survivability for instrument components, especially for geophysical network sensors, seismometers, and advanced detectors (iCCDs, PMT arrays, etc.). Instruments geared towards rock/sample interrogation prior to sample return are desired.
- Europa & Io: Technologies for high radiation environments, e.g., radiation mitigation strategies, radiation tolerant detectors, and readout electronic components, which enable orbiting instruments to be both radiation-hard and undergo the planetary protection requirements of sterilization (or equivalent) for candidate instruments on the Europa-Jupiter System Mission (JEO) and Io Observer are sought.
- Titan: Low mass and power sensors, mechanisms and concepts for converting terrestrial instruments such as turbidimeters and echo sounders for lake measurements, weather stations, surface (lake and solid) properties packages etc., to cryogenic environments (95K). Mechanical and electrical components and subsystems that work in cryogenic (95K) environments; sample extraction from liquid methane/ethane, sampling from organic 'dunes' at 95K and robust sample preparation and handling mechanisms that feed into mass analyzers are sought. Balloon instruments, such as IR spectrometers, imagers, meteorological instruments, radar sounders, air sampling mechanisms for mass analyzers, and aerosol detectors are also solicited.

- Venus: Sensors, mechanisms, and environmental chamber technologies for operation in Venus's high temperature, high-pressure environment with its unique atmospheric composition. Approaches that can enable precision measurements of surface mineralogy and elemental composition and precision measurements of trace species, noble gases and isotopes in the atmosphere are particularly desired.
- Small Bodies: Technologies that can enable sampling from asteroids and from depth in a comet nucleus, improved in situ analysis of comets. Also, imagers and spectrometers that provide high performance in low light environments.
- Saturn, Uranus and Neptune: Technologies are sought for components, sample acquisition and instrument systems that can enhance mission science return and withstand the low-temperatures/high-pressures of the atmospheric probes during entry.
- The Moon: This solicitation seeks advancements in the areas of compact, light-weight, low power instruments geared towards in situ lunar surface measurements, geophysical measurements, lunar atmosphere and dust environment measurements & regolith particle analysis, lunar resource identification, and/or quantification of potential lunar resources (e.g., oxygen, nitrogen, and other volatiles, fuels, metals, etc.). Specifically, advancements geared towards instruments that enable elemental or mineralogy analysis (such as high-sensitivity X-ray and UV-fluorescence spectrometers, UV/fluorescence flash lamp/camera systems, scanning electron microscopy with chemical analysis capability, time-of-flight mass spectrometry, gas chromatography and tunable diode laser sensors, calorimetry, laser-Raman spectroscopy, imaging spectroscopy, and LIBS) are sought. These developments should be geared towards sample interrogation, prior to possible sample return. Systems and subsystems for seismometers and heat flow sensors capable of long-term continuous operation over multiple lunar day/night cycles with improved sensitivity at lower mass and reduced power consumption are sought. Also of interest are portable surface ground penetrating radars to characterize the thickness of the lunar regolith, as well as low mass, thermally stable hollow cubes and retro-reflector array assemblies for lunar surface laser ranging. Of secondary importance are instruments that measure the micrometeoroid and lunar secondary ejecta environment, plasma environment, surface electric field, secondary radiation at the lunar surface, and dust concentrations and its diurnal dynamics are sought. Further, lunar regolith particle analysis techniques are desired (e.g., optical interrogation or software development that would automate integration of suites of multiple back scatter electron images acquired at different operating conditions, as well as permit integration of other data such as cathodoluminescence and energy-dispersive x-ray analysis.)

Proposers are strongly encouraged to relate their proposed development to:

- NASA's future planetary exploration goals.
- Existing flight instrument capability, to provide a comparison metric for assessing proposed improvements.

Proposed instrument architectures should be as simple, reliable, and low risk as possible while enabling compelling science. Novel instrument concepts are encouraged particularly if they enable a new class of scientific discovery. Technology developments relevant to multiple environments and platforms are also desired.

Proposers should show an understanding of relevant space science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S1.10 Atomic Interferometry
Lead Center: GSFC
Participating Center(s): JPL

“Atom/BEC (Bose Einstein Condensate) Interferometry for space applications”

Sensors based on Atom/BEC Interferometry are attractive because:

Atoms have internal and external degrees of freedom that are used to optimize detection of desired signal. These states are easily manipulated by external magnetic and electric fields. Different Atoms posses a wide range of different properties that offer the experimentalists an opportunity to address a wide range of problems. Laser Cooling and Atom trapping enable experimentalists long measurement times that translates to high precision Interferometry measurements. Generally these measurements are done in the inertial frame of the atoms, which is mostly isolated from the environment.

The Atom/BEC Interferometry based sensors of interest to NASA are:

- Accelerometers.
- Gyros.
- Inertial Measurement Units for navigation.
- Gravity Gradient sensors (Gravimeters and gradiometers).
- Optical metrology instrumentation.
- Large area matter wave interferometers.
- Precise clocks for space applications.
- Higher sensitivity space magnetometers.

These are subset of the possible sensors based on this technology that has direct applications to GRACE II, Gravity Wave Science Mission, and small explorer missions. In general, Atom/BEC Interferometry enables much higher precision of the phase than optical Interferometers.

This subtopic seeks concepts and prototypes of devices below:

- Compact Low Noise accelerometers are Vital to gravity mapping, gravity wave detections, and navigation. Noise of 5E-10 (m/s^2 Hz-1/2) over frequency range of 1E-05 Hz to 1E+00 Hz are required.
- Compact Low Noise gyroscopes based on Atom/BEC Interferometry with better than 0.01deg/hour accuracy and better than 0.001deg/sqrt(Hz) low drift.

The criteria for evaluations also include:

- Lowest temperature achieved.
- Number of Atoms in the gas.

Robustness of the design /prototype to Space environments.

S1.11 Planetary Orbital Sensors and Sensor Systems (POSSS)
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC, KSC, MSFC

This Crosscutting SBIR Subtopic seeks to fill the numerous SBIR technology gaps in the planetary orbital instrument area. Although there is a discrete subtopic for in situ instrument technologies and lunar instrument technologies (S1.09), which covers those areas, there is no corresponding one for orbital instrument technologies. S1.09 is the only subtopic in S1 that is entirely focused on planetary science, and this may be limiting funded proposal yields in the planetary area. In the past, both S1.09 and S1.11 have hosted orbital sensor concepts.

This subtopic seeks to leverage the 2011 Planetary Decadal Survey priorities to create a new subtopic within S1, whose primary emphasis would be technology for orbital instruments and instrument components. Priorities include Flagship missions to Mars and the gas giant planets Jupiter and Uranus and NASA’s two programs of competed planetary missions: New Frontiers and Discovery.

In summary, this crosscutting topic is using subtopics from other Mission Directorate topics (see list below) to address the goal of POSSS. Bidders on this topic must also address the objectives of the originating topic descriptions. Additional value may be given to proposals that also address the POSSS subtopic.

Subtopic cross reference:

- S1.04 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter.
- S1.05 Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments.
- S1.06 Particles and Field Sensors and Instrument Enabling Technologies.
- S1.09 Sensors and Sensor Systems for Lunar and Planetary Science.

TOPIC: S2 Advanced Telescope Systems

The NASA Science Missions Directorate seeks technology for cost-effective high-performance advanced space telescopes for astrophysics and Earth science. Astrophysics applications require large aperture lightweight highly reflecting mirrors, deployable large structures and innovative metrology, control of unwanted radiation for high-contrast optics, precision formation flying for synthetic aperture telescopes, and cryogenic optics to enable far infrared telescopes. A few of the new astrophysics telescopes and their subsystems will require operation at cryogenic temperatures as cold a 4-degrees Kelvin. This topic will consider technologies necessary to enable future telescopes and observatories collecting electromagnetic bands, ranging from UV to millimeter waves, and also include gravity waves. The subtopics will consider all technologies associated with the collection and combination of observable signals. Earth science requires modest apertures in the 2 to 4 meter size category that are cost effective. New technologies in innovative mirror materials, such as silicon, silicon carbide and nanolaminates, innovative structures, including nanotechnology, and wavefront sensing and control are needed to build telescope for Earth science that have the potential to cost between $50 to $150M.

S2.01 Precision Spacecraft Formations for Telescope Systems
Lead Center: JPL
Participating Center(s): GSFC

This subtopic seeks hardware and software technologies necessary to establish, maintain, and operate precision spacecraft formations to a level that enables cost effective large aperture and separated spacecraft optical telescopes and interferometers (e.g., http://planetquest.jpl.nasa.gov/TPF/, http://instrument.jpl.nasa.gov/steller/). Also sought are technologies (analysis, algorithms, and test beds) to enable detailed analysis, synthesis, modeling, and visualization of such distributed systems.

Formation flight can synthesize large effective telescope apertures through, multiple, collaborative, smaller telescopes in a precision formation. Large effective apertures can also be achieved by tiling curved segments to form an aperture larger than can be achieved in a single launch, for deep-space high resolution imaging of faint astrophysical sources. These formations require the capability for autonomous precision alignment and synchronized maneuvers, reconfigurations, and collision avoidance. The spacecraft also require onboard capability for optimal path planning and time optimal maneuver design and execution.

Innovations are solicited for:

- Sensor systems for inertial alignment of multiple vehicles with separations of tens of meters to thousands of kilometers to accuracy of 1 - 50 milli-arcseconds.
- Development of nanometer to sub-nanometer metrology for measuring inter-spacecraft range and/or bearing for space telescopes and interferometers.
- Control approaches to maintain line-of-sight between two vehicles in inertial space near Sun-Earth L2 to milli-arcsecond levels accuracy.

- Development of combined cm-to-nanometer-level precision formation flying control of numerous spacecraft and their optics to enable large baseline, sparse aperture UV/optical and X-ray telescopes and interferometers for ultra-high angular resolution imagery. Proposals addressing staged-control experiments, which combine coarse formation control with fine-level wavefront sensing based control are encouraged.

Innovations are also solicited for distributed spacecraft systems in the following areas:

- Distributed, multi-timing, high fidelity simulations.
- Formation modeling techniques.
- Precision guidance and control architectures and design methodologies.
- Centralized and decentralized formation estimation.
- Distributed sensor fusion.
- RF and optical precision metrology systems.
- Formation sensors.
- Precision microthrusters/actuators.
- Autonomous reconfigurable formation techniques.
- Optimal, synchronized, maneuver design methodologies.
- Collision avoidance mechanisms.
- Formation management and station keeping.
- Swarm modeling, simulation and control.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S2.02 Proximity Glare Suppression for Astronomical Coronagraphy
Lead Center: JPL
Participating Center(s): ARC, GSFC

This subtopic addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources. Examples include planetary systems beyond our own, the detailed inner structure of galaxies with very bright nuclei, binary star formation, and stellar evolution. Contrast ratios of one million to ten billion over an angular spatial scale of 0.05-1.5 arcsec are typical of these objects. Achieving a very low background requires control of both scattered and diffracted light. The failure to control either amplitude or phase fluctuations in the optical train severely reduces the effectiveness of starlight cancellation schemes.

This innovative research focuses on advances in coronagraphic instruments, starlight cancellation instruments, and potential occulting technologies that operate at visible and near infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission. Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development, and innovative instrument design, as well as in the fabrication of subsystem devices to include, but not limited to, the following areas:

Starlight Suppression Technologies

- Advanced starlight canceling coronagraphic instrument concepts.
- Advanced aperture apodization and aperture shaping techniques.
- Advanced apodization mask or occulting spot fabrication technology controlling smooth density gradients to 10-4 with spatial resolutions ~1 µm, low dispersion, and low dependence of phase on optical density.
- Metrology for detailed evaluation of compact, deep density apodizing masks, Lyot stops, and other types of graded and binary mask elements. Development of a system to measure spatial optical density, phase

inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of masks and stops is needed.
- Interferometric starlight cancellation instruments and techniques to include aperture synthesis and single input beam combination strategies.
- Pupil remapping technologies to achieve beam apodization.
- Techniques to characterize highly aspheric optics.
- Methods to distinguish the coherent and incoherent scatter in a broadband speckle field.
- Methods of polarization control and polarization apodization.
- Components and methods to insure amplitude uniformity in both coronagraphs and interferometers, specifically materials, processes, and metrology to insure coating uniformity.
- Coherent fiber bundles consisting of up to 10^4 fibers with lenslets on both input and output side, such that both spatial and temporal coherence are maintained across the fiber bundle for possible wavefront/amplitude control through the fiber bundle.

Wavefront Control Technologies
- Development of small stroke, high precision, deformable mirrors and associated driving electronics scalable to 104 or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple deformable mirror technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices.
- Development of instruments to perform broadband sensing of wavefronts and distinguish amplitude and phase in the wavefront.
- Adaptive optics actuators, integrated mirror/actuator programmable deformable mirror.
- Reliability and qualification of actuators and structures in deformable mirrors to eliminate or mitigate single actuator failures.
- Multiplexer development for electrical connection to deformable mirrors that has ultra-low power dissipation.
- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance.
- Optical Coating and Measurement Technologies.
- Instruments capable of measuring polarization cross-talk and birefringence to parts per million.
- Highly reflecting broadband coatings for large (> 1 m diameter) optics.
- Polarization-insensitive coatings for large optics.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S2.03 Precision Deployable Optical Structures and Metrology
Lead Center: JPL
Participating Center(s): GSFC, LaRC

Planned future NASA Missions in astrophysics, such as: Wide-Field Infrared Survey Telescope (WFIRST) and the New Worlds Technology Development Program (coronagraph, external occulter and interferometer technologies) will push the state of the art in current optomechanical technologies. Mission concepts for New Worlds science would require 10 - 30 m class, cost-effective telescope observatories that are diffraction limited at wavelengths from the visible to the far IR, and operate at temperatures from 4 - 300 K. In addition, ground based telescopes such as the Cerro Chajnantor Atacama Telescope (CCAT) require similar technology development.

The desired areal density is 1 - 10 kg/m^2 with a packaging efficiency of 3-10 deployed/stowed diameter. Static and dynamic wavefront error tolerances to thermal and dynamic perturbations may be achieved through passive means

(e.g., via a high stiffness system, passive thermal control, jitter isolation or damping) or through active opto-mechanical control. Large deployable multi-layer structures in support of sunshades for passive thermal control and 20m to 50m class planet finding external occulters are also relevant technologies. Potential architecture implementations must package into an existing launch volume, deploy and be self-aligning to the micron level. The target space environment is expected to be the Earth-Sun L2.
This subtopic solicits proposals to develop enabling, cost effective component and subsystem technology for deploying large aperture telescopes with low cost. Research areas of interest include:

- Precision deployable structures and metrology for optical telescopes (e.g., innovative active or passive deployable primary or secondary support structures).
- Architectures, packaging and deployment designs for large sunshields and external occulters.

In particular, important subsystem considerations may include:

- Innovative concepts for packaging fully integrated subsystems (e.g., power distribution, sensing, and control components).
- Mechanical, inflatable, or other precision deployable technologies.
- Thermally-stable materials (CTE < 1ppm) for deployable structures.
- Innovative systems, which minimize complexity, mass, power and cost.
- Innovative testing and verification methodologies.

The goal for this effort is to mature technologies that can be used to fabricate 16 m class or greater, lightweight, ambient or cryogenic flight-qualified observatory systems. Proposals to fabricate demonstration components and subsystems with direct scalability to flight systems through validated models will be given preference. The target launch volume and expected disturbances, along with the estimate of system performance, should be included in the discussion. Proposals with system solutions for large sunshields and external occulters will also be accepted. A successful proposal shows a path toward a Phase II delivery of demonstration hardware scalable to 5 meter diameter for ground test characterization.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop the relevant subsystem technologies and to transition into future NASA program(s).

S2.04 Advanced Optical Component Systems
Lead Center: MSFC
Participating Center(s): GSFC, JPL

The National Academy Astro2010 Decadal Report specifically identifies optical components and coatings as key technologies needed to enable several different future missions, including:

- X-ray imaging mirrors for the International X-Ray Observatory (IXO).
- Active lightweight x-ray imaging mirrors for future very large advanced x-ray observatories.
- Large aperture, lightweight mirrors for future UV/Optical telescopes.
- Broadband high reflectance coatings for future UV/Optical telescopes.

X-ray mirrors are identified by the Decadal as the most important, critical technology needed for IXO. IXO requires 3 m^2 collecting aperture x-ray imaging mirror with 5 arc-second angular resolution. Mirror areal density depends upon available launch vehicle capacities. Additionally, future x-ray missions require advanced multilayer high-reflectance coating for hard x-ray mirrors (i.e., NuSTAR) and x-ray transmission/reflection gratings.

Future UVOIR missions require 4 to 8 or 16 meter monolithic and/or segmented primary mirrors with < 10 nm rms surface figures. Mirror areal density depends upon available launch vehicle capacities to Sun-Earth L2 (i.e., 15

kg/m^2 for a 5 m fairing EELV vs. 60 kg/m^2 for a 10 m fairing SLS). Additionally, future UVOIR missions require high-reflectance mirror coatings with spectral coverage from 100 to 2500 nm.

Heliophysics missions also require advanced lightweight, super-polished precision normal and grazing incidence optical components and coatings. Potential missions which could be enabled by these technologies include: Origins of Near-Earth Plasma (ONEP); Ion-Neutral Coupling in the Atmosphere (INCA); Dynamic Geospace Coupling (DGC); Fine-scale Advanced Coronal Transition-Region Spectrograph (FACTS); Reconnection and Micro-scale (RAM); and Solar-C. Heliophysics missions need normal incidence mirror systems ranging from 0.35 meter to 1.5 meters with surface figure errors of 0.1 micro-radians rms slope from 4-mm to 1/2 aperture spatial periods, roughness of 0.2-nm rms and micro-roughness of 0.1-nm rms; and, grazing incidence mirror systems with an effective collecting area of ~3 cm^2 from 0.1 to 4 nm, 4 meter effective focal length, 0.8 degree angle of incidence and surface roughness of 0.2-nm rms. Additionally, future Heliophysics missions require high-reflectance normal incidence spectral, broadband, dual and even three-band pass multi-layer EUV coatings.

The geosynchronous orbit for GEO-CAPE coastal ecosystem imager requires technology for alternative solar calibration strategies including new materials to reduce weight, and new optical analysis to reduce the size of calibration systems. GEO-CAPE will need a lightweight large aperture (greater than 0.5 m) diffuse solar calibrator, employing multiple diffusers to track on-orbit degradation. Typical materials of interest are PTFE (such as Spectralon® surface diffuser) or development of new Mie scattering materials for use as volume diffusers in transmission or reflection.

Finally, NASA is developing a heavy lift space launch system (SLS). An SLS with a 10 meter fairing and 100 mt capacity to LEO would enable extremely large space telescopes. Potential systems include 12 to 30 meter class segmented primary mirrors for UV/optical or infrared wavelengths and 8 to 16 meter class segmented x-ray telescope mirrors. These potential future space telescopes have very specific mirror technology needs. UV/optical telescopes (such as ATLAST-9 or ATLAST-16) require 1 to 3 meter class mirrors with < 5 nm rms surface figures. IR telescopes (such as SAFIR/CALISTO) require 2 to 3 to 8 meter class mirrors with cryo-deformations < 100 nm rms. X-ray telescopes (such as GenX) require 1 to 2 meter long grazing incidence segments with angular resolution < 5 arc-sec down to 0.1 arc-sec and surface micro-roughness < 0.5-nm rms.

In all cases, the most important metric for an advanced optical system is affordability or areal cost (cost per square meter of collecting aperture). Currently both x-ray and normal incidence space mirrors cost $3 million to $4 million per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 20 to 100 times, to less than $\$100K/m^2$.

The subtopic has three objectives:

- Develop and demonstrate technologies to manufacture and test ultra-low-cost precision optical systems for x-ray, UV/optical or infrared telescopes. Potential solutions include, but are not limited to, new mirror materials such as silicon carbide, nanolaminates or carbon-fiber reinforced polymer; or new fabrication processes such as direct precision machining, rapid optical fabrication, roller embossing at optical tolerances, slumping or replication technologies to manufacture 1 to 2 meter (or larger) precision quality mirror or lens segments (either normal incidence for UV/optical/infrared or grazing incidence for x-ray). Solutions include reflective, transmissive, diffractive or high order diffractive blazed lens optical components for assembly of large (16 to 32 meter) optical quality primary elements. The EUSO mission requires large-aperture primary segmented refractive, Fresnel or kinoform PMMA or CYTOP lenses with < 20 nm rms smooth surfaces for low scatter.
- Develop and demonstrate optical coatings for EUV and UVOIR telescopes. UVOIR telescopes require broadband (from 100 nm to 2500 nm) high-reflectivity mirror coating with extremely uniform amplitude and polarization properties. Heliophysics missions require high-reflectance (> 90%) normal incidence spectral, broadband, dual and even three-band pass multi-layer coatings over the spectral range from 6 to 200 nm. Studies of improved deposition processes for new UV reflective coatings (e.g., MgF_2),

investigations of new coating materials with promising UV performance, and examination of handling processes, contamination control, and safety procedures related to depositing coatings, storing coated optics, integrating coated optics into flight hardware are all areas where progress would be valuable. In all cases, an ability to demonstrate optical performance on 2 to 3 meter class optical surfaces is important.

- Large aperture diffusers (up to 1 meter) for periodic calibration of GeoStationary Earth viewing sensors by viewing the sun either in reflection or transmission off the diffuser.

Successful proposals will demonstrate an ability to manufacture, test and control a prototype precision mirror, lens or replicating mandrel in the 0.25 to 0.5 meter class; or to coat a 0.25 to 0.5 meter class representative optical component. Additionally, the proposal shall provide a scale-up roadmap (including processing and infrastructure issues) for 1 to 2+ meter class space qualifiable flight optics systems. Material behavior, process control, optical performance, and mounting/deploying issues should be resolved and demonstrated
An ideal Phase I deliverable would be a UV, visible or x-ray precision mirror, lens or replicating mandrel of at least 0.25 meters. The Phase II project would further advance the technology to produce a space-qualifiable precision mirror, lens or mandrel greater than 0.5 meters, with a TRL in the 4 to 5 range. Both deliverables would be accompanied by all necessary documentation, including the optical performance assessment and all data on processing and properties of its substrate materials. The Phase II would also include a mechanical and thermal stability analysis.

In regard to large-aperture diffusers material needs to be stable in BTDF/BSDF to 2%/year from 250nm -2.5 microns and highly lambertian (no formal specification for deviation from lambertian.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S2.05 Optics Manufacturing and Metrology for Telescope Optical Surfaces
Lead Center: GSFC
Participating Center(s): JPL, MSFC

This subtopic focuses primarily on manufacturing and metrology of optical surfaces, especially for very small or very large and/or thin optics. Missions of interest include:

Dark Energy Mission concepts (e.g., http://wfirst.gsfc.nasa.gov)
Large X-Ray Mission concepts (e.g., http://ixo.gsfc.nasa.gov/),
Gravity Wave Science Mission concepts (e.g., http://lisa.gsfc.nasa.gov/)
ICESAT (http://icesat.gsfc.nasa.gov/), CLARIO, and ACE
ATLAST (http://www.stsci.edu/institute/atlast/)

Optical systems currently being researched for these missions are large area aspheres, requiring accurate figuring and polishing across six orders of magnitude in period. Technologies are sought that will enhance the figure quality of optics in any range as long as the process does not introduce artifacts in other ranges. For example, mm-period polishing should not introduce waviness errors at the 20 mm or 0.05 mm periods in the power spectral density. Also, novel metrological solutions that can measure figure errors over a large fraction of the PSD range are sought, especially techniques and instrumentation that can perform measurements while the optic is mounted to the figuring/polishing machine. A new area of interest is large lightweight monolithic metallic aspheres manufactured using innovative mirror substrate materials that can be assembled and welded together from smaller segments.

By the end of a Phase II program, technologies must be developed to the point where the technique or instrument can dovetail into an existing optics manufacturing facility producing optics at the R&D stage. Metrology instruments should have 10 nm or better surface height resolution and span at least 3 orders of magnitude in lateral spatial frequency.

Examples of technologies and instruments of interest include:

- Innovative metal mirror substrate materials or manufacturing methods such as welding component segments into one monolith that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods.
- Interferometric nulling optics for very shallow conical optics used in x-ray telescopes.
- Segmented systems commonly span 60 degrees in azimuth and 200 mm axial length and cone angles vary from 0.1 to 1 degree.
- Low stress metrology mounts that can hold very thin optics without introducing mounting distortion.
- Low normal force figuring/polishing systems operating in the 1 mm to 50 mm period range with minimal impact at significantly smaller and larger period ranges.
- In situ metrology systems that can measure optics and provide feedback to figuring/polishing instruments without removing the part from the spindle.
- Innovative mirror substrate materials or manufacturing methods that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods.
- Extreme aspheric and/or anamorphic optics for pupil intensity amplitude apodization.
- Metrology systems useful for measuring large optics with high precision.
- Metrology systems for measuring optical systems while under cryogenic conditions.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

TOPIC: S3 Spacecraft and Platform Subsystems

The Science Mission Directorate will carry out the scientific exploration of our Earth, the planets, moons, comets, and asteroids of our solar system and the universe beyond. SMD's future direction will be moving away from exploratory missions (orbiters and flybys) into more detailed/specific exploration missions that are at or near the surface (landers, rovers, and sample returns) or at more optimal observation points in space. These future destinations will require new vantage points, or would need to integrate or distribute capabilities across multiple assets. Future destinations will also be more challenging to get to, have more extreme environmental conditions and challenges once the spacecraft gets there, and may be a challenge to get a spacecraft or data back from. A major objective of the NASA science spacecraft and platform subsystems development efforts are to enable science measurement capabilities using smaller and lower cost spacecraft to meet multiple mission requirements thus making the best use of our limited resources. To accomplish this objective, NASA is seeking innovations to significantly improve spacecraft and platform subsystem capabilities while reducing the mass and cost, that would in turn enable increased scientific return for future NASA missions. A spacecraft bus is made up of many subsystems like: propulsion; thermal control; power and power distribution; attitude control; telemetry command and control; transmitters/antenna; computers/on-board processing/software; and structural elements. Science platforms of interest could include unmanned aerial vehicles, sounding rockets, or balloons that carry scientific instruments/payloads, to planetary ascent vehicles or Earth return vehicles that bring samples back to Earth for analysis. This topic area addresses the future needs in many of these sub-system areas, as well as their application to specific spacecraft and platform needs. Innovations for 2011 are sought in the areas of:

- Command and Data Handling, and Instrument Electronics.
- Thermal Control Systems.
- Power Generation and Conversion.
- Propulsion Systems.
- Power Electronics and Management, and Energy Storage.
- Guidance, Navigation and Control.
- Unmanned Aircraft and Sounding Rocket Technologies.

- Terrestrial and Planetary Balloons.

Significant changes to the S3 Topic for 2011 are:

- Merged the 2010 subtopics of S3.08 Planetary Ascent Vehicles and S3.10 Earth Entry Vehicles into a broader “Spacecraft Technology for Sample Return Missions” sub-topic under the S5 Topic.
- Moved power electronics/power processing unit content for electric propulsion systems from S3.04 Propulsion Systems to the revised sub-topic of S3.05 Power Electronics and Management, and Energy Storage.

The following references discuss some of NASA’s science mission and technology needs:

- The Astrophysics Roadmap: http://nasascience.nasa.gov/about-us/science-strategy.
- Astrophysics Decadal Survey - “New Worlds, New Horizons: in Astronomy and Astrophysics”: http://www.nap.edu/catalog.php?record_id=12951.
- The Earth Science Decadal Survey: http://books.nap.edu/catalog.php?record_id=11820.
- The Heliophysics roadmap: “The Solar and Space Physics of a New Era: Recommended Roadmap for Science and Technology 2009-2030”: http://sec.gsfc.nasa.gov/2009_Roadmap.pdf.
- The 2011 Planetary Science Decadal Survey was released March 2011. This decadal survey is considering technology needs. http://www.nap.edu/catalog.php?record_id=13117.
- The 2006 Solar System Exploration Roadmap: http://nasascience.nasa.gov/about-us/science-strategy.
- 2010 Science Plan: http://science.nasa.gov/about-us/science-strategy/.

S3.01 Command, Data Handling, and Electronics
Lead Center: GSFC
Participating Center(s): ARC, JPL, LaRC

NASA's space based observatories, fly-by spacecraft, orbiters, landers, and robotic and sample return missions, require robust command and control capabilities. Advances in technologies relevant to command and data handling and instrument electronics are sought to support NASA's goals and several missions and projects under development.

The subtopic goals are to:

- Develop high-performance processors, memory architectures, and reliable electronic systems.
- Develop tools technologies that can enable rapid deployment of high-reliability, high-performance onboard processing applications and interface to external sensors on flight hardware. The subtopic objective is to elicit novel architectural concepts and component technologies that are realistic and operate effectively and credibly in environments consistent with the future NASA science missions.

Successful proposal concepts should significantly advance the state-of-the-art. Proposals should clearly:

- State what the product is.
- Identify the needs it addresses.
- Identify the improvements over the current state of the art.
- Outline the feasibility of the technical and programmatic approach.
- Present how it could be infused into a NASA program.

Furthermore, proposals should indicate an understanding of the intended operating environment, including temperature and radiation. It should be noted that environmental requirements can vary significantly from mission to mission. For example, some low Earth orbit missions have a total ionizing dose (TID) radiation requirement of less than 10 krad(Si), while some planetary missions can have requirements well in excess of 1 Mrad(Si). For descriptions of radiation effects in electronics, the proposer may visit (http://radhome.gsfc.nasa.gov/radhome/overview.htm). If a Phase II proposal is awarded, the combined Phase I and Phase II developments should produce a prototype that can be characterized by NASA.

The technology priorities sought are listed below:

Novel, Ruggedized Packaging/Interconnect

- High-density packaging (enclosures, printed wiring boards) enabling miniaturization.
- Novel high density and low resistance cabling, including carbon nanotube (CNT) based wiring.

Discrete Components for C&DH Subsystems

- Processors - General purpose (processor chips and radiation-hardened by design synthesizable IP cores) and special purpose single-chip components (DSPs), with sustainable processing performance and power efficiency (>40,000 MIPS at >1,000 MIPS/W for general purpose processing platforms, >20 GMACs at >5 GMACS/W for computationally-intensive processing platforms), and tolerance to total dose and single-event radiation effects. Concepts must include tools required to support an integrated hardware/software development flow.

Tunable, Scalable, Reconfigurable, Adaptive Fault-Tolerant Onboard Processing Architectures

- Development system design tools that:
    - Take full advantage of rapid prototyping hardware-in-the-loop (HIL) environments for hybrid processing platforms.
    - Automate/accelerate the deployment of data processing and sensor interface design on flight hardware.

Technologies Enabling Custom Radiation-Hardened Component Development

- Radiation-Hardened-By-Design (RHBD) cell libraries.
- Radiation-hardened Programmable Logic Devices (PLDs) and structured ASIC devices (digital and/or mixed-signal).
- Intellectual Property (IP) cores allowing the implementation of highly reliable System-On-a-Chip (SOC) devices for spacecraft subsystems or instrument electronics. Functions of interest include processors, memory interfaces, and data bus interfaces.

Power Conversion and Distribution relevant to Command, Data Handling, and Electronics, will be covered in sub-topic S3.05 Power Management and Storage.

S3.02 Thermal Control Systems
Lead Center: GSFC
Participating Center(s): ARC, GRC, JPL, JSC, MSFC

Future Spacecraft and instruments for NASA's Science Mission Directorate will require increasingly sophisticated thermal control technology. Innovative proposals for the crosscutting thermal control discipline are sought in the following areas:

- New generations of electronics used on numerous missions have higher power densities than in the past. High conductivity, vacuum-compatible interface materials that minimize losses across make/break interfaces are needed to reduce interface temperature gradients and facilitate heat removal.
- Sensitive instruments and electronics drive increased requirements for high electrical conductivity on spacecraft surfaces. This has increased the need for advanced thermal control coatings, particularly those with low absorptance, high emittance, and good electrical conductivity. Also, variable emittance surfaces to modulate heat rejection are needed.

- Exploration science missions beyond Earth orbit present engineering challenges requiring systems that can withstand extreme temperatures ranging from high temperatures on Venus to the cryogenic temperatures of the outer planets. High performance insulation systems, which are more easily fabricated than traditional multi-layer (MLI) systems, are required for both hot and cold environments. Potential applications include traditional vacuum environments, low-pressure carbon dioxide atmospheres on Mars, and high-pressure atmospheres found on Venus. Systems that incorporate Micro-meteorite and Orbital Debris protection (MMOD) are also of interest.
- Future high-powered missions, some possibly nuclear powered, may require active cooling systems to efficiently transport large amounts of heat. These include single and two-phase mechanically pumped fluid loop systems which accommodate multiple heat sources and sinks; and long life, lightweight pumps which are capable of generating a high pressure head. It also includes efficient, lightweight, oil-less, high lift vapor compression systems or novel new technologies for high performance cooling up to 2 KW.
- Phase change systems are needed for Mars, Venus, or Lunar applications. Reusable phase change systems are desired which can be employed to absorb transient heat dissipations during instrument operations. Technology is sought for phase change systems, typically near room temperature, which can then either store this energy or provide an exothermic process that would provide heat for instrument power-on after the dormant phase.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration. Phase II should deliver a demonstration unit for NASA testing at the completion of the Phase II contract.

Note to Proposer: Subtopic X3.04 Thermal Control Systems for Human Spacecraft, under the Exploration Mission Directorate, also addresses thermal control technologies. Proposals more aligned with exploration mission requirements should be proposed in X3.04.

S3.03 Power Generation and Conversion
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC, MSFC

Future NASA science missions will employ Earth orbiting spacecraft, planetary spacecraft, balloons, aircraft, surface assets, and marine craft as observation platforms. Proposals are solicited to develop advanced power generation and conversion technologies to enable or enhance the capabilities of future science missions. Requirements for these missions are varied and include long life, high reliability, significantly lower mass and volume, higher mass specific power, and improved efficiency over the state of practice for components and systems. Other desired capabilities are high radiation tolerance and the ability to operate in extreme environments (high and low temperatures and over wide temperature ranges).

While power generation technology affects a wide range of NASA missions and operational environments, technologies that provide substantial benefits for key mission applications/capabilities are being sought in the following areas:

Radioisotope Power Conversion
Radioisotope technology enables a wide range of mission opportunities, both near and far from the Sun and hostile planetary environments including high energy radiation, both high and low temperature and diverse atmospheric chemistries. Technology innovations capable of advancing lifetimes, improving efficiency, highly tolerant to hostile environments are desired for all thermal to electric conversion technologies considered here. Specific systems of interest for this solicitation are listed below.

Stirling Power Conversion: advances in, but not limited to, the following
- System specific mass greater than 10 We/kg.
- Highly reliable autonomous control.

- Low EMI.
- High temperature, high performance materials, 850-1200 C.
- Radiation tolerant sensors, materials and electronics.

Thermoelectric Power Conversion: advances in, but not limited to, the following

- High temperature, high efficiency conversion greater than 10%.
- Long life, minimal degradation.
- Higher power density.

Photovoltaic Energy Conversion

Photovoltaic cell, blanket, and array technologies that lead to significant improvements in overall solar array performance (i.e., conversion efficiency >33%, array mass specific power >300watts/kilogram, decreased stowed volume, reduced initial and recurring cost, long-term operation in high radiation environments, high power arrays, and a wide range of space environmental operating conditions) are solicited. Technologies specifically addressing the following mission needs are highly sought:

- Photovoltaic cell and blanket technologies capable of low intensity, low-temperature operation applicable to outer planetary (low solar intensity) missions.
- Photovoltaic cell, blanket and array technologies capable of enhancing solar array operation in a high intensity, high-temperature environment (i.e., inner planetary and solar probe-type missions).
- Lightweight solar array technologies applicable to solar electric propulsion missions. Current missions being studied require solar arrays that provide 1 to 20 kilowatts of power at 1 AU, are greater than 300 watts/kilogram specific power, can operate in the range of 0.7 to 3 AU, provide operational array voltages up to 300 volts and have a low stowed volume.

Thermophotovoltaic conversion is currently focused on follow-on technology for the International Lunar Network (ILN) and for the outer planets mission. Advances sought, but not limited to, include:

- Low-bandgap cells having high efficiency and high reliability.
- High temperature selective emitters.
- Low absorptance optical band-pass filters.
- Efficient multi-foil insulation.

Note to Proposer: Topic X8 under the Exploration Mission Directorate also addresses power technologies (X8.03 Space Nuclear Power Systems, and X8.04 Advanced Photovoltaic Systems). Proposals more aligned with exploration mission requirements should be proposed in X8.

S3.04 Propulsion Systems
Lead Center: GRC
Participating Center(s): JPL, MSFC

The Science Mission Directorate (SMD) needs spacecraft with more demanding propulsive performance and flexibility for more ambitious missions requiring high duty cycles, more challenging environmental conditions, and extended operation. Planetary spacecraft need the ability to rendezvous with, orbit, and conduct in situ exploration of planets, moons, and other small bodies in the solar system (http://www.nap.edu/catalog.php?record_id=10432). Future spacecraft and constellations of spacecraft will have high-precision propulsion requirements, usually in volume- and power-limited envelopes.

This subtopic seeks innovations to meet SMD propulsion requirements, which are reflected in the goals of NASA's In-Space Propulsion Technology program to reduce the travel time, mass, and cost of SMD spacecraft. Advancements in chemical and electric propulsion systems related to sample return missions to Mars, small bodies (like asteroids, comets, and Near-Earth Objects), outer planet moons, and Venus are desired. Additional electric propulsion technology innovations are also sought to enable low cost systems for Discovery class missions, and eventually to enable radioisotope electric propulsion (REP) type missions.

The focus of this solicitation is for next generation propulsion systems and components, including high-pressure chemical rocket technologies and low cost/low mass electric propulsion technologies. Specific sample return propulsion technologies of interest include higher-pressure chemical propulsion system components, lightweight propulsion components, and Earth-return vehicle propulsion systems. Propulsion technologies related specifically to planetary ascent vehicles will be sought under S3.08 Planetary Ascent Vehicle. Propulsion technologies related specifically to Power Processing Units will be sought under S3.05 Power Management and Storage.

Chemical Propulsion Systems
Technology needs include:

- Pump or alternate pressurization technologies that provide for high-pressure operation (chamber pressures > 500 psia) of spacecraft primary propulsion systems (100- to 200-lbf class) using Earth storable or space storable bipropellants.
- Catalytic and non-catalytic ignition technologies that provide reliable ignition of high-performance (Isp > 240 sec), nontoxic monopropellants for power-limited spacecraft.

Electric Propulsion Systems
This subtopic also seeks proposals that explore uses of technologies that will provide superior performance for high specific impulse/low mass electric propulsion systems at low cost. These technologies include:

- Thrusters with efficiencies > 50% and up to 1 kW of input power that operate with a specific impulse between 1600 to 3500 seconds.
- An efficient (>60 %), dual mode thruster that is capable of operating in both high thrust (>60 mN/kW) and high specific impulse (>3000 sec) modes for a fixed power level.
- High power electric propulsion thrusters (up to 25 kW) and components including cathodes, ion optics, low sputtering materials with long life (>1x10^8 N-s), high temperature insulators with low secondary electron emission, and high temperature, low electrical resistivity wire.

Proposals should show an understanding of the state of the art, how their technology is superior, and of one or more relevant science needs. The proposals should provide a feasible plan to develop fully a technology and infuse it into a NASA program.

Note to Proposer: Topic X2 under the Exploration Mission Directorate also addresses advanced propulsion. Proposals more aligned with exploration mission requirements should be proposed in X2.

S3.05 Power Electronics and Management, and Energy Storage
Lead Center: GRC
Participating Center(s): ARC, JPL, JSC

Future NASA science objectives will include missions such as Earth Orbiting, Venus, Europa, Titan/Enceladus Flagship, Lunar Quest and Space Weather missions. Under this subtopic, proposals are solicited to develop energy storage and power electronics to enable or enhance the capabilities of future science missions. The unique requirements for the power systems for these missions can vary greatly, with advancements in components needed above the current State of the Art (SOA) for high energy density, high power density, long life, high reliability, low mass/volume, radiation tolerance, and wide temperature operation. Other subtopics that could potentially benefit from these technology developments include S5.05 – Extreme Environments Technology, and S5.01 – Planetary Entry, Descent and Landing Technology. Battery development could also be beneficial to X6.02 – Advanced Space-rated Batteries, which is investigating some similar technologies in the secondary battery area but with very different operational requirements. Power Management and Distribution could be beneficial to X8.05 – Advanced

Power Conversion, Management and Distribution (PMAD) for High Power Space Exploration Applications, which is investigating some similar technologies but at a much higher power level. This subtopic is also directly tied to S3.04 – Propulsion Systems for the development of advanced Power Processing Units and associated components.

Power Electronics and Management

The 2009 Heliophysics roadmap (http://sec.gsfc.nasa.gov/2009_Roadmap.pdf), the 2010 SMD Science Plan (http://science.nasa.gov/about-us/science-strategy/), the 2010 Planetary Decadal Survey White Papers & Roadmap Inputs (http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412), the 2011 PSD Relevant Technologies document, the 2006 Solar System Exploration (SSE) Roadmap (http://nasascience.nasa.gov/about-us/science-strategy), and the 2003 SSE Decadal Survey describe the need for lighter weight, lower power electronics along with radiation hardened, extreme environment electronics for planetary exploration. Radioisotope power systems (RPS) and Power Processing Units (PPUs) for Electric Propulsion (EP) are two programs of interest that would directly benefit from advancements in this technology area. Advances in electrical power technologies are required for the electrical components and systems for these future platforms to address program size, mass, efficiency, capacity, durability, and reliability requirements. In addition, the Outer Planet Assessment Group has called out high power density/high efficiency power electronics as needs for the Titan/Enceladus Flagship and planetary exploration missions. These types of missions, including Mars Sample Return using Hall thrusters and PPUs, require advancements in radiation hardened power electronics and systems beyond the state-of-the-art. Of importance are expected improvements in energy density, speed, efficiency, or wide-temperature operation (-125^{o} C to over 450 ^{o}C) with a number of thermal cycles. Advancements are sought for power electronic devices, components and packaging for programs with power ranges of a few watts for minimum missions to up to 20 kilowatts for large missions. In addition to electrical component development, RPS has a need for intelligent, fault-tolerant Power Management And Distribution (PMAD) technologies to efficiently manage the system power for these deep space missions.

SMD's In-space Propulsion Technology and Radioisotope Power Systems programs are direct customers of this subtopic, and the solicitation is coordinated with the 2 programs each year.

Overall technologies of interest include:

- High voltage, radiation hardened, high temperature components, such as capacitors and semiconductors, for EP PPU applications.
- High power density/high efficiency power electronics.
- High temperature devices and components/power converters (up to 450^{o} C).
- Intelligent, fault-tolerant electrical components and PMAD systems.
- Advanced electronic packaging for thermal control and electromagnetic shielding.

In addition, development is needed in the area of advanced High Voltage Transformer-Rectifier Technology Development for Advanced Cloud and Precipitation Radars, Interferometers, and other Advanced SAR applications where an integrated Transformer-Rectifier Assembly is needed to provide increased stability in the output voltages provided to the Cathode and Collector of a Vacuum Tube (EIK). This would result in increases in the RF phase stability of the output RF Pulse or current approaches. The Transformer-Rectifier Assembly should address using innovative, single-integrated body regulator designs that regulate collector vs. cathode potential, and demonstrate increasing voltage stability over other approaches. The entire Transformer-Rectifier Assembly (Cathode-Collector-Body) should be optimized to achieve maximum energy efficiency and minimum size/mass of the system taking into account necessary high voltage insulation and potting for operation in a space environment (vacuum). Of interest are assemblies that demonstrate:

- Cathode voltages in excess of -12 kV, and Collector voltage in the -3 KV ranges with Beam currents in excess of 340 mA.
- Assemblies for which the primary winding of the transformer is driven through 60VDC (full load) switched at a nominal frequency of 40.5±1.5kHz, or higher.

- Duty cycles up to 16%.

Energy Storage
Future science missions will require advanced primary and secondary battery systems capable of operating at temperature extremes from -100°C for Titan missions to 400° to 500°C for Venus missions, and a span of -230°C to +120°C for Lunar Quest. The Outer Planet Assessment Group and the 2011 PSD Relevant Technologies Document have specifically called out high energy density storage systems as a need for the Titan/Enceladus Flagship and planetary exploration missions. In addition, high energy-density rechargeable electrochemical battery systems that offer greater than 50,000 charge/discharge cycles (10 year operating life) for low-Earth-orbiting spacecraft, 20-year life for geosynchronous (GEO) spacecraft, are desired. Advancements to battery energy storage capabilities that address one or more of the above requirements for the stated missions combined with very high specific energy and energy density (>200 Wh/kg for secondary battery systems), along with radiation tolerance are of interest.

In addition to batteries, other advanced energy storage/load leveling technologies designed to the above mission requirements, such as flywheels, supercapacitors or magnetic energy storage, are of interest. These technologies have the potential to minimize the size and mass of future power systems.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II, and when possible, deliver a demonstration unit for NASA testing at the completion of the Phase II contract. Phase II emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into science-worthy systems.

Disclaimer: Technology Available (TAV) subtopics may include an offer to license NASA Intellectual Property (NASA IP) on a non-exclusive, royalty-free basis, for research use under the SBIR award. When included in a TAV subtopic as an available technology, use of the available NASA IP is strictly voluntary. Whether or not a firm uses available NASA IP within their proposal effort will not in any way be a factor in the selection for award.

Patent **6,461,944**, Methods for growth of relatively large step-free SiC crystal surfaces Neudeck, et al. October 8, 2002

Summary: A method for growing arrays of large-area device-size films of step-free (i.e., atomically flat) SiC surfaces for semiconductor electronic device applications is disclosed. This method utilizes a lateral growth process that better overcomes the effect of extended defects in the seed crystal substrate that limited the obtainable step-free area achievable by prior art processes. The step-free SiC surface is particularly suited for the heteroepitaxial growth of 3C (cubic) SiC, AlN, and GaN films used for the fabrication of both surface-sensitive devices (i.e., surface channel field effect transistors such as HEMT's and MOSFET's) as well as high-electric field devices (pn diodes and other solid-state power switching devices) that are sensitive to extended crystal defects.

S3.06 Guidance, Navigation and Control
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC

Advances in the following areas of guidance, navigation and control are sought.

Navigation systems (including multiple sensors and algorithms/estimators, possibly based on existing component technologies) that work collectively on multiple vehicles to enable inertial alignment of the formation of vehicles (i.e., pointing of the line-of-sight defined by fixed points on the vehicles) on the level of milli-arcseconds relative to the background star field.

Lightweight sensors (gyroscopic or other approach) to enable milli-arcsecond class pointing measurement for individual large telescopes and low cost small spacecraft.

Isolated pointing and tracking platforms (pointing 0.5 arcseconds, jitter to 5 milli-arcsecond), targeted to placing a scientific instrument on GEO communication satellites that can track the sun for > 3 hours/day.

Working prototypes of GN&C actuators (e.g., reaction or momentum wheels) that advance mass and technology improvements for small spacecraft use. Such technologies may include such non-contact approaches such as magnetic or gas bearings. Superconducting materials, driven by temperature conditioning may also be appropriate provided that the net power used to drive and condition the "frictionless" wheels is comparable to traditional approaches.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.07 Terrestrial and Planetary Balloons
Lead Center: GSFC
Participating Center(s): JPL

NASA's Scientific Balloons provide practical and cost effective platforms for conducting discovery science, development and testing for future space instruments, as well as training opportunities for future scientists and engineers. Balloons can reach altitudes above 36 kilometers, with suspended masses up to 3600 kilograms, and can stay afloat for several weeks. Currently, the Balloon Program is on the verge of introducing an advanced balloon system that will enable 100-day missions at mid latitudes and thus resemble the performance of a small spacecraft at a fraction of the cost. In support of this development, NASA is seeking innovative technologies in three key areas to monitor and advance the performance of this new vehicle.

Power Storage
Devices or methods to store electrical energy onboard the balloon with lower mass than current techniques are needed. Long duration balloon flights at mid-latitudes will experience up to 12 hours of darkness, during which electrical power is needed for experiments and NASA support systems. Typically, solar panels are flown to generate power during the daylight hours, and excess power is readily available. This excess power needs to be stored for use during the night. Current power storage techniques consist of rechargeable batteries that range from lead-acid to lithium-ion chemistries. Innovative alternatives to these batteries, either advanced chemistries or alternate power storage techniques such as capacitors or flywheels, which result in overall mass savings are needed. Nominal voltage levels for balloon systems are 28 volts DC, and nominal power levels can vary from 100 watts to 1000 watts. Therefore, power storage requirements range from 1000 watt-hours to 12,000 watt-hours or more. Alternative power systems that do not rely on solar panels may also be proposed. These alternative systems may use energy storage techniques such as fuel cells or flywheels, which are prepared or charged on the ground prior to flight, and then would provide continuous power throughout the flight at the power levels specified above.

Balloon Instrumentation
Devices or methods are desired to accurately measure ambient air temperature, helium gas temperature, balloon film temperatures, film strain, and tendon load. These measurements are needed to accurately model the balloon performance during a typical flight at altitudes of approximately 36 kilometers. The measurements must compensate for the effects of direct solar radiation through shielding or calculation. Minimal mass and volume are highly desired. Remote sensing of the parameters and non-invasive and non-contact approaches are also desired. The non-invasive and non-contact approaches are highly desired for the thin polyethylene film measurements used as the balloon envelope, with film thickness ranging from 0.8 to 1.5 mil. Strain measurements of these thin films via in-flight photogrammetric techniques would be beneficial. Devices or methods to accurately measure axially loaded tendons on an array of ~50 or up to 300 separate tendons during flight are of interest. Tendons are typically captured at the end fittings via individual pins with loading levels ranging from ~20 N to ~8,000 N per tendon, and

can be exposed to temperatures from room temperature to the troposphere temperatures of -90^{o}C or colder. The measurement devices must be compatible with existing NASA balloon packaging, inflation, and launch methods. These instruments must also be able to interface with existing NASA balloon flight support systems or alternatively, a definition of a data acquisition solution be provided. Support telemetry systems are not part of the this initiative; however, data from any sensors (devices) that are selected from this initiative must be able to be stored on board and/or telemetered in-flight using single-channel (two-wire) interface into existing NASA balloon flight support systems. The devices of interest shall be easily integrated and shall have minimal impact on the overall mass of the balloon system.

Low-Cost Variable Conductance Heat Pipes for Balloon Payloads

With the ever-increasing complexity of both scientific instruments and NASA mission support equipment, advanced thermal control techniques are needed. The type of advanced thermal control techniques desired are similar to those utilized on large-budget orbital and deep space payloads (variable conductance heat pipes, diode heat pipes, loop heat pipes, capillary pumped loops, heat switches, louvers), but these techniques are far more expensive to implement on balloon payloads that their limited budgets can afford. Innovative solutions are sought that would allow these more advanced thermal control measures to be utilized with reduced expense.

Though not considered "cutting-edge technology", commercial quality, constant conductance, copper-methanol heat pipes have begun to be utilized on balloon payloads to effectively move heat significant distances. The problem with these devices is that the conductance cannot effectively be reduced under cold operating or cold survival environment conditions without expending significant energy in an active heater to keep the condenser section warm. It is desirable to develop a cost-effective method of conducting the heat in this manner while allowing the flow to be reduced/eliminated when conditions warrant. Innovative thermal control techniques and devices developed must be inexpensive to implement. They must function reliably at balloon altitudes of 30-40 km and temperature ranges from -90°C to +40°C. They should require little or no energy consumption and provide the capability of moderating heat flow autonomously or by remote control under certain thermal conditions.

Planetary Balloon Technologies

Innovations in materials, structures, and systems concepts have enabled buoyant vehicles to play an expanding role in planning NASA's future Solar System Exploration Program. Balloons are expected to carry scientific payloads at Titan and Venus that will perform in situ investigations of their atmospheres and near surface environments. Both Titan and Venus feature extreme environments that significantly impact the design of balloons for those two worlds. Proposals are sought in the following areas:

Steerable Antenna for Titan and Venus Telecommunications

Many concepts for Titan and Venus balloons require high gain antennas mounted on the balloon gondola to transmit data directly back to Earth. This approach requires that the antenna remain pointed at the Earth despite the motions experienced during balloon flight. A beacon signal from the Earth will be available to facilitate pointing. Innovative concepts are sought for such an antenna and pointing system with the following characteristics: antenna diameter of 0.8 m, total mass of antenna and pointing system of $\leq$ 10 kg, power consumption for the steering system $\leq$ 5 W (avg.), pointing accuracy $\leq$ 0.5 deg (continuous), hemispheric pointing coverage (2 pi steradians), azimuthal and rotational slew rates $\geq$ 30 deg/sec. It is expected that a Phase I effort will involve a proof-of-concept experiment leading to a plan for full scale prototype fabrication and testing in Phase II. Phase II testing will need to include an Earth atmosphere balloon flight in the troposphere to evaluate the proposed design under real flight conditions.

Long-Life Ballonets for Titan Aerobots

Maintenance of a pressurized balloon shape during large altitude changes requires an internal bladder, or ballonet, that can fill and discharge atmospheric gas and thereby maintain the total gas-filled volume. Ballonets are commonplace in terrestrial blimps and airships; however, the cryogenic 85 K temperature at Titan reduces the flexibility of polymer materials and greatly increases the likelihood of pinhole defect formation over time. Innovative concepts are sought for materials and system designs of a ballonet that can function pinhole-free at 85 K for a minimum of 6 months at Titan while executing repeated altitude excursions from 100 m to 10,000 m. The proposed ballonet design should be scalable across the range of 1 to 50 m^3 in volume. Preference will be given to projects that do some cryogenic experimentation in Phase I that builds confidence in the viability of the proposed approach.

S3.08 Unmanned Aircraft and Sounding Rocket Technologies
Lead Center: GSFC
Participating Center(s): ARC, DFRC, GRC, KSC, JPL, LaRC

All proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

Unmanned Aircraft Systems
Unmanned Aircraft Systems (UAS) offer significant potential for Suborbital Scientific Earth Exploration Missions over a very large range of payload complexities, mission durations, altitudes, and extreme environmental conditions. To more fully realize the potential improvement in capabilities for atmospheric sampling and remote sensing, new technologies are needed. Scientific observation and documentation of environmental phenomena on both global and localized scales that will advance climate research and monitoring; e.g., U.S. Global Change Research Program as well as Arctic and Antarctic research activities (Ice Bridge, etc.).

NASA is increasing scientific participation to understand impacts associated with worldwide environmental changes. Capability for suborbital unmanned flight operations in either the North or South Polar Regions are limited because of technology gaps for remote telemetry capabilities and precision flight path control requirements. It is also highly desirable to have UAS ability to perform atmospheric and surface sampling.

Telemetry, Tracking and Control
Low cost over-the-horizon global communications and networks are needed. Efficient and cost effective systems that enable unmanned collaborative multi-platform Earth observation missions are desired.

Avionics and Flight Control
Precise/repeatable flight path control capabilities are needed to enable repeat path observations for Earth monitoring on seasonal and multi-year cycles. In addition, long endurance atmospheric sampling in extreme conditions (hurricanes, volcanic plumes) can provide needed observations that are otherwise not possible at this time:

- Precision flight path control solutions in smooth atmospheric conditions.
- Attitude and navigation control in highly turbulent atmospheric conditions.
- Low cost, high precision inertial navigation systems (< 0.10 degree accuracy, resolution).

UA Integrated Vehicle Health Management
- Fuel Heat/Anti-freezing.
- Unmanned platform icing detection and minimization.

Guided Dropsondes
NASA Earth Science Research activities can benefit from more capable dropsondes than are currently available. Specifically, dropsondes that can effectively be guided through atmospheric regions of interest such as volcanic plumes could enable unprecedented observations of important phenomena. Capabilities of interest include:

- Compatibility with existing dropsonde dispensing systems on NASA/NOAA P-3's, the NASA Global Hawk, and other unmanned aircraft.
- Guidance schemes, autonomous or active control.
- Cross-range performance and flight path accuracy.
- Operational considerations including airspace utilization and de-confliction.

Sounding Rockets:
The NASA Sounding Rocket Program (NSRP) provides low-cost, sub-orbital access to space in support of space and Earth sciences research and technology development sponsored by NASA and other users by providing payload development, launch vehicles, and mission support services. NASA utilizes a variety of vehicle systems comprised of military surplus and commercially available rocket motors, capable of lofting scientific payloads, up to 1300lbs, to altitudes from 100km to 1500km.

NASA launches sounding rocket vehicles worldwide, from both land-based and water-based ranges, based on the science needs to study phenomenon in specific locations.

NASA is seeking innovations to enhance capabilities and operations in the following areas:

- Autonomous vehicle environmental diagnostics system capable of monitoring flight loading (thermal, acceleration, stress/strain) for solid rocket vehicle systems.
- Location determination systems to provide over-the-horizon position of buoyant payloads to facilitate expedient location and retrieval from the ocean.
- Flotation systems, ranging from tethered flotation devices to self-encapsulation systems, for augmenting buoyancy of sealed payload systems launched from water-based launch ranges.
- High-glide parachute designs capable of deploying at altitudes above 25,000 ft to facilitate mid-air retrieval and/or fly-back/fly-to-point precision landing.

Disclaimer: Technology Available (TAV) subtopics may include an offer to license NASA Intellectual Property (NASA IP) on a non-exclusive, royalty-free basis, for research use under the SBIR award. When included in a TAV subtopic as an available technology, use of the available NASA IP is strictly voluntary. Whether or not a firm uses available NASA IP within their proposal effort will not in any way be a factor in the selection for award.

Patent **7,431,243** Guidance and Control for an Autonomous Soaring UAV, Allen, Michael J., October 7, 2008

Summary: The invention provides a practical method for UAVs to take advantage of thermals in a manner similar to piloted aircrafts and soaring birds. In general, the invention is a method for a UAV to autonomously locate a thermal and be guided to the thermal to greatly improve range and endurance of the aircraft.

TOPIC: S4 Low-Cost Small Spacecraft and Technologies

Low-Cost Small Spacecraft and Technologies This subtopic is targeted at the development of technologies and systems that can enable the realization of small spacecraft science missions. While small spacecraft have the benefit of reduced launch costs by virtue of their lower mass, they may be currently limited in performance and their capacity to provide on-orbit resources to payload and instrument systems. With the incorporation of smaller bus technologies, launch costs, as well as total life cycle costs, can continue to be reduced, while still achieving and expanding NASA's mission objectives. The Low-Cost Small Spacecraft and Technologies category is focused on the identification and development of specific key spacecraft technologies primarily in the areas of integrated avionics, attitude determination and control including de-orbit technologies, and spacecraft power generation and management. The primary thrust of this topic is directed at reducing the footprint and resources that these bus subsystems require (size, weight, and power), allowing more of these critical resources to be shifted to payload and instrument systems, and to further reduce the overall launch mass and volume requirements for small spacecraft. Note that related topics of interest to S4 Low-cost Small Spacecraft and Technologies may be found in other areas of the solicitation: S3.01 Command, Data Handling and Electronics; S3.03 Power Generation and Conversion; and S3.05 Power Management and Storage. Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program. Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and/or software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

S4.01 Unique Mission Architectures Using Small Spacecraft
Lead Center: ARC

Advancements in space technologies can now enable discussions on how small spacecraft might be used to assemble or form large space structures, which are significantly more capable than the individual spacecraft unit, while exploiting the advantages of small spacecraft such as low unit and launch costs.

This subtopic solicits technologies that include the integration of critical subsystems required to allow small spacecraft to work collaboratively to create sparse arrays, large-scale or synthetic apertures, distributed sensors or clusters of sensors, and robotic technologies which could be used in space to perform novel missions using multiple spacecraft in a coordinated fashion. These technologies could include, but are not limited to: high precision timing systems combined with high precision attitude determination and control systems, satellite-to-satellite communications technologies, autonomous systems, and small, efficient in-space propulsion technologies.

Proposers are asked to build a conceptual system/spacecraft design/operational scenario that details the architecture, components and specifications, as well as existing technology gaps necessary to replace the function of a single large spacecraft with an alternative that uses small spacecraft. Supporting analysis including cost and feasibility should be included. Phase II contract efforts should be used to simulate and prototype to the extent possible the system or further reaching subsystems detailed in Phase I.

For small spacecraft planetary missions, planetary protection requirements vary by planetary destination, and additional backward contamination requirements apply to hardware with the potential to return to Earth (e.g., as part of a sample return mission). Technologies intended for use at/around Mars, Europa (Jupiter), and Enceladus (Saturn) must be developed so as to ensure compliance with relevant planetary protection requirements. Constraints could include surface cleaning with alcohol or water, and/or sterilization treatments such as dry heat (approved specification in NPR 8020.12; exposure of hours at 115C or higher, non-functioning); penetrating radiation (requirements not yet established); or vapor-phase hydrogen peroxide (specification pending).

TOPIC: S5 Robotic Exploration Technologies

NASA is pursuing technologies to enable robotic exploration of the Solar System including its planets, their moons, and small bodies. NASA has a development program that includes technologies for the atmospheric entry, descent, and landing, mobility systems, extreme environments technology, sample acquisition and preparation for in situ experiments, and in situ planetary science instruments. Robotic exploration missions that are planned include a Europa Jupiter System mission, Titan Saturn System mission, Venus In Situ Explorer, sample return from Comet or Asteroid and lunar south polar basin and continued Mars exploration missions launching every 26 months including a network lander mission, an Astrobiology Field Laboratory, a Mars Sample Return mission and other rover missions. Numerous new technologies will be required to enable such ambitious missions. The solicitation for in situ planetary instruments can be found in the in situ instruments section of this solicitation. See URL: (http://solarsystem.nasa.gov/missions/index.cfm) for mission information. See URL: (http://marsprogram.jpl.nasa.gov/) for additional information on Mars Exploration technologies. Planetary protection requirements vary by planetary destination, and additional backward contamination requirements apply to hardware with the potential to return to Earth (e.g., as part of a sample return mission). Technologies intended for use at/around Mars, Europa (Jupiter), and Enceladus (Saturn) must be developed so as to ensure compliance with relevant planetary protection requirements. Constraints could include surface cleaning with alcohol or water, and/or sterilization treatments such as dry heat (approved specification in NPR 8020.12; exposure of hours at 115C or higher, non-functioning); penetrating radiation (requirements not yet established); or vapor-phase hydrogen peroxide (specification pending).

S5.01 Planetary Entry, Descent and Landing Technology
Lead Center: JPL
Participating Center(s): ARC, JSC, LaRC

NASA seeks innovative sensor technologies to enhance success for entry, descent and landing (EDL) operations on missions to Mars. This call is not for sensor processing algorithms. Sensing technologies are desired that determine the entry point of the spacecraft in the Mars atmosphere; provide inputs to systems that control spacecraft trajectory, speed, and orientation to the surface; locate the spacecraft relative to the Martian surface; evaluate potential hazards at the landing site; and determine when the spacecraft has touched down. Appropriate sensing technologies for this topic should provide measurements of physical forces or properties that support some aspect of EDL operations. NASA also seeks to use measurements made during EDL to better characterize the Martian atmosphere, providing data for improving atmospheric modeling for future landers. Proposals are invited for innovative sensor technologies that improve the reliability of EDL operations.

Products or technologies are sought that can be made compatible with the environmental conditions of spaceflight, the rigors of landing on the Martian surface, and planetary protection requirements. Successful candidate sensor technologies can address this call by:

- Providing critical measurements during the entry phase (e.g., pressure and/or temperature sensors embedded into the aeroshell).
- Improving the accuracy on measurements needed for guidance decisions (e.g., surface relative velocities, altitudes, orientation, localization).
- Extending the range over which such measurements are collected (e.g., providing a method of imaging through the aeroshell, or terrain-relative navigation that does not require imaging through the aeroshell).
- Enhancing the situational awareness during landing by identifying hazards (rocks, craters, slopes), or providing indications of approach velocities and touchdown.
- Substantially reducing the amount of external processing needed to calculate the measurements.
- Significantly reducing the impact of incorporating such sensors on the spacecraft in terms of volume, mass, placement, or cost.
- Providing testbeds (e.g., free-flying vehicles) for closed-loop testing of GNC sensors and technologies used in the powered descent landing phase.

For a sample return mission, monitoring local environmental (weather) conditions on the surface just prior to planetary ascent vehicle launch, via appropriate low-mass sensors.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.02 Sample Collection, Processing, and Handling
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC

Robust systems for sample acquisition, handling and processing are critical to the next generation of robotic explorers for investigation of planetary bodies (http://books.nap.edu/openbook.php?record_id=10432&page=R1). Limited spacecraft resources (power, volume, mass, computational capabilities, and telemetry bandwidth) demand innovative, integrated sampling systems that can survive and operate in challenging environments (e.g., extremes in temperature, pressure, gravity, vibration and thermal cycling). Special interest lies in sampling systems and components (actuators, gearboxes, etc.) that are suitable for use in the extremely hot high-pressure environment at the Venusian surface (460ºC, 93 bar), as well as for asteroids and comets. Relevant systems could be integrated on multiple platforms, however of primary interest are samplers that could be mounted on a mobile platform, such as a rover. For reference, current Mars-relevant rovers range in mass from 200 - 800 kg.

Sample Acquisition
Research should be conducted to develop compact, low-power, lightweight subsurface sampling systems that can obtain 1 cm diameter cores of consolidated material (e.g., rock, icy regolith) up to 10 cm below the surface. Systems should be capable of autonomously acquiring and ejecting samples reliably, with minimal physical alteration of samples. Also of interest are methods of autonomously exposing rock interiors from below weathered rind layers. Other sample types of interest are unconsolidated regolith, dust, and atmospheric gas. Asteroid and comet samplers are also of interest.

Sample Manipulation (e.g., core management, sub-sampling/sorting, powder transport)
Sample manipulation technologies are needed to enable handling and transfer of structured and unstructured samples from a sampling device to instruments and sample processing systems. Core, cuttings, and regolith samples may be variable in size and composition, so a sample manipulation system needs to be flexible enough to handle the sample variability. Core samples will be on the order of 1 cm diameter and up to 10 cm long. Soil and rock fragment samples will be of similar volumes.

Sample Integrity (e.g., encapsulation and contamination control)
For a sample return mission, it is critical to find solutions for maintaining physical integrity of the sample during the surface mission (rover driving loads, diurnal temperature fluctuations) as well as the return to Earth (cruise, atmospheric entry and impact). Technologies are needed for characterizing state of sample in situ - physical integrity (e.g., cracked, crushed), sample volume, mass or temperature, as well as retention of volatiles in solid (core, regolith) samples, and retention of atmospheric gas samples.

Also of particular need are means of acquiring subsurface rock and regolith samples with minimum contamination. This contamination may include contaminants in the sampling tool itself, material from one location contaminating samples collected at another location (sample cross-contamination), or Earth-source microorganisms brought to the Martian surface prior to drilling ('clean' sampling from a 'dirty' surface). Consideration should be given to use of materials and processes compatible with 110 - 125°C dry heat sterilization. In situ sterilization may be explored, as well as innovative mechanical or system solutions - e.g., single-use sample "sleeves," or fully-integrated sample acquisition and encapsulation systems.

For a sample return mission, solutions are sought for sample transfer of a payload into a planetary ascent vehicle including automated payload transfer mechanisms and Orbiting Sample (OS) sealing techniques.

Sample Return Facility capabilities
Technologies are needed for terrestrial handling of returned samples, including sample quarantine, biological activity and biohazard assessment, techniques for performing sample science.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program. Technical feasibility should be demonstrated during Phase I and a full capability unit of at least TRL 4 should be delivered in Phase II.

S5.03 Surface and Subsurface Robotic Exploration
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC, LaRC

Technologies are needed to enable access, mobility, and sample acquisition at surface and subsurface sampling sites of scientific interest on Mars, Venus, small planetary bodies, and the moons of Earth, Mars, Jovian and Saturnian systems.

For planetary bodies where gravity dominates, such as the Moon and Mars, many scientifically valuable sites are accessible only via terrain that is too difficult for state-of-the-art planetary rovers to traverse in terms of ground slope, rock obstacle size, plateaus, and non-cohesive soils types. Sites include crater walls, canyons, gullies, sand dunes, and high rock density regions. Tethered systems, non-wheeled systems, and marsupial systems are examples of mobility technologies that are of interest. Mars is particularly interested in fast traverse capabilities aimed at a fetch rover that would potentially need to travel a long distance to retrieve a sample cache deposited by a prior mission. For small planetary bodies with micro-gravity environments, novel access systems are desired to enable exploration and sample acquisition. Small body missions include Comet Surface Sample Return, Cryogenic Comet Sample Return, and asteroid Trojan Tour and Rendezvous.

For surface and subsurface sampling, advanced manipulation technologies are needed to deploy instruments and tools from spacecraft, landers and rovers. Technologies to enable acquisition of subsurface samples are also needed. Technologies are needed to acquire core samples in the shallow subsurface to about 10cm and to enable subsurface sampling in multiple holes at least 1 - 3 meters deep through rock, regolith, or ice compositions. For Europa, penetrators and deployment systems to allow deep drilling are needed to sample and bore the outer water-ice layer and through 10 to 30km to a potential liquid ocean below.

Innovative component technologies for low-mass, low-power, and modular systems tolerant to the in situ environment are of particular interest, e.g., for Europa, the radiation environment is estimated at 2.9 Mrad total ionizing dose (TID) behind 100 mil thick aluminum. Technical feasibility should be demonstrated during Phase I and a full capability unit of at least TRL level 4 should be delivered in Phase II. Specific areas of interest include the following.

- Steep terrain adherence for vertical and horizontal mobility.
- Tether play-out and retrieval systems including tension and length sensing.
- Low-mass tether cables with power and communication.
- Sampling system deployment mechanisms such as tethers, booms, and manipulators.
- Low mass/power vision systems and processing capabilities that enable faster surface traverse while maintaining safety over a wide range of surface environments.
- Modular actuators with 1000:1 scale gear ratios.
- Electro-mechanical couplers to enable change out of instruments at the end of a manipulator.s
- Autonomy to enable adaptation of exploration to new conditions.

Proposals should show an understanding of relevant science needs and engineering constraints and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.04 Spacecraft Technology for Sample Return Missions
Lead Center: GRC
Participating Center(s): ARC, DFRC, JPL, LaRC, MSFC

NASA plans to perform sample return missions from a variety of targets including Mars, outer planet moons, and small bodies such as asteroids and comets. In terms of spacecraft technology, these types of targets present a variety challenges. Some targets, such as Mars and some moons, have relatively large gravity wells and will require ascent propulsion. Other targets are small bodies with very complex geography and very little gravity, which present difficult navigational and maneuvering challenges. In addition, the spacecraft will be subject to extreme environmental conditions including low temperatures (120K or below), dust, and ice particles. Technology innovations should either enhance vehicle capabilities (e.g., increase performance, decrease risk, and improve environmental operational margins) or ease mission implementation (e.g., reduce size, mass, power, cost, increase reliability, or increase autonomy). Specific areas of interest are listed below.

SMD's In-Space Propulsion Technology (ISPT) program is a direct customer of this subtopic, and the solicitation is coordinated with the ISPT program each year. The ISPT program views this subtopic (and the previous Planetary Ascent Vehicle subtopic) as a fertile area for providing possible Phase III efforts. Many of the Planetary Decadal

Survey white papers/studies evaluating technologies needed for various planetary, small body, and sample return missions refer to the need for sample return spacecraft technologies.

Small body missions:

- Autonomous operation.
- Terrain based navigation.
- Guidance and control technology for landing and touch-and-go.
- Anchoring concepts for asteroids.
- Propulsion technology for proximity or landed operations.
- Low temperature capable non-contaminating propellants.
- Surface manipulation technologies (e.g., rakes, drills, etc.).
- Concept to obtain a stratified subsurface comet core sample.
- Sample mass, volume, ice content verification.
- Hermetic sample sealing concepts.
- Low power long life cryogenic sample storage.

Mars and other larger bodies:

- Applicable propulsion technologies for ascent vehicles and for the return to Earth.
- Erection mechanisms for setting azimuth and elevation of the Mars Ascent Vehicle.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.05 Extreme Environments Technology
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC, MSFC

High-Temperature, High-Pressure, and Chemically-Corrosive Environments
NASA is interested in expanding its ability to explore the deep atmosphere and surface of Venus through the use of long-lived (days or weeks) balloons and landers. Survivability in extreme high-temperatures and high-pressures is also required for deep atmospheric probes to giant planets. Proposals are sought for technologies that enable the in situ exploration of the surface and deep atmosphere of Venus and the deep atmospheres of Jupiter or Saturn for future NASA missions. Venus features a dense, CO_2 atmosphere completely covered by sulfuric acid clouds at about 55 km above the surface, a surface temperature of about 486^{o} Centigrade and a surface pressure of about 90 bars. Technologies of interest include high-temperature and acid resistant high strength-to-weight textile materials for landing systems (balloons, parachutes, tethers, bridles, airbags), high-temperature electronics components, high-temperature energy storage systems, light-mass refrigeration systems, high-temperature actuators and gear boxes for robotic arms and other mechanisms, high-temperature drills, phase change materials for short term thermal maintenance, low-conductivity and high-compressive strength insulation materials, high-temperature optical window systems (that are transparent in IR, visible and UV wavelengths) and advanced materials with high-specific-heat-capacity and high-specific-strength for pressure vessel construction, and pressure vessel components compatible with materials such as steal, titanium and beryllium for applications like low leak rate wide-temperature (-50^{o} Centigrade C to 500^{o} Centigrade) seals capable of operating between 0 and 90 bars.

Low-Temperature Environments
Low-temperature survivability is required for surface missions to Titan (-180^{o} Centigrade), Europa (-220^{o} Centigrade), Ganymede (-200^{o} Centigrade) and comets. Also the Earth's Moon equatorial regions experience wide temperature swings from -180^{o} Centigrade to +130^{o} Centigrade during the lunar day/night cycle, and the sustained temperature at the shadowed regions of lunar poles can be as low as -230^{o} Centigrade. Mars diurnal temperature

changes from about -120^{o} Centigrade to +20^{o} Centigrade. Also for the baseline concept for Europa Jupiter System Mission (EJSM), with a mission life of 10 years, the radiation environment is estimated at 2.9 Mega-rad total ionizing dose (TID) behind 100 mil thick aluminum. Proposals are sought for technologies that enable NASA's long duration missions to low-temperature and wide-temperature environments. Technologies of interests include low-temperature-resistant high strength-weight textiles for landing systems (parachutes, air bags), low-power and wide-operating-temperature radiation-tolerant /radiation hardened RF electronics, radiation-tolerant/radiation-hardened low-power/ultra-low-power wide-operating-temperature low-noise mixed-signal electronics for space-borne system such as guidance and navigation avionics and instruments, low-temperature radiation-tolerant/radiation-hardened power electronics, low-temperature radiation-tolerant/radiation-hardened high-speed fiber optic transceivers, low-temperature and thermal-cycle-resistant radiation-tolerant/radiation-hardened electronic packaging (including shielding, passives, connectors, wiring harness and materials used in advanced electronics assembly), low to medium power actuators, gear boxes, lubricants and energy storage sources capable of operating across an ultra-wide temperature range from -230^{o} Centigrade to 200^{o} Centigrade and Computer Aided Design (CAD) tools for modeling and predicting the electrical performance, reliability, and life cycle for wide-temperature electronic/electro-mechanical systems and components.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware/software demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

S5.06 Planetary Protection
Lead Center: JPL
Participating Center(s): LaRC

Technologies intended for use at/around Mars, Europa (Jupiter), and Enceladus (Saturn) must be developed so as to ensure compliance with relevant planetary protection requirements. NASA seeks innovative technologies to facilitate meeting Forward and Backward Contamination Planetary Protection objectives especially for a potential Mars Sample Return (MSR) mission and to facilitate Forward Planetary Protection implementation for a potential mission to Europa.

Backward Contamination Planetary Protection deals with the possibility that Mars (or other planetary) material may pose a biological threat to the Earth’s biosphere. This leads to a constraint that returned samples of Mars material be contained with extraordinary robustness until they can be tested and proved harmless or be sterilized by an accepted method. Achieving this containment goal will require new technology for several functions. Containment assurance requires “breaking the chain of contact” with Mars: the exterior of the sample container must not be contaminated with Mars material. Also, the integrity of the containment must be verified, the sample container and its seals must survive the worst-case Earth impact corresponding to the candidate mission profile, and the Earth entry vehicle (EEV) must withstand the thermal and structural rigors of Earth atmosphere entry - all with an unprecedented degree of confidence.

Backward Contamination Planetary Protection technologies for the following MSR functions are included in this call:

- Container Design, Sealing, & Verification: Options for sealing the sample container include (but are not limited to) brazing, explosive welding, and various types of soft seals, with sealing performed either on the Mars surface or in orbit. Confirmation of sealing can be provided by observation of sealing system parameters and by leak detection after sealing. Wireless data and power transmission may be needed to support such leak detection technologies. Additional containment using a flexible liner within the EEV that is sealed while in Mars orbit has also been considered. Further validation prior to Earth entry may also be needed.
- Breaking-the-Chain & Dust Mitigation: Several paths have been identified that would result in Mars material contaminating the outside of the sealed sample container and/or the Earth return vehicle (ERV).

Technology options for mitigation include ejection of containment layers during ascent and orbit and/or capturing a contaminated “Orbiting Sample” into a clean container on the ERV and then ejecting the capture device.

- Meteoroid Protection & Breach Detection: Protection is required for both the sample container and the EEV heat shield. New lightweight shielding techniques are needed. Even with these, there may be a requirement for technology to detect a breach of the shield or damage to the EEV.

Forward Contamination Planetary Protection technologies are desired, particularly for Mars and Europa missions that allow sterilization of previously non-sterilizable flight hardware by either i) dry heat processing or ii) gamma/e-beam irradiation. NASA also seeks to use iii) hydrogen peroxide vapor processes for resterilization of assembled flight hardware elements. Proposals are invited for innovative approaches to sterilization of flight hardware in the pre-flight environment using this technology. Note: this call is not for novel sterilization processes. For Europa, products and technologies are sought that can be demonstrated to be compatible with the three identified sterilization processes, as well as the environmental conditions of spaceflight and the Jovian system.

Candidate technologies for the following functions and capabilities are included in this call:

- Sterilization Process Compatibility: Options for proving compatibility of novel product elements (materials, parts) with recognized spacecraft sterilization process parameters are desired.
- Redesign for Sterilization: Development of alternative solutions for spacecraft hardware is needed where there are known sterilization process incompatibilities. Current planning is to facilitate system-level sterilization of spacecraft, so heat tolerant technology solutions for sensors, seals (battery, valve), optical coatings, etc., are highly desired.
- Biobarrier Technology: Demonstration of novel biobarrier and recontamination prevention approaches for spacecraft hardware is needed when applying one or more of these three sterilization processes.

Proposals should show an understanding of one or more relevant technology needs and present a feasible plan to fully develop a technology and infuse it into a NASA program.

TOPIC: S6 Information Technologies

NASA Missions and Programs create a wealth of science data and information that are essential to understanding our Earth, our solar system and the universe. Advancements in information technology will allow many people within and beyond the Agency to more effectively analyze and apply these data to create knowledge. In particular, modeling and simulation are being used more pervasively throughout NASA, for both engineering and science pursuits, than ever before. These are tools that allow high fidelity simulations of systems in environments that are difficult or impossible to create on Earth, allow removal of humans from experiments in dangerous situations, and provide visualizations of datasets that are extremely large and complicated. In many of these situations, assimilation of real data into a highly sophisticated physics model is needed. Information technology is also being used to allow better access to science data, more effective and robust tools for analyzing and manipulating data, and better methods for collaboration between scientists or other interested parties. The desired end result is to see that NASA science information be used to generate the maximum possible impact to the nation: to advance scientific knowledge and technological capabilities, to inspire and motivate the nation's students and teachers, and to engage and educate the public.

S6.01 Technologies for Large-Scale Numerical Simulation
Lead Center: ARC
Participating Center(s): GSFC

NASA scientists and engineers are increasingly turning to large-scale numerical simulation on supercomputers to advance understanding of complex Earth and astrophysical systems, and to conduct high-fidelity aerospace engineering analyses. The goal of this subtopic is to increase the mission impact of NASA's investments in supercomputing systems and associated operations and services. Specific objectives are to:

- Decrease the barriers to entry for prospective supercomputing users.
- Minimize the supercomputer user's total time-to-solution (e.g., time to discover, understand, predict, or design).
- Increase the achievable scale and complexity of computational analysis, data ingest, and data communications.
- Reduce the cost of providing a given level of supercomputing performance on NASA applications.
- Enhance the efficiency and effectiveness of NASA's supercomputing operations and services.

Expected outcomes are to improve the productivity of NASA's supercomputing users, broaden NASA's supercomputing user base, accelerate advancement of NASA science and engineering, and benefit the supercomputing community through dissemination of operational best practices.

The approach of this subtopic is to seek novel software and hardware technologies that provide notable benefits to NASA's supercomputing users and facilities, and to infuse these technologies into NASA supercomputing operations. Successful technology development efforts under this subtopic would be considered for follow-on funding by, and infusion into, NASA's high-end computing (HEC) projects: the High End Computing Capability project at Ames and the Scientific Computing project at Goddard. To assure maximum relevance to NASA, funded SBIR contracts under this subtopic should engage in direct interactions with one or both HEC projects, and with key HEC users where appropriate. Research should be conducted to demonstrate technical feasibility and NASA relevance during Phase I and show a path toward a Phase II prototype demonstration.

Offerors should demonstrate awareness of the state-of-the-art of their proposed technology, and should leverage existing commercial capabilities and research efforts where appropriate. Open Source software and open standards are strongly preferred. Note that the NASA supercomputing environment is characterized by: HEC systems operating behind a firewall to meet strict IT security requirements, communication-intensive applications, massive computations requiring high concurrency, complex computational workflows and immense datasets, and the need to support hundreds of complex application codes – many of which are frequently updated by the user/developer. As a result, solutions that involve the following must clearly explain how they would work in the NASA environment: Grid computing, web services, client-server models, embarrassingly parallel computations, and technologies that require significant application re-engineering. Projects need not benefit all NASA HEC users or application codes, but demonstrating applicability to an important NASA discipline, or even a key NASA application code, could provide significant value.

Specific technology areas of interest:

Efficient Computing
In spite of the rapidly increasing capability and efficiency of supercomputers, NASA's HEC facilities cannot purchase, power, and cool sufficient HEC resources to satisfy all user demands. This subtopic element seeks dramatically more efficient and effective supercomputing approaches in terms of their ability to supply increased HEC capability or capacity per dollar and/or per Watt for real NASA applications. Examples include:

- Novel computational accelerators and architectures.
- Enhanced visualization technologies.
- Improved algorithms for key codes.
- Power-aware "Green" computing technologies and techniques.
- Systems (including both hardware and software) for data-intensive computing.
- Approaches to effectively manage and utilize many-core processors including algorithmic changes, compiler techniques and runtime systems.

User Productivity Environments
The user interface to a supercomputer is typically a command line in a text window. This subtopic element seeks more intuitive, intelligent, user-customizable, and integrated interfaces to supercomputing resources, enabling users to more completely leverage the power of HEC to increase their productivity. Such an interface could enhance many essential supercomputing tasks: accessing and managing resources, training, getting services, developing codes (e.g., debugging and performance analysis), running computations, managing files and data, analyzing and visualizing results, transmitting data, collaborating, etc.

Cloud Supercomputing
Cloud computing has made tremendous promises, and demonstrated some success, for business computing. For operations, potential benefits include: resource virtualization, incremental and transparent provisioning, enhanced resource consolidation and utilization, automated resource management, automated job migration, and increased service availability, and others. For users, potential benefits include: out-sourced operations, on-demand resource availability, increased service reliability, customized software environments, a web user interface, and more. This subtopic element seeks technologies that enable Cloud computing to be used for efficient and effective supercomputing operations and services.

S6.02 Earth Science Applied Research and Decision Support
Lead Center: SSC
Participating Center(s): ARC, DFRC, JPL

The NASA Applied Sciences Program (http://nasascience.nasa.gov/earth-science/applied-sciences) seeks innovative and unique approaches to increase the utilization and extend the benefit of Earth Science research data to better meet societal needs. One area of interest is new decision support tools and systems for a variety of ecological applications such as managing coastal environments, natural resources or responding to natural disasters.

This subtopic seeks proposals for utilities, plug-ins or enhancements to geobrowsers that improve their utility for Earth science research and decision support. Examples of geobrowsers include Google Earth, Microsoft Virtual Earth, NASA World Wind (http://worldwindcentral.com/wiki/Main_page) and COAST (http://www.coastal.ssc.nasa.gov/coast/COAST.aspx). Examples include, but are not limited to, the following:

- Visualization of high-resolution imagery in a geobrowser.
- Enhanced geobrowser animation capabilities to provide better visual-analytic displays of time-series and change-detection products.
- Discovery and integration of content from web-enabled sensors.
- Discovery and integration of new datasets based on parameters identified by the user and/or the datasets currently in use.
- Innovative mechanisms for collaboration and data layer sharing.
- Applications that subset, filter, merge, and reformat spatial data.

This subtopic also seeks proposals for advanced information systems and decision environments that take full advantage of multiple data sources and platforms. Special consideration will be given to proposals that provide enhancements to existing, broadly used decision support tools or platforms. Tailored and timely products delivered to a broad range of users are needed to protect vital ecosystems such as coastal marshes, barrier islands and seagrass beds; monitor and manage utilization of critical resources such as water and energy; provide quick and effective response to manmade and natural disasters such as oil spills, earthquakes, hurricanes, floods and wildfires; and promote sustainable, resilient communities and urban environments.

Proposals shall present a feasible plan to fully develop and apply the subject technology.

S6.03 Algorithms and Tools for Science Data Processing, Discovery and Analysis, in State-of-the-Art Data Environments
Lead Center: GSFC
Participating Center(s): ARC, JPL, LaRC, MSFC, SSC

This subtopic seeks technical innovation and unique approaches for the processing, discovery and analysis of data from NASA science missions. Advances in such algorithms will support science data analysis and decision support systems related to current and future missions, and will support mission concepts for:

- All current operational missions (http://www.nasa.gov/missions/current/index.html).
- Future Earth Science Decadal Survey missions (http://science.nasa.gov/earth-science/decadal-surveys).
- The Landsat Data Continuity Mission (LDCM) (http://ldcm.nasa.gov/).
- The Joint Polar Satellite System (JPSS) (http://www.nesdis.noaa.gov/pdf/jpss.pdf).
- The Lunar Reconnaissance Orbiter mission (LRO) (http://lunar.gsfc.nasa.gov/).
- The Moon Mineralogy Mapper (M3) on Chandrayaan (http://moonmineralogymapper.jpl.nasa.gov/).
- The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) (http://crism.jhuapl.edu).
- The Visual Infrared Mapping Spectrometer (VIMS) on Cassini (http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassinivims/).
- The James Webb Space Telescope (JWST) (http://www.jwst.nasa.gov/).

Research proposed to this subtopic should demonstrate technical feasibility during Phase I, and in partnership with scientists show a path toward a Phase II prototype demonstration, with significant communication with missions and programs to ensure a successful Phase III infusion. It is highly desirable that the proposed projects lead to software that is infused into NASA programs and projects.

In the area of algorithms, innovations are sought in the following areas:

- Optimization of algorithms and computational methods to increase the utility of scientific research data for models, data assimilation, simulations, and visualizations. Success will be measured by both speed improvements and output validation.
- Improvement of data discovery, by identifying data gaps in real-time, and/or derive information through synthesis of data from multiple sources. The ultimate goal is to increase the value of data collected in terms of scientific discovery and application.
- Techniques for data analysis, that focus on data mining, data search, data fusion and data subsetting that scale to extremely large data sets in cloud, large cluster, or distributed computing environments.

In the area of tools, innovations are sought in the following areas:

- Frameworks and related tools such as open source frameworks or framework components that would enable sharing and validation of tools and algorithms.
- Integrated ecosystem of tools for developing and monitoring applications for high performance processing environments, including cloud computing, high performance cluster, and GPU processing environments, that support software development for science data discovery applications, including support for compilation, debugging, and parallelization.
- Integrated tools to collect, analyze, store, and present performance data for cloud computing and large scale cluster environments, including tools to collect data throughput of system hardware and software components such as node and network interconnects (GbE, 10 GbE, and Infiniband), storage area networks, and disk subsystems, and to allow extensibility for new metrics, and verification of the configuration and health of a system.

Tools and products developed under this subtopic may be used for broad public dissemination or within a narrow scientific community. These tools can be plug-ins or enhancements to existing software, on-line data/computing services, or new stand-alone applications or web services, provided that they promote interoperability and use standard protocols, file formats and Application Programming Interfaces (APIs) or prevalent applications. When appropriate, compliance with the FDGC (Federal Geographic Data Committee) and OGC (Open Geospatial Consortium) is recommended.

S6.04 Integrated Mission Modeling for Opto-mechanical Systems
Lead Center: GSFC
Participating Center(s): ARC

NASA seeks innovative systems engineering modeling methodologies and tools to define, develop and execute future science missions, many of which are likely to feature designs and operational concepts that will pose significant challenges to existing approaches and applications.

Specific areas of interest include the following:

Low-cost Model-Based Systems Engineering (MBSE) methodologies (defined as some combination of tools, methods, and processes - refer to the "INCOSE Survey of MBSE Methodologies") for rapid and agile definition of mission architectures during the conceptual design phase. Here, "low-cost" is intended to capture multiple aspects of the investment in the methodology, including initial purchase, maintenance, and training/learning-curve. These methodologies must support requirements analysis, functional decomposition, definition of verification and validation methods, and analysis of system behavior and performance. Development of methods and applications based on, or supporting, standards such as UML and SysML is highly encouraged, as is tight integration with Microsoft Office and Microsoft Project.

Interfaces between existing (or proposed) MBSE tools and CAD/CAE/PM applications used to support NASA science mission development, which typically include (but are not limited to): Pro/E, NX, NASTRAN, ANSYS, ABAQUS, ADAMS (for MCAD and structural/mechanical systems analysis); TSS, SINDA, Thermal Desktop, TMG (for thermal systems analysis); Code V, ZEMAX, OSLO (for optical systems analysis); Hyperlynx Analog, Hyperlynx GHz, System Vision, DxDesigner, ModelSim (for ECAD and electrical systems analysis); Matlab, Simulink, STK (for guidance, navigation and control systems analysis); Excel, MathCAD, Mathematica (for general purpose numerical and symbolic analysis); DOORS (for requirements management); PRICE-H, SEER, SSCM, COSYSMO (for cost modeling)

S6.05 Fault Management Technologies
Lead Center: MSFC
Participating Center(s): ARC, JPL

As science missions are given increasingly complex goals and have more pressure to reduce operations costs, system autonomy increases. Fault Management (FM) is one of the key components of system autonomy. FM consists of the operational mitigations of spacecraft failures. It is implemented with spacecraft hardware, on-board autonomous software that controls hardware, software, information redundancy, and ground-based software and operations procedures.

Many recent Science Mission Directorate (SMD) missions have encountered major cost overruns and schedule slips during test and verification of FM functions. These overruns are due to a lack of understanding of FM functions early in the mission definition cycles, and to FM architectures that do not provide attributes of transparency, verifiability, fault isolation capability, or fault coverage. The NASA FM Handbook is under development to improve the FM design, development, verification & validation and operations processes. FM approaches, architectures, and tools are needed to improve early understanding of needed FM capabilities by project managers and FM engineers, and to improve the efficiency of implementing and testing FM.

Specific objectives are to:

- Improve ability to predict FM system complexity and estimate development and operations costs.
- Enable cost-effective FM design architectures and operations.
- Determine completeness and appropriateness of FM designs and implementations.
- Decrease the labor and time required to develop and test FM models and algorithms.
- Improve visualization of the full FM design across hardware, software, and operations procedures.
- Determine extent of testing required, completeness of verification planned, and residual risk resulting from incomplete coverage.
- Increase data integrity between multi-discipline tools.
- Standardize metrics and calculations across FM, SE, S&MA and operations disciplines.
- Increase reliability of FM systems.

Expected outcomes are better estimation and control of FM complexity and development costs, improved FM designs, and accelerated advancement of FM tools and techniques.

The approach of this subtopic is to seek the right balance between sufficient reliability and cost appropriate to the mission type and risk posture. Successful technology development efforts under this subtopic would be considered for follow-on funding by, and infusion into, SMD missions. Research should be conducted to demonstrate technical feasibility and NASA relevance during Phase I and show a path toward a Phase II prototype demonstration.

Offerors should demonstrate awareness of the state-of-the-art of their proposed technology, and should leverage existing commercial capabilities and research efforts where appropriate.
Specific technology in the forms listed below is needed to increase delivery of high quality FM systems. These approaches, architectures and tools must be consistent with and enable the NASA FM Handbook concepts and processes.

- FM design tools: System modeling and analyses significantly contributes to the quality of FM design; however, the time it takes to translate system design information into system models often decreases the value of the modeling and analysis results. Examples of enabling techniques and tools are modeling automation, spacecraft modeling libraries, expedited algorithm development, sensor placement analyses, and system model tool integration.
- FM visualization tools: FM systems incorporate hardware, software, and operations mechanisms. The ability to visualize the full FM system and the contribution of each mechanism to protecting mission functions and assets is critical to assessing the completeness and appropriateness of the FM design to the mission attributes (mission type, risk posture, operations concept, etc.). Fault trees and state transition diagrams are examples of visualization tools that could contribute to visualization of the full FM design.
- FM verification and validation tools: As complexity of spacecraft and systems increases, the extensiveness of testing required to verify and validate FM implementations can be resource intensive. Automated test case development, false positive/false negative test tools, model verification and validation tools, and test coverage risk assessments are examples of contributing technologies.
- FM Design Architectures: FM capabilities may be implemented through numerous system, hardware, and software architecture solutions. The FM architecture trade space includes options such as embedded in the flight control software or independent onboard software; on board versus ground-based capabilities; centralized or distributed FM functions; sensor suite implications; integration of multiple FM techniques; innovative software FM architectures implemented on flight processors or on Field Programmable Gate Arrays (FPGAs); and execution in real-time or off-line analysis post-operations. Alternative architecture choices could help control FM system complexity and cost and could offer solutions to transparency, verifiability, and completeness challenges.

Multi-discipline FM Interoperation: FM designers, Systems Engineering, Safety and Mission Assurance, and Operations perform analyses and assessments of reliabilities, failure modes and effects, sensor coverage, failure probabilities, anomaly detection and response, contingency operations, etc. The relationships between multi-discipline data and analyses are inconsistent and misinterpreted. Resources are expended either in effort to resolve disconnects in data and analyses or worse, reduced mission success due to failure modes that were overlooked. Solutions that address data integrity, identification of metrics, and standardization of data products, techniques and analyses will reduce cost and failures.

9.1.4 SPACE OPERATIONS

The Space Operations Mission Directorate (SOMD) provides the foundation for NASA's space programs — space travel for human and robotic missions, in-space laboratories, processing and operations of space systems, and the means to return data to the Earth. The directorate provides the daily operational capabilities for the agency. These capabilities: Space Communications; Space Transportation; Processing and Operations; Navigation; and International Space Station (ISS) operations must continue to evolve synergistically as the directorate guides their development and enhancement. In addition, as NASA programs develop new mission requirements and capabilities, potentially varying in size and complexity from micro satellites to manned missions, SOMD's operational capability will evolve to include these new enhancements. In summary, the Space Operations Mission Directorate provides space access and operations for our customers with a high standard of safety, reliability, and affordability.

The Space Operations Mission Directorate supports the NASA mission by focusing its SBIR efforts around four key technology areas: 1) Space Communications; 2) Space Transportation; 3) Processing and Operations; and 4) Navigation. These areas contain numerous development opportunities for innovators to impact and enable efficient and affordable technology developments for: communications and navigation; human operation in space; science missions; space access services and cost reduction; ISS utilization; ISS Life Extension; daily system operations; cubesat technologies and many more. We go forward as explorers and as scientists to understand the universe in which we live.

(http://www.nasa.gov/directorates/somd/home/index.html)

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TOPIC: O1 Space Communications

NASA's communications capability is based on the premise that communications shall enable and not constrain missions. Communications must be robust to support the numerous missions for space science, Earth science and exploration of the universe. Technologies such as optical communications, RF including antennas and ground based Earth stations, surface networks, cognitive networks, access links, reprogrammable communications systems, advanced antenna technology, transmit array concepts, and communications in support of launch services including space based assets are very important to the future of exploration and science activities of the Agency. Emphasis is placed on size, weight and power improvements, and even greater emphasis is placed on these attributes as small satellites (e.g., micro and nano satellite) technology matures. Communication technologies enabling acquisition of range safety data from sensitive instruments is imperative. Innovative solutions centered on operational issues are needed in all of the aforementioned areas. All technologies developed under this topic area to be aligned with the Architecture Definition Document and technical direction as established by the NASA Office of Space Communications and Navigation (SCaN). For more details, see: (https://www.spacecomm.nasa.gov/spacecomm/ https://www.spacecomm.nasa.gov/spacecomm/programs/default.cfm, https://www.spacecomm.nasa.gov/spacecomm/programs/technology/default.cfm, https://www.spacecomm.nasa.gov/spacecomm/programs/technology/sbir/default.cfm). A typical approach for flight hardware would include: Phase I - Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable. Phase II - Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. Some of the subtopics in this topic could result in products that may be included in a future flight opportunity or on-orbit testing. Please see the following for more details:

- NASA Office of the Chief Technologist: (http://www.nasa.gov/offices/oct/home/index.html, http://www.nasa.gov/offices/oct/game_changing_technology/small_satellite_subsystem_tech/index.html, http://www.nasa.gov/offices/oct/crosscutting_capability/index.html).
- International Space Station payload opportunities: (http://www.nasa.gov/mission_pages/station/research/nlab/index.html, http://www.nasa.gov/mission_pages/station/research/experiments_category.html).
- CoNNeCT (Communications, Navigation & Networking Reconfigurable Testbed): (http://spaceflightsystems.grc.nasa.gov/SpaceOps/CoNNeCT/).
- Terrestrial analogs (Desert Rats, Haughton Field):(http://science.ksc.nasa.gov/d-rats/, http://ti.arc.nasa.gov/tech/asr/intelligent-robotics/haughton-field/).
- SMD Topic S4 for more details concerning requirements for Small Satellite flight opportunities. NOTE: Communications technologies relevant to space-based range are solicited for in Space Transportation Subtopic O2.03 – 21st Century Spaceport Ground System Technologies.

O1.01 Antenna Technology
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC, LaRC

NASA seeks advanced antenna systems and technologies to enable communications for future space operations, space science, Earth science and solar system exploration missions. These areas, in priority order, are:

Novel Materials for Next Generation Antennas
NASA is interested in exploiting novel materials approaches for next generation antennas. For example, “smart” materials such as shape memory polymers or ionic polymer metal composites to permit active shape control or beam correction are of interest. Artificial electromagnetic media for phase velocity control and impedance tuning to improve the efficiency and bandwidth of electrically small antennas is of interest. Emerging novel technologies such

as ferroelectrics, multiferroics and spintronics concepts leading to new antenna designs are desirable.

Smart, Reconfigurable Antennas
Smart antennas, reconfigurable in frequency, polarization and radiation pattern, are of interest for space and planetary exploration missions. In particular, antenna designs and proof-of-concepts leading to the reduction of the number of antennas needed to meet the communication requirements associated with rovers, pressurized surface vehicles, habitats, etc., are highly desired. In addition to the aforementioned reconfigurability requirements, specific antenna features include multi-beam operation to support connectivity to different communication nodes on planetary surfaces, or in support of communication links for satellite relays around planetary orbits. Innovative receiver front-ends or technologies that allow for the DSP to move closer to the antenna terminal furthering the impact of the aforementioned, revolutionary “game-changing” antenna technology concepts are highly desirable.

Ground-based Uplink Antenna Array Designs
NASA is considering arrays of ground-based antennas to increase capacity and system flexibility, to reduce reliance on large antennas and high operating costs, and eliminate single point of failure of large antennas. A large number of smaller antennas arrayed together results in a scalable, evolvable system, which enables a flexible schedule and support for more simultaneous missions. A significant challenge is the implementation of an array for transmitting (uplinking), which may or may not use the same antennas that are used for receiving. Arraying concepts that can enable technology standardization across each NASA network (i.e., DSN, NEN, and SN), within the framework of the newly envisioned NASA integrated network architecture, at Ka-band frequencies and above, are highly desired.

Phased Array Antennas
High performance phased array antennas, i.e., with efficiencies at least 3X that of state-of-practice MMIC-based phased arrays, are needed for high-data rate communication at Ka-Band frequencies and above as well as for remote sensing applications. Communications applications include: planetary exploration, landers, probes, rovers, extravehicular activities (EVA), suborbital vehicles, sounding rockets, balloons, unmanned aerial vehicles (UAV's), TDRSS communication, and expendable launch vehicles (ELV's). Also of interest are multi-band phased array antennas (e.g., X- and Ka-band) and RF/optical shared aperture dual use antennas, which can dynamically reconfigure active elements in order to operate in either band as required to maximize flexibility, efficiency and minimize the mass of hardware delivered to space. Phased array antennas for space-based range applications to accommodate dynamic maneuvers are also of interest. The arrays are required to be aerodynamic or conformal in shape for sounding rockets, UAV's, and expendable platforms and must be able to withstand the launch environment. Potential remote sensing applications include: radiometers, passive radar interferometer platforms, and synthetic aperture radar (SAR) platforms for planetary science.

Large Aperture Deployable Antennas
Large aperture deployable antennas with surface root-mean-square (rms) quality better than $\lambda/40$ at Ka-Band frequencies and above, are desired. In addition, these antennas should significantly reduce stowage volume (packaging efficiencies as high as 50:1), provide high deployment reliability, and significantly reduced mass density (i.e., < 1kg/m2). These large Gossamer-like antennas are required to provide high-capacity communication links with low fabrication costs from deep space (Mars and beyond). Concepts addressing antenna adaptive beam correction with pointing control are also of interest.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.

Phase II Deliverables: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

O1.02 Reconfigurable/Reprogrammable Communication Systems
Lead Center: GRC
Participating Center(s): ARC, DFRC, GSFC, JPL, JSC

NASA seeks novel approaches in reconfigurable, reprogrammable communication systems to enable the vision of space, exploration, science, and aeronautical flight systems. Advancements are required in communication systems to manage the demands of the harsh space environment on space electronics, maintain flexibility and adaptability to changing needs and requirements, and provide flexibility and survivability due to increased mission durations. NASA missions can have vastly different transceiver requirements ranging from 1's to 10's Mbps at UHF & S frequency bands while X & Ka frequency bands require 10's to 1000's of Mbps. Available mission resources also vary greatly depending on the science objective, operating environment, and spacecraft resources. For example, deep space missions are often power constrained; operating over large distances, and subsequently have lower data transmission rates when compared to near-Earth or near planetary satellites. These requirements and resource limitations are known prior to launch, which can be used to maximize transceiver efficiency while minimizing resources consumed. Larger platforms such as vehicles or relay spacecraft may provide more resources but may also be expected to perform more complex functions or support multiple and simultaneous communication links to a diverse set of assets.

This solicitation seeks advancements in reconfigurable transceiver and associated component technology with a goal of providing flexible, reconfigurable communications capability while minimizing on-board resources and cost. Technological domains of interest include the development of software defined radios or radio subsystems which demonstrate reconfigurability, flexibility, reduced power consumption of digital signal processing systems, increased performance and bandwidth, reduced software qualification cost, and error detection and mitigation technologies. Complex reconfigurable systems will provide multiple channel and multiple and simultaneous waveforms. Within these domains of interest, desired proposal focus areas to develop and/or demonstrate technologies are as follows:

- Software/firmware for the management of waveform and/or functional reconfiguration during simultaneous radio operation while adhering to the Space Telecommunications Radio System (STRS) is desired.
- Methods and tools for the development of software/firmware components that are portable across multiple platforms. Standards-based approaches are preferred.
- Dynamic/distributed on-board processing architectures that are scalable and designed to operate in space environments.
- Component technology advancements in bandwidth capacity and reduced resource consumption.
- Analog-to-digital converters or digital-to-analog converters to increase sampling and resolution capabilities.
- Novel techniques or processes to increase memory densities.
- Novel approaches to mitigate device susceptibility to radiation effects.

STRS Architecture documentation is available at the following link:

(http://spaceflightsystems.grc.nasa.gov/SpaceOps/CoNNeCT/).

The above URL also provides an overview of the Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) flight program. The reconfigurable radios developed for this system represent the state-of-the-art in technology for space flight communication systems and may be used as a reference for the focus areas above. See also subtopic O1.06 – CoNNeCT Experiments for additional information.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.

Phase II Deliverables: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

O1.03 Game Changing Technologies
Lead Center: GRC
Participating Center(s): ARC, JSC

NASA seeks revolutionary, highly innovative, game changing communications technologies that have the potential to enable order of magnitude performance improvements for space operations, exploration systems, and/or science mission applications. Research is geared towards far-term research focused in (but not limited to) the following areas:

- Develop novel techniques for size, weight, and power (SWAP) of communications sys-tems by addressing digital processing and logic implementation tradeoffs, dynamic power management, hardware and software partitioning. Address high-speed, high resolution, low power consumption, and radiation tolerance (e.g., SiGe) to support near Earth and deep space mission environments. Investigate and demonstrate novel technologies to alleviate the demanding requirements (3- to- 5X improvement in sampling rate/resolution over state-of-the-art) on analog to digital converters (ADCs) and digital signal processors (DSPs).
- Develop technologies to evolve NASA communication networking and radio capabilities to autonomously sense and adapt to their environment, detect and repair problems and learn as they operate. Nodes will be dynamically aware of state and configuration of other nodes and adapt accordingly. Communications and navigation subsystems on future missions will interpret their situation on their own, understand their options, and select the best means to communicate or navigate.
- High-performance, multifunctional, nano-structured materials are of interest for applications in human spaceflight and exploration. These materials (notably single wall carbon nanotubes) exhibit extraordinary mechanical, electrical, and thermal properties at the nanoscale and possess exceptionally high surface area. The development of nano-scale communication devices and systems including nano-antennas, nano-transceivers, etc. are of interest for nano-spacecraft applications.
- Quantum entanglement, quantum key distribution or innovative breakthroughs in quantum information physics. Address proposed revolutionary improvements in communicating data, information or knowledge. Methods or techniques that demonstrate extremely novel means of effectively packaging, storing, encrypting, and/or transferring information are sought. Significant development is needed in high flux single photon sources and entangled pair sources for highly efficient, free space communications.
- Small spacecraft, due to their limited surface area, are typically power constrained, limiting small spacecraft communications systems to low-bandwidth architectures. Technologies and architectures, which can exploit commercial or other terrestrial communication infrastructures to enable novel smallsat missions to enable a wider variety of space missions are desired. Address how existing communications architectures

can be adapted and utilized to provide routine, low cost, high bandwidth communications capabilities for spacecraft to ground, and spacecraft to spacecraft applications.

- Ultra wide-band (UWB) technology is sought to support robotic localization of surface assets. Whether two-way ranging (time -of-flight) or time-difference of arrival, the ability to synchronize the receivers determine the localization accuracy. Efficient Media Access Control (MAC) and networking protocols are paramount to ensure power efficiency and scalability. Integrating communications and positioning in an ad hoc network can indeed enable situational awareness, keeping track of location and relative position to other astronauts, robots, and vehicles at any time through visual and/or audio cues. Because initial synchronization or signal acquisition for Impulse Radio Ultra-Wide Band (IR-UWB) using equivalent-time sampling takes a long time especially for low pulse repetition rate systems, precise timing and coherent reception demand more power consumption and complexity than non-coherent IR-UWB. To maintain clock stability, most IR-UWB systems do not power down the receivers during operation. Narrower pulse width spreads the RF energy over a wider bandwidth but generation of precise low jitter (<10 picoseconds) programmable timing of the interval between triggers is highly desirable. For instance, a pulse wide of 1 nanosecond provides a RF signal bandwidth of 1 GHz or more. Low pulse-to-pulse or sample-to-sample jitter implies a sampler on a lobe of pulse N can be precisely place on the same lobe of pulse N +1 with only 10 picoseconds of error. This enables high pulse integration and high resolution waveform scanning. To improve power consumption of IR-UWB systems, it is desirable to have multi-correlator architecture and a fast search schemes that allow rapid switching between power modes and minimizing waking time.
- Develop methods for use of neutrinos for communications, timing, and ranging. Neutrinos are small, near light speed particles with no electric charge. Since neutrinos travel through most matter, they could be used for extreme long-distance signaling. Detection of neutrinos currently require massive underground liquid detectors. Highly innovative concepts, methods, techniques to enable neutrino based communication, ranging, timing, are sought.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Deliverables expected at the end of Phase I include trade studies, conceptual designs, simulations, analyses, reports, etc. at TRL 1-2.

Phase II Deliverables: Demonstrate performance of technique or product through simulations and models, hardware or software prototypes. It is expected that at the end of the Phase II award period, the resulting deliverables/products will be at or above TRL 3.

O1.04 Long Range Optical Telecommunications
Lead Center: JPL
Participating Center(s): GRC, GSFC

This subtopic seeks innovative technologies for long range Optical Telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

Systems and technologies relating to acquisition, tracking and sub-micro-radian pointing of the optical communications beam under typical deep-space ranges (to 40 AU) and spacecraft micro-vibration environments. Within these domains of interest, desired proposal focus areas to develop and/or demonstrate technologies are as follows:

Isolation Platforms
Compact, lightweight, space qualifiable vibration isolation platforms for payloads massing between 3 and 50 kg that require less than 15 W of power and mass less than 3 kg that will attenuate an integrated angular disturbance of 150 micro-radians from 0.01 Hz to 500 Hz to less than 0.5 micro-radians 1-sigma.

Laser Transmitters
Space-qualifiable, greater than 20% DC to optical efficiency, 0.2 to 16 nanosecond pulse-width 1550-nm laser transmitter for pulse-position modulated data with from 16 to 320 slots per symbol, less than 35 picosecond pulse rise and fall times, near transform limited spectral width, single polarization output with at least 20 dB polarization extinction ratio, amplitude extinction ratio greater than 38 dB, average power of 5 to 20 Watt, massing less than 500 grams per Watt. Also of interest for the laser transmitter are: robust and compact packaging with radiation tolerant electronics inherent in the design, and high speed electrical interface to support output of pulse position modulation encoding of sub nanosecond pulses and inputs such as Spacewire, Firewire or Gigabit Ethernet. Detailed description of approaches to achieve the stated efficiency is a must.

Photon Counting Near-Infrared Detectors Arrays for Ground Receivers
Hexagonal close packed kilo-pixel arrays sensitive to 1000 to 1650 nm wavelength range with single photon detection efficiencies greater than 60% and single photon detection jitters less than 40 picoseconds 1-sigma, active diameter greater than 15 microns/pixel, and 1 dB saturation rates of at least 10 mega-photons (detected) per pixel and dark count rates of less than 1 MHz/square-mm.

Photon Counting Near-Infrared Detectors Arrays for Flight Receivers
For the 1000 to 1600 nm wavelength range with single photon detection efficiencies greater than 40% and 1dB saturation rates of at least 1 mega-photons/pixel and operational temperatures above 220K and dark count rates of <10 MHz/mm. Radiation doses of at least 20 Krad (unshielded) shall result in less than 10% drop in single photon detection efficiency and less than 2X increase in dark count rate.

Ground-Based Telescope Assembly
Telescope/photon-buckets with primary mirror diameter ~2.5-m, f–number of ~1.1 and Cassegrain focus to be used as optical communication receiver/transmitter optics at 1000-1600nm. Maximum image spot size of ~20 micro-radian, and field-of-view of a~50 micro-radian. Telescope shall be positioned with a two-axis gimbal capable of 0.25 milli-radian pointing. Desired manufacturing cost for combined telescope, gimbal and dome in quantity (tens) of approximately $2 M each.

Research should be conducted to convincingly prove technical feasibility during Phase I, ideally through hardware development, with clear pathways to demonstrating and delivering functional hardware, meeting all objectives, in Phase II.

Phase I Deliverables:

- Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4).
- Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables:

- Working model of proposed product, along with full report of development and measurements, including populated verification matrix from phase II (TRL 5).
- Opportunities and plans should also be identified and summarized for potential commercialization.

O1.05 Long Range Space RF Telecommunications
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC

This subtopic seeks to develop innovative long-range RF telecommunications technologies supporting the needs of space missions.

Purpose (based on NASA needs) and current state-of-the-art
In the future, spacecraft with increasingly capable instruments producing large quantities of data will be visiting the moon and the planets. To enable the communication needs of these missions and maximize the data return to Earth, innovative long-range telecommunications technologies that maximize power efficiency, transmitted power and data rate, while minimizing size, mass and DC power consumption are required.

The current state-of-the-art in long-range RF space telecommunications is 6 Mbps from Mars using microwave communications systems (X-Band and Ka-Band) with output power levels in the low tens of Watts and DC-to-RF efficiencies in the range of 10-25%.

Technologies of interest
This subtopic seeks innovative technologies in the following areas:

- Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders and components, incorporating MMICs, MEMs and Bi-CMOS circuits.
- MMIC modulators with drivers to provide a wide range of linear phase modulation (greater than 2.5 rad), high-data rate (10 - 200 Mbps) BPSK/QPSK modulation at X-band (8.4 GHz), and Ka-band (26 GHz, 32 GHz and 38 GHz).
- High DC-to-RF-efficiency (> 60%), low mass Solid-State Power Amplifiers (SSPAs), of both medium output power (10 W-50 W) and high-output power (150 W-1 KW), using power combining and/or wide band-gap semiconductors at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz).
- Utilization of nano-materials and/or other novel materials and techniques for improving the power efficiency or reducing the mass and cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons).
- Ultra low-noise amplifiers (MMICs or hybrid, uncooled) for RF front-ends (< 50 K noise temperature).
- MEMS-based integrated RF subsystems that reduce the size and mass of space transceivers and transponders. Frequencies of interest include UHF, X- and Ka-Band. Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path towards Phase II hardware/software demonstration with delivery a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4). Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables: Working engineering model of proposed product, along with full report of development and measurements, including populated verification matrix from Phase I (TRL 5-6). Opportunities and plans should also be identified and summarized for potential commercialization.

O1.06 CoNNeCT Experiments
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC

NASA has developed an on-orbit, reprogrammable, software defined radio-based (SDR) testbed facility aboard the International Space Station (ISS), to conduct a suite of experiments to advance technologies, reduce risk, and enable future mission capabilities. The Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) provides SBIR recipients and through other mechanisms NASA, large business, other Government agencies, and academic partners the opportunity to develop and field communications, navigation, and networking technologies in the laboratory and space environment based on reconfigurable, software defined radio platforms. Each SDR is compliant with the Space Telecommunications Radio System (STRS) Architecture, NASA's common architecture for SDRs. The Testbed is installed on the truss of ISS and communicates with both NASA's Space Network via Tracking Data Relay Satellite System (TDRSS) at S-band and Ka-band and direct to/from ground systems at S-band. One SDR is capable of receiving L-band at the GPS frequencies of L1, L2, and L5.

NASA seeks innovative software experiments to run aboard CoNNeCT to demonstrate and enable future mission capability using the reconfigurable features of the software defined radios. Experiment software/firmware can run in the flight SDRs, the flight avionics computer, and on a corresponding ground SDR at the Space Network, White Sands Complex. Unique experimenter ground hardware equipment may also be used.

Experimenters will be provided with appropriate documentation (e.g., flight SDR, avionics, ground SDR) to aid their experiment application development, and may be provided access to the ground-based and flight SDRs to prepare and conduct their experiment. Access to the ground and flight system will be provided on a best effort basis and will be based on their relative priority with other approved experiments. Please note that selection for award does not guarantee flight opportunities on the ISS.

Desired capabilities include, but are not limited to, the examples below:

- Demonstration of mission applicability of SDR.
- Aspects of reconfiguration.
    - Unique/efficient use of processor, FPGA, DSP resources.
    - Inter-process communications.
- Spectrum efficient technologies.
- Space internetworking.
    - Disruption Tolerant Networking.
- Position, navigation and timing (PNT) technology.
- Technologies/waveforms for formation flying.
- High data rate communications.
- Uplink antenna arraying technologies.
- Multi-access communication.
- RF sensing applications (science emulation).
- Cognitive applications.

Experimenters using ground or flight systems will be required to meet certain pre-conditions for flight including:

- Provide software/firmware deliverables suitable for flight (i.e., NASA Class C flight software).
- Document development and build environment and tools for waveform/applications.
- Provide appropriate documentation (e.g., experimenter requirements, waveform/software user's guide, ICD's) throughout the development and code deliverable process.
- Software/firmware deliverables compliant to the Space Telecommunications Radio System (STRS) Architecture, Release 1.02.1.

- Verification of performance on ground based system prior to operation on the flight system.

Methods and tools for the development of software/firmware components that is portable across multiple platforms and standards-based approaches are preferred.

Documentation for both the CoNNeCT system and STRS Architecture may be found at the following link:

(http://spaceflightsystems.grc.nasa.gov/SpaceOps/CoNNeCT/).

These documents will provide an overview of the CoNNeCT flight and ground systems, ground development and test facilities, and experiment flow. Documentation providing additional detail on the flight SDRs, hardware suite, development tools, and interfaces will be made available to successful SBIR award recipients. Note that certain documentation available to SBIR award recipients is restricted by export controls and available to U.S. citizens only.

For all above technologies, Phase I will provide experimenters time to develop and advance waveform/application architectures and designs along with detailed experiment plans. The subtopic will seek to leverage more mature waveform developments to reduce development risk in subsequent phases. The experiment plan will show a path toward Phase II software/firmware completion, ground verification process, and delivering a software/firmware and documentation package for NASA space demonstration aboard the flight SDR. Phase II will allow experimenters to complete the waveform development and demonstrate technical feasibility and basic operation of key algorithms on CoNNeCT ground-based SDR platforms and conduct their flight system experiment. Opportunities and plans should also be identified and summarized for potential commercialization.

Phase I Deliverables:

- Experiment Reference Design Mission Document.
- Waveform/application architecture and detailed design document, including plan/approach for STRS compliance.
- Experiment Plan.
- Demonstrate simulation or model of key waveform/application functions.
- Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4).

Phase II Deliverables:

- Experiment Requirements Document.
- Simulation or model of waveform application.
- Demonstration of waveform/application in the laboratory on CoNNeCT breadboards or engineering models.
- Software/firmware application source and binary code and documentation. Source/binary code will be run on engineering models and/or demonstrated on-orbit in flight system (at TRL-5-7) SDRs.

TOPIC: O2 Space Transportation

Achieving space flight remains a challenging enterprise. It is an undertaking of great complexity, requiring numerous technological and engineering disciplines and a high level of organizational skill. Overcoming Earth's gravity to achieve orbit demands collections of quality data to maintain the security required of the range. The harsh environment of space puts tight constraints on the equipment needed to perform the necessary functions. Not only is there a concern for safety but the 2004 Space Transportation Policy directive states that the U.S. should maintain robust transportation capabilities to assure access to space. This crosscutting SBIR Topic seeks to enable commercial solutions for U.S. space transportation systems providing significant reductions in cost, and increases in reliability, flight-rate, and frequency of access to space. The goal is a breakthrough in cost and reliability for a wide range of payload sizes and types (including passenger transportation) supporting future orbital flight that can be demonstrated on interim suborbital vehicles. The vision is a competitive marketplace with multiple commercial providers of highly-reusable space transportation systems and services with aircraft-like operations, high-flight rates, and short turnaround times (days-to-hours, rather than months). Lower cost and reliable space access will provide significant benefits to civil space (human and robotic exploration beyond Earth as well as Earth science), to commercial industry, to educational institutions, for support to the International Space Station National Laboratory, and to national security. While other strategies can support frequent, low-cost and reliable space access, this topic focuses on the technologies that dramatically alter reusability, reliability and operability of next generation space access systems.

O2.01 Nano/Small Sat Launch Vehicle Technology
Lead Center: KSC
Participating Center(s): ARC

The space transportation industry is in need of low-cost, reliable, on-demand, routine space access. Both government and private entities are pursuing various small launch systems and architectures aimed at addressing this market need. Significant technical risk and cost exists in new system development and operations - reducing incentive for private capital investment in this still-nascent industry. Public and private sector goals are aligned in reducing these risks and enabling the development of small launch systems capable of reliably delivering payloads to low Earth orbit. The Nano/Micro Launch Vehicle (NMLV) will provide the nation with a new, small payload access to space capability. The primary objective is to develop a capability to place nano and micro satellites weighing up to approximately 20 kilograms into a reference orbit defined as circular, 450 kilometer altitude, from various inclinations ranging from 0 to 98 degrees.

This SBIR subtopic seeks commercial solution in the areas of nano and micro spacecraft launch vehicle technologies.

This subtopic will particularly focus on higher risk entrepreneurial projects for dedicated nano and micro spacecraft launch vehicles. This subtopic seeks proposals including, but not limited to, the following areas:

- Sub-orbital booster conceptual designs of system/architectures capable of reducing the mission costs associated with the launching of small payloads to LEO.
- Sub-orbital booster technologies traceable to an orbital capable Nano/Micro Launch Vehicle (NMLV)*, whereby specific technologies are identified for Phase II development and test.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path towards Phase II hardware/software demonstration with delivery of a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product.

Also required are for all technologies are performance predictions, cost objectives, and development and demonstration plans for the Nano/Micro Launch Vehicle (NMLV). Formulate and deliver a verification matrix of measurements to be performed in Phase II, along with specific quantitative pass-fail ranges for each quantity listed.
The report shall also provide options for commercialization opportunities after Phase II.

Phase II Deliverables: Working engineering model of proposed Phase I components or technologies, along with full report on development and measurements, including populated verification matrix from Phase I. The prototype hardware shall emphasize launch cost reduction technologies, and possess sufficient design information to fabricate, integrate, and operate the selected high-risk component(s) for demonstration. Refinement of the sub-orbital booster design is required as knowledge is gained through the critical component development process. Exit TRL 5-6 is expected at the end of Phase II

*The NMLV would be a smaller vehicle than the Pegasus launch vehicle which is considered a Small Launch Vehicle (SLV).

O2.02 Propulsion Technologies
Lead Center: GRC
Participating Center(s): ARC, DFRC, MSFC

Current launch to orbit vehicles, both expendable and reusable, require months of preparation for flight. Although there are available (in-production) practical propulsion options for such a vehicle, the costs for outfitting the booster stage are in the hundreds of millions of dollars. If reusable, additional months are required to verify all components and systems before re-flight. These costs severely limit what missions NASA can perform. The propulsion systems are a major focus during this time, yet aircraft engines are checked and certified for re-flight in less than an hour. While rocket engines actually have many similarities to aircraft engines, there are several factors that drive the complexity and therefore the cost of rocket engines. These include toxic propellants that require special protections for personnel and the environment, cryogenic propellants that require complex tank fill operations and costly specialized ground support equipment, high combustion chamber temperatures for increased performance and thrust, and high combustion chamber pressures for increased performance and reduced engine size and weight.

To move more toward low cost access to space, the above barriers to low-cost propulsion systems must be addressed and overcome. Of primary focus are non-toxic propellant combinations that provide adequate performance without requiring excessive specialized handling equipment and procedures, and engines that provide reliable and adequate performance without needing to push the far limits of temperature and pressure environments. Component technologies that move toward these top-level goals that are of interest include:

- Ablative materials and manufacturing techniques that increase capability while reducing production time and cost.
- Innovative chamber cooling concepts that reduce manufacturing complexity, reduce pressure drop, and minimize performance losses caused by cooling.
- Development of non-toxic propellants and technologies that enable their use such as catalysts, compatible materials, feed/storage systems, etc.
- Low-cost nozzle materials, manufacturing techniques, and coatings to reduce the amount of active cooling required.
- Ignition concepts that require low part count and/or low energy to be used as either primary or redundant ignition sources.
- Manufacturing techniques that lower the cost of manufacturing complex components such as injectors and coolant channels. Examples include, but are not limited to, development and demonstration of rapid prototype techniques for metallic parts, power metallurgy techniques for the manufacture of geometrically complex parts, and application of nanotechnology for near net shape manufacturing.
- Sensors, instruments, and algorithms to diagnose the health of the engine valves, injector, igniter, chamber, coolant channels, etc. without requiring hours of manual inspections.

Specified target metrics include:

- A cost target of <50% of current earth-to-orbit propulsion with similar performance.
- Reduced ground support equipment.
- Increased performance margin (e.g., operating temperature % of material limit, operating stress % of component limit, etc.).

These are critical technology improvements that are required in the next 3 – 8 years. Projects are required to demonstrate the component or technology to a TRL level of 5 – 6 in order to allow for infusion into low-cost earth-to-orbit propulsion systems. The NASA Office of Chief Technologist has developed Technology Roadmaps that identify technology gaps and needs to enable certain future missions. This subtopic calls for technologies that are discussed in more detail in the Technology Area 1 (Launch Propulsion Systems) and Technology Area 13 (Ground & Launch Systems Processing) roadmaps. These are available for viewing at (http://www.nasa.gov/offices/oct/home/roadmaps/index.html). Proposals should reference specific elements from these and other relevant roadmaps and explain how the proposed technology will address identified technology gaps and needs.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase II and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Lab-scale component or technology demonstrations and reports of target metric performance.

Phase II Deliverables: Subscale component or technology demonstrations and reports of target metric performance. Opportunities and plans should also be identified and summarized for potential commercialization,

O2.03 21st Century Spaceport Ground Systems Technologies
Lead Center: KSC
Participating Center(s): ARC, DFRC, GRC, GSFC

This subtopic seeks innovative solutions that will allow spaceport launch service providers to operate in an efficient, low cost manner and increases capabilities associated with integration, checkout, and preparations required to configure and ready space systems for launch. The goal is a set of technologies, processes, and strategic concepts that can be collectively used to facilitate launch vehicle processing by reducing complexity, turn-around times, and mission risk while implementing novel concepts for the processing of launch vehicles.

The long-term vision is to have “airport-like” spaceport operations. Therefore, the development of effective spaceport technologies is of primary importance to NASA. These technologies will need to support both the existing and future vehicles and programs. Additional key operating characteristics for a spaceport focus are interoperability, ease of use, flexibility, safety/environmental protection, support multiple concurrent operations, and the de-coupling of pre-launch processing from other users on the range.

Specific areas of interest:

- End-to-End Command and Control Services.
- Technologies and Capabilities that enable flexible and adaptable control by integrating enterprise capabilities with remote and distributed control functions while simultaneously maintaining security and safety for critical operation.
- Communications Services and RF/Optical Services to enable virtual distributed teams for control, engineering, safety analysis and support.
- Technologies and Capabilities that enable multi-government teams of operate existing or new assets in the most cost efficient manner. In, addition technologies or capabilities that would move existing government provided capabilities and provide a path to commercialization in the future.
- Preventative and condition based maintenance along with self-healing capabilities for ground systems.
- Technologies and Capabilities that reduce required work content, through an automated understanding of when and if maintenance work needed to be performed, in addition, capabilities that reduce cost or provide additional mission assurance capabilities at comparable or reduced cost.
- De-coupled pre-launch processing where the strategy for de-coupling involves the spaceport?s capacity, configurability and Space-Based capabilities.

- Technologies and Capabilities that reduce the amount of ground operations that must be coordinated with other Range users, which would enable every user on the Range to believe they are the only user of the range throughout the ground flow.
- Spaceport and Range technologies and capabilities that increase launch attempts per day and/or consecutive days across the entire Florida Launch and Range Complex.
- Technologies and Capabilities that provide, localized, accurate forecasting of weather in support of Ground Operations.
- Improve security and control of range hazard areas.
- Technologies and Capabilities that improve the security of the range while reducing the cost to perform and monitor the Range volume.
- Innovative systems for payload recovery techniques with advancements in the areas of Mid-Air Retrieval (MAR) systems and guided payload recovery systems (such as a guided parafoil system).
- Technologies and Capabilities that allow in-flight recovery of small vehicles and payloads. In addition, Technologies and Capabilities that significantly reduce the cost of recovery operations.

Priority will be given to innovative solutions that:

- Enable low-cost concepts that reduce operations and life cycle costs.
- Demonstrate a transition path into spaceport operations.
- Can achieve high-fidelity ground-based demonstrations within the next 4 years; longer-term development proposals will be accepted, but will be considered at a lower priority for funding.

Research should be conducted to convincingly prove technical feasibility during Phase I, with clear pathways to demonstrating and delivering functional prototypes, meeting all objectives, in Phase II.

Phase I Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4). Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables: Working model of proposed product, along with full report of development and measurements, shall emphasize cost reduction and efficiency technologies, and include a populated verification matrix from Phase II (TRL 5). Opportunities and plans should also be identified and summarized for potential commercialization.

O2.04 Advanced Tank Technology Development
Lead Center: MSFC
Participating Center(s): JSC

The objective of this subtopic is to dramatically reduce the cost of achieving low Earth orbit by advancing the technology required for spaceflight propellant tank development. The ability for launch vehicles to combine the significant weight savings of composite tanks and composite overwrap pressure vessels (COPVs) with airline like operations could be possible if these tanks are reusable, reliable, and need little to no maintenance between flights.

Composite and composite overwrap tanks offer significant weight savings, however, there are significant shortfalls in terms of reusability, especially when using cryogenic fluids. This lack of reusability severely hampers adoption of this enabling technology in future reusable vehicle designs. This subtopic seeks to mature such emerging technologies pertaining to high performance, light-weight tanks and pressure vessels suitable for cryogenic and non-cryogenic temperatures at high pressures; seeks to develop technologies that extend life and/or decrease cost while being mindful of permeability, damage tolerance, safe-life and checkout issues; and seek out seal and joint development, increasing tank robustness and life while not increasing weight or cost; all against the current state-of-the-art capabilities and technologies.

Areas of interest to develop and/or demonstrate are as follows:

- Material Development: New composite material development specifically for cryogenic use demonstrating cycling, reparability, and knowledge of permeability and damage tolerance. Data should clearly show materials and processes used in producing a vessel that performs well under long-term use in a cryogenic condition. Vessel performance and cycling should be analyzed at and during operational conditions (i.e., cryogenic conditions) to verify material integrity. The vessel would minimize micro cracking, should be damage tolerant and repairable, and have mounting capabilities. Permeability of the material should be addressed and evaluated against current material usage and limitations.
- Reusability and Reliability: Reusable, reliable, and low cost tanks that need little to no maintenance between flights and minimal check-out are required for economic and operational sustainability. These innovative propellant tank (either cryogenic or non-cryogenic) developments can:
  - Ease operability of the tank diagnostics.
  - Enable tank prognostics.
  - Enable tanks to handle high pressure cycles and loads without leaking or developing structural failure.
  - Promote ease of manufacture by more than one American company.
  - Promote ease of repair without returning tanks to the manufacturer’s facility.
  - Promote rapid certification/recertification techniques to meet expected FAA commercial RLV requirements.
- Data and Technology Development: Of specific concern and interest are safe-life and damage tolerance testing. There is much scrutiny regarding the manner and degree of testing in these areas, specifically after some number of pressure cycles. Also of concern is the effect of temperature during cycling and on material integrity. Due to the limited amount of flight and long term performance data there is little to base future design on when the desire is heritage similarity. Thus, development in regards to these specific metrics (safe-life and damage tolerance testing) would be most beneficial to both short and long term missions.

For the proposed technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware demonstration and testing. Delivery of a demonstration unit for NASA testing at the completion of the Phase II contract is also required.

Phase I Deliverables: Desired deliverables at the end of Phase I should be at TRL 3-4. Final report containing:

- Optimal design and feasibility of concept.
- Detailed path towards Phase II demonstration.
- Detailed results of Phase I analysis, modeling, prototyping and development testing .
- Material coupon data and a prototype sub-scale tank.

Phase II Deliverables: Deliverables expected at the end of Phase II should be at TRL 5-6. By the end of Phase II, working proof-of-concept technologies, including features and demonstration of long term, high cycle performance at cryogenic temperatures, demonstrated and delivered to NASA for testing and verification.

O2.05 Advanced Propulsion Testing Technologies
Lead Center: SSC

The aim of this subtopic is to develop new technologies to reduce cost and schedule, improve reliability and quality, and increase safety of Rocket Propulsion Testing. To this end, proposals for technology development will be accepted for any of the following four subject areas:

- Critical Vacuum Sensing.
- Helium Recovery.

- Robust Components.
- Advanced Propulsion Test Data Management.

Critical Vacuum Sensing Technology
Develop new innovative methods for remotely and automatically locating and quantifying vacuum leaks in large vacuum chambers subject to harsh environmental conditions. A new test stand, A3, is being built at SSC to test rocket engines at altitude conditions. Information on A3 Test Stand can be found at the following URLs:

- http://sscfreedom.ssc.nasa.gov/etd/ETDTestFacilitiesA3.asp.
- http://www.tulane.edu/~sse/FORUM_2010/pdfs/e1.pdf.
- http://www.nasa.gov/centers/stennis/pdf/436170main_A-3%20Test%20Stand%20FS-2010-03-00093.pdf.

To simulate altitude during rocket engine testing, A3 test stand produces a vacuum of 0.15psia inside a large, 40 ft diameter, rocket engine test chamber using 27 chemical steam generators and a 2-stage diffuser/ejector system. If vacuum leaks occur, the desired simulated altitude may not be achievable thus any leaks must be located and repaired. However, personnel access to the vacuum test chamber during operation is restricted due to the hazardous nature of its operation. This makes locating vacuum leaks difficult, if not impossible. Therefore, automated remote detection and location of areas of air in-leakage is required. Due to the unique nature of this test facility, innovation in these technologies is necessary. Performance metrics include accuracy and sensitivity in detecting leaks in the harsh operational environment with high levels of noise and vibration while not producing false leak indications, as well as robust design for the harsh environment.

Helium Recovery Technology
Helium is a rare and nonrenewable resource with many properties critical to the commercial, military, and fundamental scientific research sectors. NASA consumes approximately 1 million pounds of helium each year, primarily for purging of cryogenic propellant systems in which the helium is discharged to atmosphere and lost. The goal of this subtopic thrust area is to develop innovative helium recovery technologies that economically dissociate helium from large volumes of mixtures of helium, air, and hydrogen purge discharge, and pressurize the reclaimed helium for storage and reuse. The total cost of recovering and reusing helium, from both capital and energy expenditure, should be less than procuring the same amount of helium from traditional sources. Also, particular emphasis is placed on portability (i.e., not a fixed installation) and speed of separation (near-real-time) that accommodates a single system servicing numerous distinct sources of helium, air, and hydrogen mixtures developed over the range of rocket propulsion testing and ground and flight operations and the temporal transient nature of production of these mixtures.

Robust Component Technologies
Rocket propulsion test hardware as well as ground and flight launch operations hardware regularly experience large and rapid changes in pressures, temperatures, vibration, and fluid flow rates while demanding high precision control and reliability. Typical ranges in these parameters are pressures from vacuum all the way up to 10,000 psi, working fluids at ambient temperature all the way down to -420F, vibration environments in the 100’s of G RMS acceleration. These parameters can span their entire range in milliseconds. State of the art propulsion system testing hardware has evolved over time as better materials and experience in hardware interactions with these environments have progressed. Innovation in component performance diagnostics technology is required to continue the current progression in hardware operational reliability, cost, and weight optimization. Accordingly, the goal of this subtopic thrust area is to develop innovative in situ hardware performance measurement and diagnostics technology along with the accompanying data acquisition and management systems required for utilization the new technologies.

Advanced Propulsion Test Data Management Capability
Substantial advances in data capture and storage technologies have exponentially increased real and near-real time data availability in rocket propulsion testing. Effective utilization of this increase in data availability requires evolution of data management technologies, methods, and concepts that will enable greater and more effective real-time access, manipulation, and application in the control and quality of propulsion systems testing. Recent initiatives

in development of hardware-in-the-loop technologies, merging measured and simulation data in real time feedback with propulsion test hardware have demonstrated the feasibility and utility of this technology. The goal of this subtopic thrust area is to develop innovative ways to take advantage of increased propulsion test data availability utilizing high performance hardware such as GPU based computer systems along with innovation in algorithms and software to implement new data management technologies, methods, and concepts.

In these subject areas, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward hardware and/or software development as appropriate, which occurs during Phase II and culminates in a proof-of-concept system.

Phase I Deliverables: A final report describing optimal design for the technology concept including feasibility, trade studies, detailed results of Phase I analysis, modeling, prototyping, and testing as applicable. The report should also contain a detailed path towards Phase II hardware and/or software proof-of-concept system. The technology concept at the end of Phase I should be at a TRL of 3-4.

Phase II Deliverables: A working proof-of-concept system successfully demonstrated in a relevant environment and delivered to NASA for testing and verification. The technology at the end of Phase II should be at a TRL of 6-7.

TOPIC: O3 Processing and Operations

The Space Operations Mission Directorate (SOMD) provides mission critical space exploration services to both NASA customers and to other partners within the U.S. and throughout the world: from flying out the Space Shuttle, to assembling and operating the International Space Station; ensuring safe and reliable access to space; maintaining secure and dependable communications between platforms across the solar system; and ensuring the health and safety of our Nation's astronauts. Activities include ground-based and in-flight processing and operations tasks, along with support that ensures these tasks are accomplished efficiently and accurately enables successful missions and healthy crews. This topic area, while largely focused on operational space flight activities, is broad in scope. NASA is seeking technologies that address how to improve and lower costs related to ground and flight assets, and maximize and extend the life of the International Space Station. A typical flight focused approach would include:

- Phase I: Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.
- Phase II: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions.

The proposal shall outline a path showing how the technology could be developed into space-worthy systems. For ground processing and operations tasks, the proposal shall outline a path showing how the technology could be developed into ground or flight systems. The contract shall deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract and, if possible, demonstrate earth based uses or benefits.

O3.01 Remotely Operated Mobile Sensing Technologies for inside ISS
Lead Center: ARC
Participating Center(s): JPL

This subtopic seeks proposals to develop technologies that advance capabilities for space telepresence and mission operations situation awareness, fault diagnosis, isolation, and recovery onboard the ISS using an onboard free-flyer as a mobile sensor platform. In order to increase productivity and reduce risks on long-missions on spacecraft, such as the ISS, leading toward human exploration, commercialization, and colonization of space, ground personnel have a need to remotely command a wide-variety of sensors on mobile platforms to collect data from a variety of positions within spacecraft. The sensors include, but are not limited to, those capable of performing imaging, identifying inventory, and measuring electromagnetic radiation, temperature, acoustics, atmospheric properties, and chemical concentrations. To increase crew productivity, it is highly desirable that the mobile platform be capable of being deployed by ground command, move to the commanded location, collect data, and then return to its storage dock where it is recharged all without requiring crew assistance.

This subtopic solicitation calls for developing a variety of software and hardware technologies that would enable a free-flyer to operate in multiple modules inside ISS including but not limited to:

- Free-flyer localization capability without engineering environment.
- Collision avoidance capability.
- Adjustable autonomous control software that supports safe operation with low-bandwidth, intermittent command communication loop with varying latencies > 10 sec.
- EXPRESS rack-based auto-docking, recharging, refueling, deployment mechanism with matching free-flyer mechanism.
- Quiet propulsion capability meeting ISS noise limit requirements (<50dB) (e.g., blower, compressed air: compressor may be onboard or EXPRESS rack-based).
- Vision-based object identification capability.
- RFID-based inventory identification capability.

Proposals may address any one or a combination of the above or related subjects.

Three SPHERES satellites have operated inside ISS since 2006. In addition to performing dozens of experiments, these satellites demonstrate that mobile platforms in the form of free-flyers can be operated on ISS. However, these satellites have not been operated by ground personnel and their current design is inadequate to meet the needs described above for several reasons, e.g., the satellites require crew assistance to operate, require that batteries and CO_2 cartridges (propellant) be replaced by crew between test sessions, and are confined to a work area bounded by external beacons used by the satellites to localize themselves within their workspace, approximately 2x2x2 meters. However, the SPHERES satellites may be useful in demonstrating technologies called for by this subtopic. Proposals are encouraged that leverage the SPHERES satellites operating onboard ISS and SPHERES engineering units at the NASA Ames Research Center. More information on SPHERES is at:

- http://www.nasa.gov/mission_pages/station/research/experiments/SPHERES.html.
- http://ssl.mit.edu/spheres.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Report with a feasibility study including: simulations and measurements demonstrating the approach used to develop and test the prototype, constraints on other systems, concept of operations, verification matrix of measurements with pass/fail ranges for each quantity to be verified at the end of Phase II, and the Phase II integration path.
- Proof-of-concept simulation and/or bench top demonstration (TRL 3-4).

Phase II Deliverables:

- Midterm Technical Report.

- Final Phase II Technical Report with specifications including: design, development approach, tests to verify the prototype, verification matrix of measurements with pass/fail ranges for each quantity verified, constraints on other systems, and operations guide. Opportunities and plans for potential commercialization should also be included.
- Fully-functional engineering prototype of proposed product (TRL 5-6).

O3.02 ISS Utilization
Lead Center: JSC
Participating Center(s): ARC, GRC, KSC

NASA is investigating the near- and mid-term development of highly-desirable systems and technologies that provide innovative ways either to leverage existing ISS facilities for new scientific payloads or, to provide on orbit analysis to enhance capabilities and reduce sample return requirements.

Current utilization of the ISS is limited by available upmass, downmass, and crew time as well as by the capabilities of the interfaces and hardware already developed. Innovative interfaces between existing hardware and systems, which are common to ground research, could facilitate both increased, and faster, payload development.

Desired capabilities include, but are not limited to, the below examples:

- Enabling additional cell and molecular biology culture techniques. Providing innovative hardware to allow for safe, contained transfer of cells from container to container within the Microgravity Sciences Glove Box (MSG) would permit new types of studies on ISS. On orbit analysis techniques that would reduce or remove the need for downmass - such as a system for gene array tests, or kits for DNA extractions for long term storage - are also examples of hardware possibilities that would extend and enable additional research.
- Providing compact Dynamic Light Scattering (DLS) hardware. Development of a compact robust DLS instrument based on diode lasers and photo detectors capable of providing significant power and weight savings now make it possible to measure the diffusion coefficient of experimental systems using the Light Microscopy Module (LMM) on the International Space Station (ISS). The light scattering instrument (laser, detector, optics) to be mounted on a Leica DM/RXA microscope camera port should be about the size of a 40mm diameter tube around 60mm long) with associated support electronics (including the correlator) being able to fit into a volume of about 30mm x 100mm x 100mm, or less. The intensity dynamic range should be able to cover between 10^-10 to 10^-7 Watts. The relaxation time range should be capable to spanning 200nsec to 50sec. This peer-reviewed science was considered a decade ago but not developed due to technology limitations. It is now possible to meet the required performance criteria (with the above size and power requirements) to measure diffusion coefficients. From the measured diffusion coefficient, particle size can be extracted, or the temperature determined for the location being viewed (e.g., in a capillary cell with a temperature gradient along it) can be deduced (for known particles and solvents) using the Stokes-Einstein equation.
- Providing compact laser tweezers and supporting software. Development of a compact robust Holographic Laser Tweezers (LT) instrument and associated control scripts for use with a microscope on the International Space Station (ISS) based on the recent developments of holographic techniques. This could expand the types of experiments conducted on orbit. The laser tweezers that would mount on a Leica DM/RXA microscope should be less than ~100mm on a side and the associated control electronics should be less than ~150mm on a side. This technology should now be robust side it is solid-state and no longer requires gimbaled mirrors. This peer-reviewed science was previously considered but not developed because of the size and technology limitations of a decade ago. LT holds open the possibility of performing scientific experiments that manipulate groups of particles that evolve uniquely in space when gravitational sedimentation and jamming no longer exist. Any new LT and its corresponding control software should allow for tracking of particle positions to better than one micron in 3D (before the concentration becomes too high) and impart rotational forces. Being able to accurately track the position of particles while measuring the forces on them is important for laying the foundations of colloidal engineering. Because of

its use on space station, the instrument should be self-calibrating. The instrument would need to meet the size and volume limitations of the Light Microscopy Module (LMM).

- Providing additional on-orbit analytical tools. Providing flight qualified hardware that is similar to commonly used tools in biological and material science laboratories could allow for an increased capacity of on-orbit analysis thereby reducing the number of samples, which must be returned to Earth. Examples of tools that will reduce downmass or expand on-orbit analysis include: sample handling tools; mass measurement devices; a (micro) plate reader; a mass spectrometer; an atomic force microscope (for biological and material science samples), non-cryogenic sample preservation systems; autonomous in-situ bioanalytical technologies; centrifuges for analysis and for providing fractional-g environments; microbial and cell detection and identification systems; and fluidics and microfluidics systems to allow autonomous on-orbit experimentation and high throughput screening.
- Providing Nanorack compatible inserts to enable additional life science payloads. Development of 1, 2 and/or 4 cube design biological payload hardware for use with the ISS Nanorack platform would decrease the need for development of multiple control racks and reduce development time of future payload experiments.
- Enabling additional payloads. Innovative methods for further subdividing payloads lockers would allow for numerous pico-payloads. Developing multi-generational or multi-use habitats would reduce the upmass and downmass required to conduct biological experiments on ISS.

The existing hardware suite and interfaces available on ISS may be found at: http://www.nasa.gov/mission_pages/station/research/experiments_category.html.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Written report detailing evidence of demonstrated technology (TRL 5 or 6) in the laboratory or in a relevant environment and stating the future path toward hardware and software demonstration on orbit.

Phase II Deliverables: Hardware and/or software prototype that can be demonstrated on orbit (TRL 7).

O3.03 ISS Demonstration & Development of Improved Exploration Technologies
Lead Center: JSC
Participating Center(s): ARC

The focus of this subtopic is on technologies and techniques that may advance the state of the art of spacecraft systems by utilizing the International Space Station as a technology test bed.

Successful proposals will address using the long duration, microgravity and extreme vacuum environment available on the ISS to demonstrate component or system characteristics that extend beyond the current state of the art by:

- Increasing capability/operating time including overall operational availability.
- Reducing logistics and maintenance efforts.
- Reducing operational efforts, minimizing crew interaction with both systems and the ground.
- Reducing known spacecraft/spaceflight technical risks and needs.
- Providing information on the long-term space environment needed in the development of future spacecraft technologies through model development, simulations or ground testing verified by on orbit operational data.

While selection for award does not guarantee flight opportunities, the proposed demonstrations should focus on increasing the TRL in the following technology areas of interest:

- Propulsion (in-space and novel, electromagnetic and/or very high specific impulse systems).
- Power and energy storage.
- Robotics tele-robotics and autonomous (RTA) Systems.
- Human health, life support and habitation systems.
- Science instruments, observatories and sensor systems.
- Nanotechnology.
- Materials, structures, mechanical systems and manufacturing.
- Thermal management systems including novel heat radiation techniques.
- Spacecraft (including ISS) plasma and contamination in-situ diagnostics.
- Environmental control systems, including improved carbon dioxide removal.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.

Phase II Deliverables: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

O3.04 Vehicle Integration and Ground Processing
Lead Center: KSC
Participating Center(s): SSC

This subtopic seeks to create new and innovative technology solutions to improve safety and lower the life cycle costs of assembly, test, integration and processing of the ground and flight assets at our nation’s spaceports and propulsion test facilities. The following areas are of particular interest:

Control of Material Degradation
Technologies are needed to reduce costs due to material degradation of materials in spaceport and propulsion test facility infrastructure and ground support equipment, Material solutions must meet current and emerging environmental restrictions and endure today’s corrosive and highly acidic launch environments. These needs include:

- New environmentally friendly technologies for paint removal and surface preparation that can be applied to large structures. New technologies must achieve better performance than conventional abrasive blasting techniques by reducing the cost of collecting and/or processing waste while keeping blasting rates the same or better than conventional technologies. These technologies must work for inorganic zinc coating.
- New environmentally friendly technologies for prevention/reduction of microbial corrosion in steel piping systems utilizing brackish or untreated water.
- Sub-scale or laboratory tests that can be used to evaluate the suitability of refractory concrete for use in launch pad and rocket test facilities flame deflectors. Proposed tests must show that they are relevant to full scale blast effects.
- Innovative refractory material application methods to ensure field applications have the same properties (strength, density, performance, etc…) as small scale test coupons.

Spaceport Processing Evaluation/Inspection Tools
Innovative solutions are desired that reduce inspection times, provide higher confidence in system reliability, increase safety and lower life cycle costs. Technologies must support identifying composite material defects, evaluating material integrity, damage inspection and/or acceptance testing of composite systems. These include:

- Technologies in support of defect detection in composite materials.
- Methods for determining structural integrity of composite materials and bonded assemblies.
- Non-intrusive inspection of Composite Overwrapped Pressure Vessels (COPV), Orion heat shield and other composite systems.
- In-situ evaluation of refractory concrete as installed in the flame trenches associated with propulsion test and launch pad infrastructure.

Hypergolic Propellant Sensing Technologies
Technologies for leak detection and leak visualization for hypergolic propellants, such as:

- Novel, cost effective technology solutions to provide leak detection of hypergolic propellants at concentrations of 10ppb with minimal environmental sensitivity (i.e., humidity). Sensors and leak detection systems should provide quantitative data with minimum interferences, drift, and exposure and recovery time.
- Novel, cost effective technology solutions to provide leak detection of hypergolic propellants at concentrations of 1ppm with minimal environmental sensitivity (i.e., humidity). Sensors and leak detection systems should provide quantitative data with minimum interferences, drift, and exposure and recovery time.
- Technology to provide leak visualization of hypergolic propellants to support operations (propellant loading, pressurization, leak check).

Cold Gas Storage and Servicing of Launch Vehicle Systems
Storing high-pressure pneumatic gases in a chilled state increases the on board density of gasses used for pressurization during flight. Traditional solutions embed these 3000 – 6000 psig metallic tanks into the flight vehicles' main cryogenic propellant tanks. To achieve the lightest weight tanks, final pressurization takes place after the tanks are immersed to maximize strength gained by the lower temperatures. Under these conditions, it takes several hours to achieve thermal equilibrium with the host tank and maximize mass density of the compressed gas. Solutions are sought to reduce this time to less than 60 minutes to achieve thermal equilibrium of the compressed gas with the host liquid cryogen tank and maximize pneumatic gas mass on board the flight vehicle.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware or software demonstration and delivering a demonstration unit or package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Demonstration of technical feasibility (TRL 2-4).

Phase II Deliverables: Demonstration of technology (TRL 4-6)

O3.05 Advanced Motion Imaging
Lead Center: MSFC
Participating Center(s): JSC

Digital motion imaging technologies provide great improvements over analog systems, but also present significant challenges. Digital High Definition Television (HDTV) cameras flown on the Shuttle and International Space Station have shown higher susceptibility to ionizing radiation damage, manifested by visible "dead" pixels in the image. In order to practically deploy HDTV cameras, sensors and processors need to survive operations on orbit for years without debilitating radiation damage that degrades image quality and performance.

The focus of this subtopic is the development of components, systems, and core technologies that advance the capabilities to capture, process and distribute high-resolution digital motion imagery without performance degradation from ionizing radiation that would require frequent upmass to orbit to replace components or systems.

Current State of the Art
HDTV cameras flown on the Space Shuttle and the International Space Station have proven to be highly susceptible to damage from ionizing radiation. This damage is manifested by bad pixels that eventually render the camera useless after short periods of on-orbit use, usually less than one year. In addition, upmass and downmass constraints make the use of large format motion picture film cameras impractical, so a digital equivalent is needed for large venue documentary film productions, such as IMAX films.

Domains of Interest
Domains of interest in the near term address needs for space environment, radiation tolerant, HDTV and digital cinema cameras and down-stream video processors. Mid and Long term goals include radiation tolerant, reprogrammable, highly bandwidth efficient encoders and improved distribution systems for video data signals. Current HDTV transmissions from the ISS require approximately 25 Mbps. Bitrates with equal or better video quality are desired at half that bit rate. These systems are highly desired by the human spaceflight programs.

Technologies of Interest
Technologies are sought that provide high resolution, progressively scanned motion imagery with limited or mitigated radiation damage to sensors, are viable for astronaut hand-held applications or external spacecraft use, and that provide imagery that meets standards commonly used by digital television or digital cinema production facilities. Commercial HDTV cameras used for internal hand-held use have generally been small and light (5” x 6” x 11”, between 2 and 3 pounds), run off rechargeable batteries, and utilize standard lens mounts. Future cameras for exterior applications ideally would be smaller and more modular in design (no larger than 4” x 5” x 7” and 2.5 pounds). The critical technology need is the radiation tolerance of the sensor, not the size, weight and mass of the camera that results from such a sensor.

While commercial HDTV and Digital Cinema cameras for use on Earth are mature technologies, there are no flight-proven radiation tolerant HDTV and Digital Cinema cameras and sensors currently available. Commercial cameras flown on the Shuttle and ISS thus far do function, but degrade within a year on orbit. While hard to classify, the current TRL for these cameras within the context of spaceflight operations could be considered to be a 5 or 6. The ultimate goal is to develop radiation-hardened camera sensors capable of surviving three or more years in space.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration, and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables: Deliverables for Phase I will include designs and development plans with plausible data and rationale that demonstrates why the designs and plans should mitigate radiation effects on the sensors, and a detailed path towards Phase II hardware demonstration. The report shall also provide options for commercialization opportunities after Phase II.

Phase II Deliverables: Deliverables for Phase II will include developmental hardware suitable for testing in a lab or space flight environment (TRL 6) as well as a test plan, relevant data, and defined expected lifespan of the sensors.

O3.06 Environmental Control Systems & Technologies for NR & Cubesats
Lead Center: ARC

A significant challenge faced by free-flying spacecraft and shared by ISS-bound experiment packages is the requirement for a controlled (or at least known) environment while the payload is awaiting launch on the launch vehicle or is in transit to the ISS. Due to the retirement of the Space Shuttle, NASA has a need for flight qualified, environmentally conditioned transportation systems compatible with new space launch systems capable of sustaining and extending the life of perishable materials and specimens until experiment packages can be installed and properly interfaced on-board ISS. This solicitation seeks to develop innovative environmental control technologies for the ground and space transportation of nanorack cubes and cubesats.

Cubesat integration timelines frequently call for passively mating to the launch vehicle or deployer system many weeks in advance of launch. The environment that the payload experiences plays a major role on the shelf life of certain materials and specimens within the spacecraft. Technologies capable of monitoring and extending the shelf life of perishable payloads are of interest to NASA as the environment in and around the launch vehicle is not always controlled in a manner favorable to a payload. Technologies can be either integrated directly into the Cubesat or external to the Cubesat.

Two applications for these technologies are sought:

- ISS Nanorack Transportation System.
    - This system will have the ability to maintain temperatures within relevant ranges for biological and/or perishable Nanorack payloads from time of experiment preparation at the payload processing facility until installation into the host facility on ISS. This also includes ground transportation phases of the mission.
    - The Transportation System will also provide a time history of relevant parameters ie temperature, relative humidity, vibration, etc, during the transportation periods up to payload installation on ISS.
- Cubesat applications.
    - Cubesat applications involve technologies that may be incorporated into the Cubesat spacecraft itself, or systems that can be used as adjuncts to monitor and control the environment in and around the Cubesat payload/spacecraft. These technologies can be passive and/or active in nature.
    - Cubesat applications will also provide a time history of relevant parameters ie temperature, relative humidity, etc during the dwell time on the pad while awaiting launch.

Innovative approaches to this problem will significantly increase the utility of Nanoracks modules and/or Cubesat spacecraft in that this technology will enable an expanded set of experiment types and mission scenarios. Such a capability may also be extended in support of ground control experiments where on-orbit environments must be duplicated in the lab.

Nanorack information can be found here: http://nanoracks.com.
Cubesat information can be found here: http://cubesat.org/.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Report with a feasibility study including: simulations and measurements demonstrating the approach used to develop and test the prototype, constraints on other systems, concept of operations, verification matrix of measurements with pass/fail ranges for each quantity to be verified at the end of Phase II, and the Phase II integration path.
- Proof-of-concept simulation and/or bench top demonstration (TRL 3-4).

Phase II Deliverables:

- Midterm Technical Report.
- Final Phase II Technical Report with specifications including: design, development approach, tests to verify the prototype, verification matrix of measurements with pass/fail ranges for each quantity verified, constraints on other systems, and operations guide. Opportunities and plans for potential commercialization should also be included.
- Fully-functional engineering prototype of proposed product (TRL 5-6).

TOPIC: O4 Navigation

NASA seeks innovative research in the areas of positioning, navigation, and timing (PNT) that have relevance to Space Communications and Navigation programs and goals, as described at (https://www.spacecomm.nasa.gov/spacecomm/default.cfm). NASA's Space Communication and Navigation Office considers the three elements of PNT to represent distinct, constituent capabilities: • positioning, by which we mean accurate and precise determination of an asset's location and orientation referenced to a coordinate system • navigation, by which we mean determining an asset's current and/or desired absolute or relative position and velocity state, and applying corrections to course, orientation, and velocity to attain achieve the desired state • timing, by which we mean an asset's acquiring from a standard, maintaining within user-defined parameters, and transferring where required, an accurate and precise representation of time. This year, NASA seeks technology in Metric Tracking of Launch Vehicles, Position, Navigation, and Timing (PNT) Sensors and Components, and Flight Dynamics Technologies and Software. These areas include tracking during launch and landing operations, and research and technology relevant to the planning and development of PNT support and services that NASA may undertake over the next several years. Some of the subtopics in this topic could result in products that may be included in future flight opportunities. Please see the Science MD Topic S4 for more details as to the requirements for small satellite flight opportunities, and the Facilitated Access to the Space Environment for Technology Development and Training (FAST) website at (http://ipp.nasa.gov/ii_fast.htm).

O4.01 Metric Tracking of Launch Vehicles
Lead Center: KSC
Participating Center(s): GSFC, MSFC

The goal of this subtopic is to have a highly reliable way of tracking vehicles from launch to orbit. Launch vehicles can exhibit high dynamics during flight and there can be external interference on the GPS frequency. Proposals can either address a single area as described below or a combination of multiple areas. The following technology areas are of interest:

Position, Attitude, and Inertial Metrics
Metric tracking of launch vehicles requires the development of accurate and stable integrated metric tracking and inertial measurement units. The focus is on technologies that enable and advance development of low Size, Weight, and Power (SWaP), tactical grade, integrated metric tracking units that provide accurate and stable positioning, attitude, and inertial measurements on high dynamic platforms. Factors to address include:

- Ultra-tight coupling of rate sensors, accelerometers, and attitude determining GPS receivers that will provide very high frequency integrated metric solutions.
- The ability to reliably function on spin-stabilized rockets (up to 7 rev/s), during sudden jerk and acceleration maneuvers, and in high vibration environments.
- Advancements in MEMs-based rate sensors and accelerometers, algorithm techniques and Kalman filtering, high bandwidth and low noise outputs, phased-based attitude determination, single aperture systems, quick Time to First Fix and reacquisition.
- Robust tracking during separation.

Use of GPS and Ability to Mitigate Interference Signals
Innovative technologies to increase the accuracy of the L1 C/A navigation solution by combining the pseudo ranges and phases of the L1 C/A signals, and use of the L2 and L5 carriers. Factors that degrade the GPS signals can be obtained by differencing the available carrier phase and pseudo range measurements and then removing these differences from the navigation solution.

Technologies are sought that combine spatial processing of signals from multiple antennas with temporal processing techniques to mitigate interference signals (jamming) received by the GPS receiver. The coordinated response of adaptive pattern control (beam and null steering) and digital excision of certain interfering signal components can minimize strong jamming signals. Adaptive nulling minimizes interfering signals by the optimal control of the GPS antenna pattern (null steering).

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I (to reach TRL 3) and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract (to reach TRL 5).

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Feasibility Report with a Phase II Integration Path. Proof-of-concept bench top demonstration preferred.
- Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables:

- Working model of proposed product, along with full report of development and measurements, including populated verification matrix from phase II (TRL 5).
- Final Phase II Technical Report.
- Demonstration hardware/software/field test.
- Opportunities and plans should also be identified and summarized for potential commercialization.

O4.02 PNT (Positioning, Navigation, and Timing) Sensors and Components
Lead Center: GSFC
Participating Center(s): ARC, GRC, JPL, JSC

This subtopic seeks proposals that will serve NASA's ever-evolving set of near-Earth and interplanetary missions that require precise determination of spacecraft position and velocity in order to achieve mission success. While the definition of "precise“ depends upon the mission context, typical scenarios have required meter-level or better position accuracies, and sub-millimeter-level per sec or better velocity accuracies. This solicitation is primarily focused on NASA's needs in four focused areas identified below.

Proposals are encouraged that leverage the following NASA developed state of-the-art capabilities:

- GEONS:
  - NASA Copyright, licensable technology.
  - (http://ipp.gsfc.nasa.gov/ft_tech_geons.shtm).
  - AutoNav (NTR 43546 Deep Impact Autonomous Navigation (AutoNav) Flight Software 23-FEB-2006).
- Navigator:
  - US Patent 7,548,199.
  - http://patft1.uspto.gov/netacgi/nph-Parser?patentnumber=7548199.

    - http://techtransfer.gsfc.nasa.gov/ft_tech_gps_navigator.shtm.
- GIPSY:
    - https://gipsy-oasis.jpl.nasa.gov/.
- Electra:
    - http://descanso.jpl.nasa.gov/Monograph/series9_chapter.cfm.
- Blackjack:
    - http://www.jpl.nasa.gov/releases/2000/blackjackgps.html.

NASA is not interested in funding efforts that seek to "re-invent the wheel" by duplicating the many investments that NASA and others have already made in establishing the current state-of-the-art. We seek to maximize the work listed above in the new work sought for this subtopic.

General Operational Needs, Requirements and Performance Metrics:

Onboard Near-Earth Navigation Systems
NASA seeks proposals that would develop a commercially viable transceiver with embedded orbit determination software to provide enhanced accuracy and integrity for autonomous onboard GPS- and TDRSS-based navigation and time-transfer in near-Earth space via augmentation messages broadcast by the proposed TDRSS Augmentation for Satellites Signal (TASS; http://www.gdgps.net/system-desc/papers/Bar-Sever.pdf). Innovations that will increase the integration, reducing the size, weight, and power of such transceiver platforms, and improving their performance in high radiation environments, are sought. Proposers are advised that NASA's GEONS and GIPSY orbit determination software packages already support the capability to ingest TASS messages.

Onboard Deep-Space Navigation Systems
NASA seeks proposals to develop an onboard autonomous navigation and time-transfer system for reduction of DSN tracking requirements. Such a system should provide accuracy comparable to delta differenced one-way ranging (DDOR) solutions anywhere in the inner solar system, and exceed DDOR solution accuracy beyond the orbit of Jupiter. Proposers are advised that NASA's GEONS and AutoNav navigation software packages already support the capability to ingest many one way forward Doppler, optical sensor observation, and accelerometer data types. In addition, NASA is seeking innovative solutions in the area of planetary surface navigation.

Technologies Supporting Improved TDRSS-Based Navigation
NASA seeks proposals providing improvements in TDRS orbit knowledge, TDRSS radiometric tracking, ground-based orbit determination, and Ground Terminal improvements that improve navigation accuracy for TDRS users. Methods for improving TDRS orbit knowledge should exploit the possible future availability of accelerometer data collected onboard future TDRS. The goal is navigation and communications integrated into a single processor.

Navigation Payload Technology for Planetary Relay Satellites
NASA seeks planetary relay navigation payload technologies that can:

- Transmit accurate spread spectrum signals (emphasizing the stability of the frequency reference yielding accurate timing and chipping rate of the PN code and a low noise carrier).
- Receive same in return (either in coherent mode (the relay transmits and receives using the same frequency reference) or non-coherent mode (where the accurate frequency reference is on one end of link, either the transmit side or the receive side)).

This relay navigation payload should be capable of receiving a satellite-to-satellite link with similar signal properties. The relay navigation payload has to measure the range (two-way), pseudo-range (one-way), and both one-way and two-way Doppler. The relay navigation payload must be able to de-commutate data received from Earth and bases on other planetary surfaces to maintain time synchronization with a master time source, use the data onboard to either slave its frequency reference or to update its reference, and turn-around the data to modulate onto the user data stream.

Additionally, the relay navigation payload must have:

- ‘Reasonable fidelity’ autonomous filtered navigation capability to fuse all data types listed above as well as antenna gimbal angles, accelerometer data, and rendezvous radar data, to estimate the lunar relay state.
- Output data rates of 1 Hz for the states of multiple satellites and comprehensive fault detection and correction data.
- State outputs that can be modulated on transmitted data streams.
- TASS-like broadcast beacon capability for navigation. The data on the beacon can originate either at a base location (earth, moon), the relay, or another asset with which the relay communicates.
- Dissemination of time and navigation data for the local environment.

Proposals can either address a single subject as described above or a combination of subjects.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I (to reach TRL 3) and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract (to reach TRL 5).

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Feasibility Report with a Phase II Integration Path. Proof-of-concept bench top demonstration preferred.

Phase II Deliverables:

- Final Phase II Technical Report.
- Demonstration hardware/software/field test.

O4.03 Flight Dynamics Technologies and Software
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL

NASA is beginning to invest in re-engineering its suite of tools and facilities that provide navigation and mission design services for design and operations of mid-term and long-term near-Earth and interplanetary missions. This solicitation seeks proposals that will develop the highly desired flight dynamics technologies and software that support these efforts.

Proposals that leverage state-of-the-art capabilities already developed by NASA are especially encouraged, such as:

- GPS-Enhanced Onboard Navigation Software: http://techtransfer.gsfc.nasa.gov/ft_tech_gps_navigator.shtm.
- General Mission Analysis Tool: http://sourceforge.net/projects/gmat/.
- GPS-Inferred Positioning System and Orbit Analysis Simulation Software: http://gipsy.jpl.nasa.gov/orms/goa/.
- Optimal Trajectories by Implicit Simulation: http://otis.grc.nasa.gov/.

Proposers who contemplate licensing NASA technologies are highly encouraged to coordinate with the appropriate NASA technology transfer offices prior to submission of their proposals.

Areas of interest: In the context of this solicitation, flight dynamics technologies and software are algorithms and software that may be used in ground support facilities, or onboard a spacecraft, so as to provide Position, Navigation, and Timing (PNT) services that re-duce the need for ground tracking and ground navigation support. Flight dynamics technologies and software also provide critical support to pre-flight mission design, planning, and analysis activities.

This solicitation is primarily focused on NASA's operational needs in the following focused areas:

- Applications of cutting-edge estimation techniques, such as, but not limited to, sigma-point and particle filters, to spaceflight navigation problems.
- Applications of estimation techniques that have an expanded state vector (be-yond position and velocity components) to monitor non-Gaussian state noise processes and/or non-Gaussian measurement noise processes.
- Applications of estimation techniques that combine measurements from multiple sensor suites in a highly coupled manner to improve upon the overall system ac-curacy.
- Addition of novel estimation techniques to existing NASA mission design software that is either freely available via NASA Open Source Agreements, or that is licensed by the proposer.
- Applications of advanced dynamical theories to space mission design and analysis, especially in the context of unstable orbital trajectories in the vicinity of small bodies and libration points.
- Addition of novel measurement technologies to existing NASA onboard navigation software that is licensed by the proposer.
- Addition of orbit determination capabilities to existing NASA mission design software that is either freely available via NASA Open Source Agreements, or that is licensed by the proposer.

Technologies and software should support a broad range of spaceflight customers. Technologies and software specifically focused on a particular mission's or mission set's needs, for example rendezvous and docking, or formation flying, are the subject of other solicitations by the relevant sponsoring organizations and should not be submitted in response to this solicitation.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I (to reach TRL 3) and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract (to reach TRL 5).

Phase I Deliverables:

- Midterm Technical Report.
- Final Phase I Technical Feasibility Report with a Phase II Integration Path.

Phase II Deliverables:

- Final Phase II Technical Report.
- Algorithm Specification.
- Delivery of software package.
- Demonstration of software package.

9.2 STTR

The STTR Program Solicitation topics correspond to strategic technology research areas of interest at the NASA Centers. The subtopics reflect the current highest priority technology thrusts of the Centers in their particular area of interest.

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TOPIC: T1 Center 2011 Technology Investments

This year's STTR topic hosted by NASA Ames Research Center spans three technology investment areas at the center. These interests include: Synthetic Biology for Space Exploration, Commodity Based Technologies, and Information Technologies for Intelligent Planetary Robotics. Please see the subtopic descriptions for what is sought under each of these solicitations.

T1.01 Synthetic Biology for Space Exploration
Lead Center: ARC

The field of Synthetic Biology is a rapidly growing area of study that encompasses research ranging from the introduction of incremental function or regulation into existing organisms to the creation of fully synthetic living structures and systems. NASA is interested in harnessing this emerging field to create technological advances for multiple mission focus areas. Topics include biological life support for air, water and waste management; local production of fuels, food and plastics; in situ resource utilization (ISRU) technologies such as biomining for metals and biocementation of regolith for building materials/radiation shielding; biomedical applications including in situ therapeutic production and radiation/gravity countermeasures; advanced chemical and life sensing; and fabrication of advanced materials. Overarching research concerns include using synthetic biology techniques for the development of life forms that have been specifically adapted to perform well in extraterrestrial environments, including increased resistance to radiation, desiccation and temperature extremes. Foundational and applied solutions are sought that provide game-changing capabilities that enable cost effective and sustainable spaceflight and habitation.

T1.02 Commodity Based Technologies
Lead Center: ARC

This subtopic seeks out-of-the-box, innovative, broad-based approaches to address space mission requirements.

Desired proposals would enable the commoditization of space mission requirements by utilizing existing commercial technology goods and services to reduce schedule and costs of implementation.

Examples:

Smart-phones today are able to perform many of the basic capabilities of the spacecraft, having a high speed processor with large memory capacity, a set of sensors such as an accelerometer, rate gyroscopes, magnetometer, global positioning system (GPS).

Another example would be using multiple COTS (commercial off the shelf) digital cameras with multiple color filter settings, and then combining the image as a hyper-spectral imager at low cost. Other consumer goods that may have high utility for small spacecraft include but are not limited to:

- PDA-based smart phones.
- High resolution digital cameras.
- Consumer robotics.
- Lego-like assemblies.
- Medical grade surgical adhesives.
- Pressure sensitive paint.
- In-situ bioanalytical diagnostics.
- Mining technologies.
- Biohybrid devices.
- Diagnostics.

- X10-based domonics.

Proposers are asked to build a conceptual system/spacecraft design/operational scenario that details the architecture, components and specifications. Supporting analysis including cost and feasibility should be included. Phase II contract efforts should be used to prototype the system(s) detailed in Phase I.

Proposals should focus on the following areas of research:

- Transformational Small Spacecraft, Subsystems, and Mission Architectures.
- Biological Technologies for Life Beyond Low Earth Orbit.
- GREEN Technologies (Technologies for Sustainability).
- Emerging Aeronautics Systems and Technologies.
- Autonomous Laboratories on Planetary Surfaces.
- Hybrid Systems Modeling and Analysis.
- Advanced Information, Robotics, and Autonomous Systems.

Proposals that focus on the above areas of research, and contribute to the NASA Space Technology Grand Challenges will have higher priority.

Reference Documents:

- Grand Challenges
    - http://www.nasa.gov/pdf/503466main_space_tech_grand_challenges_12_02_10.pdf
- Roadmaps
    - http://www.nasa.gov/offices/oct/home/roadmaps/index.html

T1.03 Information Technologies for Intelligent Planetary Robotics
Lead Center: ARC

The objective of this subtopic is to develop information technologies that enable robots to better support planetary exploration. Intelligent robots are already at work in all of NASA's Mission Directorates and will be critical to the success of future exploration missions. The 2010 NASA "Robotics, Tele-Robotics, and Autonomous Systems Roadmap" (RTA Roadmap) indicates that extensive and pervasive use of intelligent robots can significantly enhance exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

Robots can do a variety of work to increase the productivity of planetary exploration. Robots can perform tasks that are highly-repetitive, long-duration, or tedious. Robots can perform tasks that help prepare for subsequent human missions. Robots can perform "follow-up" work, completing tasks started by astronauts. Example tasks include: robotic recon (advance scouting), systematic site surveys, documenting sites or samples, and unskilled labor (site clean-up, close-out tasks, etc).

The RTA Roadmap identifies three key areas for improvements in robotics:

- Technology should aim to exceed human performance in sensing, piloting, driving, manipulating, rendezvous and docking.
- Technology should target cooperative and safe human interfaces to form human-robot teams.
- Autonomy should make human crews independent from Earth and robotic missions more capable.

Thus, proposals are sought which address the following topics:

- Advanced user interfaces for remote robotic exploration, which include Web-based collaboration methods, panoramic and time-lapse imagery, support for public outreach/citizen science, social networking and/or visualization of geospatial information. The primary objectives are to enable more efficient interaction with robots, to facilitate situational awareness, and to enable a broad range of users to participate in robotic exploration missions.
- Ground control data systems for robotic exploration. Proposals should focus on software tools for planning variable-duration and adjustable autonomy command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing; and/or for automating ground control functions.
- Mobile robot navigation (localization, hazard avoidance, etc.) for multi-km traverses in unstructured environments. Novel "infrastructure free" techniques that utilize passive computer vision (real-time dense stereo, optical flow, etc.), active illumination (e.g., line striping), repurposed flight vehicle sensors (low light imager, star trackers, etc.), and/or wide-area simultaneous localization and mapping (SLAM) are of particular interest.
- Robot software architecture that radically reduces operator workload for remotely operating planetary rovers. This may include: on-board health management and prognostics, on-board automated data triage (to prioritize information for downlink to ground), and learning algorithms to improve hazard detection and selection of locomotion control modes.

TOPIC: T2 Atmospheric Flight Research and Technology Demonstration

This topic solicits innovative aerospace concepts and techniques that would advance aerospace technologies in all flight regimes. NASA's flight research mission is to demonstrate aeronautic and space technologies through flight research and testing. NASA also seeks advance flight test techniques and analysis tools for efficient and timely flight research. The principle areas of interest encompass game-changing aerodynamic concepts; flight controls; multi-disciplinary flight system analysis and validation; miniaturized, low-power, light-weight sensors and systems for flight research data and processing; Airborne Science Platform instrument support capabilities to more effectively conduct NASA’s scientific missions and investigations.

T2.01 Technologies for Aeronautics Experimental Capabilities
Lead Center: DFRC

The emphasis of this subtopic is proving feasibility, developing, and demonstrating technologies for advanced flight research experimentation that matures new methodologies, technologies, and concepts. It seeks advancements that promise significant gains in NASA's flight research capabilities or addresses barriers to measurements, operations, safety, and cost in all flight regimes from low sub-sonic to high supersonic. This subtopic solicits innovative technologies that enhance flight research competencies by advancing capabilities for in-flight experimentation. Proposals that demonstrate and confirm reliable application of concepts and technologies suitable for flight research and the test environment are a high priority.

Measurement techniques are needed to acquire aerodynamic, structural, flight control, and propulsion system performance characteristics to safely expand the flight envelope of aerospace vehicles. The goals are to improve the effectiveness of flight-testing by simplifying and minimizing sensor installation, measuring parameters in novel ways, improving the quality of measurements, and minimizing the disturbance to the measured parameter from the sensor presence. Sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.
Special areas of interest include:

- Methods and associated technologies for conducting flight research and acquiring test information in flight.
- Numerical methods for the planning, prediction, analysis and validation of flight-test experimentation.

- Sensors and data systems that have fast response, low volume, minimal intrusion, and increased accuracy and reliability.
- Innovative techniques that decrease turn-around time for inspections and assessments for safe operations of aircraft (e.g.,, non destructive examination of composites through ultrasonic techniques).
- Advanced design and manufacturing techniques for improved upper stage performance for nano- & small-satellite booster technologies (e.g.,, manufacturability, affordability, and performance of a small upper-stage booster rocket motors for small & nano-satellites).
- Novel dynamic modeling and simulation of aircraft flight and structural control are encouraged. Control objectives include aerodynamic boundary layer and laminar flow control, autonomous and adaptive systems for improved stability, safety, performance, and drag reduction.

T2.02 Aeroservoelastic (ASE) Control, Modeling, Simulation, and Optimization
Lead Center: DFRC

This subtopic addresses advanced control-oriented techniques for aeroservoelastic (ASE) flight systems including distributed network sensor systems, modeling, simulation, optimization and stabilization methods of ASE systems to actively and/or adaptively control wing geometry, vibration, gust/turbulence response, static/dynamic loads, and other aeroelastic (AE) objectives for enhanced aeroservoelastic performance and stability characteristics.

Technical elements for these proposals may include:

- ASE enhancements for flight control while minimizing adverse AE interaction.
- Flexible aircraft stabilization and performance optimization.
- Modeling and system identification of distributed AE dynamics with aircraft flight dynamics.
- Sensor/actuator developments and modeling for ASE control.
- Uncertainty modeling of complex ASE system behavior and interactions.
- Distributed networked control schemes for wing shape, vibration, and load control.
- Boundary-layer, shock, and viscous flow sensing with AE control feedback.
- Mission/maneuver adaptivity with dissipative optimal energy-force distribution.
- Data-driven multi-objective ASE control with physics-based aeroelastic sensing.
- Compressive information-based sensing.

This subtopic also addresses capabilities enabling design solutions for performance and environmental challenges of future air vehicles. Research in revolutionary aircraft configurations include lighter and more flexible materials, improved propulsion systems, and advanced concepts for high lift and drag reduction. This subtopic targets efficiency and environmental compatibilities requiring performance challenges and novel control-oriented techniques for aeroservoelastic considerations which are gaining prevalence in advanced aerospace flight vehicles, atmospheric and extra-terrestrial.

Development of distributed sensory-driven control-oriented ASE systems is solicited to enable game-changing flight vehicle concepts and designs that manage aerostructural dynamic uncertainty on a vehicle's overall performance. This subtopic will assist in revolutionizing improvements in performance to empower a new generation of air vehicles to meet the challenges of Next Generation Air Transportation System (NextGen) concerns, concepts and technology developments in systems analysis, integration and evaluation.

Higher performance measures include energy efficiency to reduce fuel burn and operability technologies that enable takeoff and landing on shorter runways. Distributed aeroelastic control allows for robust nonintrusive flush sensing for control near stall and ground effects, accounting for vehicle flexibility. Proposals should describe how such improvements with distributed ASE systems promote new applications of flight with experimental methods to establish validation data in areas comparable to:

- Reduced take-off and landing field length requirements.
- Improved performance with lightweight structures and low drag aerodynamics.
- Multi-disciplinary design and analysis tools and processes to enable reliable, advanced aircraft configurations with control-oriented sensory-driven design concepts for flight near performance/stability limits.
- Transonic and supersonic shock/boundary-layer control in an aeroelastic environment.
- Sensory and control systems for the reduction of ASE uncertainty from hypersonic aerodynamic heat loads, resulting in lower vehicle weight from reduced design margins for thermal structures and thermal protection systems.
- Integration of interactions among the airframe, inlet, nozzle, and propulsion systems using physics-based ASE control-oriented design approach.

TOPIC: T3 Technologies for Space Exploration

This topic seeks to solicit advanced innovative technologies and systems in space power and propulsion to fulfill our Nation's goal of space exploration. The anticipated technologies should advance the state-of-the-art or feature enabling technologies to allow NASA to meet future exploration goals.

T3.01 Technologies for Space Power and Propulsion
Lead Center: GRC

Development of innovative technologies are sought that will result in durable, long-life, lightweight, high performance space power and in-space propulsion systems to substantially enhance or enable future missions.

Innovations for space power systems are sought that will offer significant improvements in system safety, efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, design flexibility/reconfigurability, autonomy, and affordability. In the area of power generation, advances are needed in photovoltaic cell technology (e.g., materials, structures, and incorporation of nanomaterials); solar array module/panel integration (e.g., advanced coatings, advanced structural materials, monolithic interconnects, and high-voltage operational capability); and solar array designs (e.g., ultra-lightweight deployment techniques for planar and concentrator arrays, restorable/redeploy able designs, high power arrays, and planetary surface concepts). For energy storage technology, advances are needed in primary and rechargeable batteries, fuel cells, flywheels, regenerative fuel cell systems, and innovative design methods. Advances are also needed in power management and distribution systems, power system control, energy conversion technology (such as Stirling and Brayton systems) and integrated health management. Advanced nuclear power and other innovative concepts and related technologies are also sought.

Innovations, advanced concepts and processes are sought for in-space propulsion, including electric propulsion, chemical propulsion, advanced rocket propellants/alternative fuels, nuclear propulsion, and tether technology. In electric propulsion, concepts for subcomponent improvements are needed for electric propulsion systems, including cathode technologies, electrode-less plasma production, low-erosion materials, high-temperature magnetics, and lightweight simplified power processing systems. Innovations are also desired for low thrust trajectory analysis tools and new diagnostic techniques to quantify thruster performance and lifetime. In small chemical thruster propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

TOPIC: T4 Innovative Sensors, Support Subsystems and Detectors for Small Satellite Applications

This STTR topic solicits advanced technologies for satellites with masses less than approximately 20 kg and volumes less than approximately 10,000 cm3. Needed are components, subsystems, sensors, detectors and instruments that increase the capabilities of very small satellites while meeting the significant constraints imposed by the very limited size and mass of the observatory

4.01 Innovative Sensors, Support Subsystems and Detectors for Small Satellite Applications
Lead Center: GSFC

As the launch opportunities of very small satellites increase, NASA needs advanced capabilities to be developed in order to increase the viability of world-class scientific and technological applications within smaller constraints. This will allow NASA to use every class of orbiting system to make measurements to improve the scientific understanding of the Earth, the Sun and the cosmos.

This STTR solicitation is to help provide advanced technologies for satellites with masses less than approximately 20 kg and volumes less than approximately 10,000 cm3. Components or subsystems are sought that demonstrate a capability that is applicable to orbital missions to 800 km and mission durations up to 2 years. New approaches, instruments, and components are sought that will:

- Enable new Earth Science, Solar Science, or Astronomy measurements.
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal resolution, accuracy, range of regard).
- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same measurement capability.
- Provide satellite bus capabilities that increase the capabilities of very small satellites while meeting the significant constraints imposed by the very limited size and mass of the observatory.

Small Satellite Subsystem Technologies
Components and subsystems are required to furnish satellite bus capabilities for very small satellites. The subsystems are mass and volume constrained to a reasonable portion of satellites that must have total masses and volumes less than 20 kg and 10,000 cm3. In particular, NASA needs advanced component and/or subsystems designs for power, attitude control, telemetry, structures, propulsion, data and command processing, ground communication, and crosslink communication.

Components and subsystems must be those that consider the severe mass, volume, and power constraints imposed by these very small spacecraft.

Small Satellite Sensors
Sensors are required that support the assessment the state of spacecraft, and formations of spacecraft, needed to conduct sophisticated NASA science and technology missions. Sensors are required for spacecraft attitude, position, and velocity; relative attitude position and velocity; and accelerations. In addition, component temperatures, mechanism states, and magnetic field strength and direction are also needed.

Small Satellite Science Detectors and Instruments
Instruments or detectors are required that support Earth Science, Solar Physics, and Astrophysics experiments. Components and subsystems must be those that consider the severe mass, volume, and power constraints imposed by these very small spacecraft.

TOPIC: T5 Technologies for Compositional Analysis and Mapping

This topic addresses the need for low mass, low power technologies that support in situ compositional analysis and mapping. Two areas are of particular interest: micro-scale analysis and mapping of the mineralogy, organic compounds, chemistry and elemental composition of planetary materials, related to rock fabrics and textures; and remote mapping of geologic outcrops and features. Such technologies are particularly relevant for the planned Mars 2018 rover mission, but may also be proposed to future landed missions to the Moon, comets, asteroids, Europa, Titan, and other planetary bodies.

T5.01 Technologies for Planetary Compositional Analysis and Mapping
Lead Center: JPL

This subtopic is focused on developing and demonstrating technologies for both orbital and in situ compositional analysis and mapping that can be proposed to future planetary missions. Technologies that can increase instrument resolution, precision and sensitivity or achieve new & innovative scientific measurements are solicited. For example missions, see (http://science.hq.nasa.gov/missions). For details of the specific requirements see the National Research Council's, Vision and Voyages for Planetary Science in the Decade 2013-2022 (http://solarsystem.nasa.gov/2013decadal/).

Possible areas of interest include:

- Improved sources such as lasers, LEDs, X-ray tubes, etc. for imaging and spectroscopy instruments (including Laser Induced Breakdown Spectroscopy, Raman Spectroscopy, Deep UV Raman and Fluorescence spectroscopy, Hyperspectral Imaging Spectroscopy, and X-ray Fluorescence Spectroscopy).
- Improved detectors for imaging and spectroscopy instruments (e.g., flight-compatible iCCDS and other time-gated detectors that provide gain, robot arm compatible PMT arrays and other detectors requiring high voltage operation, detectors with improved UV and near-to-mid IR performance, near-to-mid IR detectors with reduced cooling requirements).
- Technologies for 1-D and 2-D raster scanning from a robot arm.
- Novel approaches that could help enable in situ organic compound analysis from a robot arm (e.g., ultra-miniaturized Matrix Assisted Laser Desorption-Ionization Mass Spectrometry).
- "Smart software" for evaluating imaging spectroscopy data sets in real-time on a planetary surface to guide rover targeting, sample selection (for missions involving sample return), and science optimization of data returned to Earth.
- Other technologies and approaches (e.g., improved cooling methods) that could lead to lower mass, lower power, and/or improved science return from instruments used to study the elemental, chemical, and mineralogical composition of planetary materials.

Projects selected under this subtopic should address at least one of the above areas of interest. Multiple-area proposals are encouraged. Proposers should specifically address:

- The suitability of the technology for flight applications, e.g., mass, power, compatibility with expected shock and vibration loads, radiation environment, interplanetary vacuum, etc.
- Advantages of the proposed technology compared to the competition.
- Relevance of the technology to NASA's planetary exploration science goals.

TOPIC: T6 Innovative Technologies and Approaches for Space

This topic seeks research and technology development that can directly support the NASA Space Technology Roadmap (STR) and Space Technology Grand Challenges. The long-term goal is to advance the technologies that will be needed to achieve the NASA mission objectives as outlined in the National Space Policy. The efforts of this STTR topic in 2011 will focus on two specific areas:

- Affordable and Sustainable Crew Support and Protection.
- Active Debris Removal Technologies.

T6.01 Affordable and Sustainable Crew Support and Protection
Lead Center: JSC

This STTR sub-topic seeks to advance the state-of-the-art in spacecraft life support, thermal control, extra-vehicular activity and habitation systems, leading toward the ability to sustain a crew in space for years with minimal supplies launched from Earth. Atmosphere, water and waste all need to be regenerated with highly reliable systems to reduce or eliminate the need to launch parts and supplies to maintain the systems. The crew must also be protected from the dangers of the deep space environment. During extra-vehicular activity, this poses additional difficulties. Specific challenges areas where NASA is soliciting new ideas are described below.

Wastewater Reuse
Recycling of wastewater from gray and black water sources with minimal mass, power, volume and expendables is needed. Source separation of hygiene wastewater and urine water may be assumed. A particular challenge is the stabilization of urine to prevent odor and fouling of systems without the use of hazardous chemicals. Any stabilization system should be compatible with the extraction of nearly 100% of the water from brine if concentrated wastewater is created by primary processors.

Improved Thermal Control
Long life (>1 year) active thermal control systems are needed that can operate over a wide range of heat loads in a wide range of thermal environments. Reduced freezing point (< -10C) non-toxic heat transfer fluids are desired that are compatible with high surface-area-to-volume ratio aluminum systems. An ideal fluid would have high thermal conductivity and specific heat and would have low viscosity over a wide range of temperatures.

Also, water/ice phase change heat exchangers are needed to accommodate thermal management in environments that vary from very cold to warmer than room temperature. A successful design will efficiently transfer heat into and out of the water while managing the location of the ice and void space. The heat exchanger should be capable of ten thousand freeze/thaw cycles without damage.

Robust Extra-Vehicular Activity
A state of the art Extra Vehicular Activity (EVA) space suit is made of multiple layers of fabrics with a hard upper torso and metal bearings. These fabric layers provide physical and mechanical protection for the astronaut, as well as thermal isolation and pressurization for EVA in vacuum. There are several materials development advances that could significantly revolutionize space suit design. These advances consist of combining some of the functions provided by the current suit layers into fewer layers or using new materials to improve suit sizing methods. There is a need not only to improve existing properties of the space suit such as flame retardancy or decreased mass but also add new properties such as microbial growth resistance, selective permeability, static build-up resistance, improved MMOD protection, and radiation shielding. These improvements would increase mission safety and the useful life of the space suit. Increased radiation protection could increase the number of hours crew members spend performing EVAs over their career. Materials that reduce charge build up or decrease shock hazards would alleviate risks associated with interfacing different vehicles or performing EVAs in a plasma environment. Materials that are self healing could improve astronaut protection by detecting punctures and small cuts and even repairing suit damage. In addition, there is a need for micrometeorite shielding technology of the crew during EVAs.

Vacuum Regenerable Trace Contamination Control for spacesuits is also sought. A spacesuit is a small, closed environment in which the atmosphere is continually recycled. Therefore, a means of removing air borne trace contaminants is needed to protect the health of the crew member during an Extravehicular Activity (EVA). The primary contaminants in question for space suit applications are thought to be ammonia and formaldehyde, and the Spacecraft Maximum Allowable Concentrations (SMAC) for these contaminants are 7 mg/m^3 and 0.3 mg/m^3, respectively. Expected generation rates for these two contaminants are approximated at ~80 mg of ammonia and ~0.3 mg of formaldehyde during an 8 hour EVA. The current Portable Life Support System (PLSS) concept uses a CO_2 and humidity control technology that regenerates with a 3 to 10 minute vacuum cycle. A trace contamination control technology that could regenerate with this same vacuum cycle, that minimizes mass, power, and system pressure drop is desired.

T6.02 Active Debris Removal Technologies
Lead Center: JSC

After more than 50 years of human space activities, orbital debris has become a problem in the near-Earth environment. The total mass of debris in orbit is close to 6000 tons at present. The U.S. Space Surveillance Network is currently tracking more than 22,000 objects larger than about 10 cm. Additional optical and radar data indicate that there are approximately 500,000 debris larger than 1 cm, and more than 100 million debris larger than 1 mm in the environment. Because of the high impact speed between orbiting objects in space, debris as small as 0.2 mm poses realistic threat to Human Space Flight (EVA suit penetration, Shuttle window replacement, etc.) and other critical national space assets.

Recent modeling studies indicate that debris mitigation measures commonly-adopted by the international community will be insufficient to stop the debris population growth in low Earth orbit (LEO, the region below 2000 km altitude). To better preserve the space environment for future generations, active debris removal (ADR) of large and massive upper stages and spacecraft must be considered. The need for ADR is also highlighted in the National Space Policy of the United States of America, released by the White House in June 2010. The Policy explicitly directs NASA and the Department of Defense to “pursue research and development of technology and techniques to mitigate and remove on-orbit debris.” Orbital debris is also one of the NASA Grand Challenges outlined by the Office of the Chief Technologist.

An end-to-end ADR operation includes, in general terms, launches; propulsion; guidance, navigation & control; proximity operations; precision tracking; rendezvous; stabilization (of the spinning/tumbling targets); capture/attachment; and deorbit/graveyard maneuvers. Some of the technologies involved in the ADR process do exist, but the difficulty is to make them more cost effective. Other technologies, such as ways to stabilize a large and massive spinning/tumbling upper stage and the capture mechanisms, are new and will require major innovative research and development efforts. In addition, many of the potential ADR targets are upper stages with leftover propellants stored in pressurized containers. Any capture mechanisms of those upper stages will have to be carefully designed to reduce the possibility of explosion.

The focus of this subtopic is to support the development and advancement of cost-effective technologies and techniques to address any of the sub-components described above for active debris removal in LEO. The ultimate goal is to develop the full capability of an end-to-end ADR demonstration in LEO in 5 to 10 years.

TOPIC: T7 Ground Effects of Launch Acoustics, Payload Integration, and Flexible Polymer Foam Systems

Kennedy Space Center (KSC) is seeking innovative solutions to improve ground systems operations. This topic highlights three areas that KSC has a vested interest. These include: improved performance of materials for cryogenic insulation, fireproofing, energy absorption, and other aerospace applications; methodologies for verification and validation of software that simulates ground effects of launch acoustics; standardization of payload integration and subsystem interfaces to enable low cost, reliable, and reusable standards and adapter systems for launch.

T7.01 Ground Effects of Launch Acoustics
Lead Center: KSC

The exhaust plume from a launch vehicle rocket engine generates severe acoustic waves, which cause acoustic loading on the ground structures and vehicle payload. Prediction and reduction of the acoustic levels in the near field of launch vehicle lift-off is an important factor that should be taken into consideration early in the design process of the space launch complex.

The Kennedy Space Center is dedicated for ground systems operation. It is crucial that ground support equipments (GSE) and launch pad structures are designed to withstand the launch-induced environments produced by the first-stage rocket exhaust plume.

High-fidelity prediction technique such as computational aeroacoustics (CAA) can be used to resolve the acoustic flow field in an accurate fashion. It is understood that CAA prediction can be computationally intensive and often prohibitive for a large domain as in the launch environment. However, recent advances in computational resources and methodology have allowed CAA to overcome these difficulties. In the past few years, researchers have employed CAA in the launch environment[1,2,3]. These results are promising, but they need to be validated against actual data. The economical way of getting acoustic data is from static firing in a subscale or full scale environment. The problem with static firing test is that they do not reveal the dynamic environment. Flight data from actual launch would yield much better data, but such data are limited and costly. The best alternative would be to collect data from a demonstration launch vehicle.

It is proposed that a capability be developed to perform launch acoustics research by launching a demonstration reusable vehicle from one of the launch pads at KSC or Cape Canaveral Air Force Station (CCAFS), with acoustic sensors installed on the vehicle and in the vicinity of the launch complex. The capability will allow raw data to be processed into one-third octave band sound pressure level and used for benchmarking results obtained from CAA analysis.

References:

- Tsutsumi, S., Kato, S., Fukuda, K., and Takaki, R., “Effect of Deflector Shape on Acoustic Field of Launch Vehicle at Lift-off”, AIAA-2009-3028, 47th AIAA Aerospace Sciences Meeting, Orlando, FL, 5-8 January 2009.
- Tsutsumi, S., Kato, S., Fukuda, K., and Takaki, R., “Numerical Study on Acoustic Radiation for Designing Launch-Pad of Advance Solid Rocket,” AIAA-2008-5148, 44th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Hartford, CT, 21-23 July 2008.
- Casalino, D., Barbarino, M., Genito, M., and Ferrara, V., “Improved Empirical Methods for Rocket Noise Prediction through CAA Computation of Elementary Source Fields, 14 th AIAA/CEAS Aeroacoustics Conference, 5-7 May 2008, Vancouver, BC, Canada.

T7.02 Payload Integration and Payload Launch Preparation Interface Standards
Lead Center: KSC

This STTR topic seeks commercial solutions that will allow and encourage standardization of key payload to launch vehicle, and subsystem interface standards to reduce the cost associated with analysis, integration, and preparation required to design and then configure space systems for launch. The goal is a set of launch vehicle adapters, processes, and avionics interface standards that can be collectively used to facilitate spacecraft and subsystem design while reducing testing duration and complexity, overall reducing mission risk and while enabling novel mission concepts.

These sets of systems will focus on new standards for payload in the following mass ranges:

- 1 to 10kg.
- 11 to 50kg.
- 51 to 100kg.
- 101 to 180kg.

These ranges have been identified as the regions where critical technologies demonstrations and new space technologies could be used to increase TRL level at a lower cost with reduced risk. Enabling these capabilities will allow space craft developers the ability to design to a specific mass range that will result in on orbit research.

This STTR will be used to evaluate each of the current and future launch vehicles in determining where cross cutting standards can be applied to the entire NASA launch vehicle fleet.

The STTR has been classified as highly desirable. This rating was determined because there are adapters in place that could support the missions. However, to have multiple systems across multiple launch vehicles will contribute to higher cost for integration of that mission. By having standards amongst the space craft and adapter community will reduce the per kilogram cost to orbit.

A significant fraction of mission costs are typically unique designs and approaches to perform relatively routine functions such as launch accommodations and subsystem-to-subsystem interface and communications. By standardizing many of these approaches, spacecraft and payload developers can design their systems with an expectation of a predictable, low-cost integration flow. Launch service providers can mitigate mission risk through the use of predictable and proven interfaces standardized to streamline analytical/physical integration processes and test flows.

Specific areas of interest:

- Launch adapters and systems and associated spacecraft standards.
- Standardized spacecraft and/or payload integration test flows, processes and qualification techniques.
- Standardized electrical interface standards, sometimes known as plug and play electrical power and data bus standards for streamlined subsystem integration.

Priority should be given to practical solutions that:

- Enable low-cost and reliable reusable standards and adapter systems.
- Demonstrate a higher likelihood of being incorporated into a wide number of commercial or government space access system, or systems.
- Can achieve flight or high-fidelity ground-based demonstrations within the next three years; longer-term development proposals will be accepted, but will be considered at a lower priority for funding.

T7.03 Flexible Polymer Foams Systems for Fireproofing and Energy Absorption
Lead Center: KSC

NASA has a growing need for flexible polymer foams for cryogenic insulation, fireproofing, energy absorption and other aerospace applications. NASA Chemists and Engineers at Langley Research Center and Kennedy Space Center have been developing high performance polyimide foams for the last 15 years or more for such applications with great success in varying densities, addressing cell content and effects on performance properties, and additionally producing composites of such foams with enhanced thermal conductivity. In addressing applications for these high performance foams, it has also been identified that increased flexibility with structural integrity foams are also needed in polyurethane foam systems. Advances in novel approaches to polyurethane foam systems are desired to address increased flexibility, good flame retardancy and acoustic attenuation properties for future vehicle and ground systems. The goal is explore new flexible foam systems that control cell content and offer "breathable" characteristics allowing for foam use in potential ice mitigation in such applications as umbilical systems. Delayed time to ignition, decreased peak heat release rates and smoke generation in non-halogen flame retardancy are also advantageous for response to this solicitation.

TOPIC: T8 Autonomous Systems

Autonomous and robotic systems are a critical capability in all of NASA's mission areas including Aeronautics, Earth and Planetary Sciences, and Human Spaceflight and will be more pervasive in the future. Current systems are primarily automated, able to respond to a predicted set of conditions and require human interaction and control. The goal of this topic area is to develop technologies and capabilities that will lead fully autonomous systems that are able to learn and adapt to changes in their environment that were not predicted to accomplish the mission goals with minimal or no human involvement required, particularly if communication delays are significant or unavailable. Specific capabilities include perception, cognition, and mobility/manipulation to enable Multi-robotic systems, Atmospheric Flight and Remote Sensing and Navigation in GNSS-Denied Environments.

T8.01 Autonomous Multi-Robotic Systems
Lead Center: LaRC

Current NASA research/development and mission capabilities are primarily focused on single, automated robotic systems. For example, exploration of remote planetary surfaces has used single automated Telerobotic vehicles, dependent on human control, which limits the area covered, scope of mission and risk of a single point mission failure.

The goal of this topic area is to develop technologies and capabilities that will lead to fully autonomous systems that are able to learn and adapt to changes in their environment that were not predicted to accomplish the mission goals with minimal or no human involvement required. Of specific interest in this topic area is techniques for cooperation among multiple robotic vehicles to achieve complete mission objectives autonomously that cannot be accomplished by current robotic architectures. This would permit the exploration of larger spatial areas/volumes, increase system redundancy and enable distributed capability deployment, where vehicles can have varying sensor/manipulator capabilities to better achieve a broad range of objectives. The system would autonomously distribute required tasks amongst themselves based upon each vehicle's capabilities/equipment package and adapt to changes in the environment, learned knowledge and failures on individual vehicles.

Three possible examples of multiple cooperating vehicles systems are described below, but other concepts will be considered:

- A "Parent" vehicle would provide transportation, control and logistical support for multiple "Child" vehicles, extending data gathering and mapping operations. For example, a Walker/Gecko could provide access to subterranean areas, the Walker navigating large rock fields, while the Gecko would be employed for exploring lava tubes and caves. The system requirements include: docking, deployment, recovery, and storage of the Child vehicles; re-fueling the Child vehicles; local navigation and communication, and adapting to potential failures, including the loss of communication.
- A flying swarm of a large number of smaller vehicles, operating autonomously yet cooperatively, could extend the exploration range while maintaining direct surface contact as the swarm "hops" from point to point. Such a design has the added benefit that individual failure would not condemn the mission to fail (e.g., 80% of individuals could fail with 100% mission success). A swarm design presents new problems such as how the swarm will effectively fly in formation and how the swarm will determine course of action.

Because much of the environment is unknown, the swarm must adapt to unforeseen situations. Centralized control and predetermined script execution is likely not practical. Without directions from a central controller, individual members of the swarm are limited to local observations and communication with neighboring members. From these observations, individuals must make autonomous decisions and take individual action. From these actions, a behavior emerges. Thus, the challenge is to design the swarm for desired emergent behavior beyond just formation flying, the swarm must demonstrate decisions on actions to complete an exploratory mission without a central controller, but rather the combined action of autonomous individuals.

- A sensor network, a distribution of a large number of connected, capable devices distributed over a region, could extend the range of exploration without the requirement for mobility. Conventional sensor network design is limited to a sense and send scenario where individual devices periodically sense the environment and send information through a multi-hop network of others to the central controller. However, a much more complex mission could be accomplished by a "virtual swarm" over the distribution. While the individual devices remain fixed after initial deployment, the application could move around the network as required to complete the mission. To take full advantage of the architecture and achieve maximum success, the application must adapt to unforeseen circumstances presented by the environment. A successful demonstration will exhibit communication among a fixed set of devices that directs where and when observations are taken and what actions will be taken to complete a mission (i.e., virtual mobility). Devices must not be directed by a central controller or a predetermined script but must exhibit adaptive behavior to a non-deterministic scenario.

Phase I activities should include an assessment of current technology capabilities relative to future requirements, identify technology gaps and lay out a technology development roadmap for an integrated system. An integrated software simulation of the proposed concepts is desirable. Potential subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of an integrated prototype system of multiple cooperating autonomous vehicles.

T8.02 Autonomous Systems for Atmospheric Flight and Remote Sensing
Lead Center: LaRC

Increasing levels of automation capabilities in the aviation arena, provides unique opportunities and challenges for civil aviation, and the aerial transport communities. Flight will be transformed as these capabilities mature and evolve in to integrated systems. In particular, autonomous and robotic, manned and unmanned civil aircraft systems will lead to a plethora of new markets, vehicle, and missions. These new systems with broad range of capabilities, and a huge diversity of shapes and sizes, must safely utilize the future National Airspace System. Both operational and machine autonomy will require tremendous breakthroughs through the new technology frontiers in machine intelligence, autonomy, robotics, and inter-connections of these technologies. Breakthroughs in these areas could lead to such societal capabilities as autonomous cargo carrying, surveillance, air taxis, small unmanned civil aircraft, Zip aircraft, on-demand VTOL aviation, airborne wind energy platforms and a host of other emerging distributed aviation systems. For purposes of this solicitation, autonomous vehicles have varying levels of autonomy that range from automated capability to fully autonomous flight where the system has the ability to learn, reason, and adapt. Military applications have demonstrated the ability to do automated flight but their use in civil aviation requires additional research and development. The primary interest of this sub-topic is to advance the technologies for robotic and autonomous vehicle perception, cognition, as well as system integration. Proposals should be written around one of the following themes described below:

- Autonomous and robotic air-vehicles can enable new markets reduce operational cost, and improve safety. Autonomous systems can be applied far beyond remotely piloted aircraft. Maximum machine effectiveness can only be realized through vehicle autonomous systems ability to learn, reason and adapt. Current practice is to have a reliance on stored information, which is complemented by GPS position information. If there is an on-board, real-time means to sense and react to the local environment (including air and ground features and traffic), then autonomous and robotic air-vehicle can be fully utilized. But addressing how adaptive systems can still be ‘trusted’ in critical flight environments and achieve FAA certification is a technical issue that must be resolved. Proposals are sought to develop innovate approaches and enabling technologies for autonomous, robotic, and embodied intelligent air-vehicles. Example scenarios could include but are not limited to carrying passengers and cargo through the NAS, search, rescue, and surveillance operations, and sentries to patrol coastal waters, and land borders. Proposal should consider perception, cognition, as well as GPS enabled, GPS-denied, and cooperating and non-cooperating traffic environments.

- There are a broad range of technical subjects relevant to these new aviation markets and highly diverse aircraft operations include Machine and Operational Autonomy, Off-Nominal Autonomy, Future Consensus and Statistically Based Regulatory Processes, Safety Assurance, Software Certification, Electric and Redundant Propulsion Systems, Airspace Separation Assurance and Detection, Peer-to-Peer Deconfliction, Wireless Sensor Networks for Smart Aircraft Sub-Systems, Fault Tolerant Systems, and Multi-Spectral Sensing and Data Fusion. Proposals are also sought in the integration of these technologies in combination to achieve new societal capabilities across specific aircraft configurations. Therefore, emergent vehicle autonomy platforms that can showcase capabilities that were previously unable to be performed (without autonomy). One example would be the ability to follow complex flight paths such as dynamic soaring, where autonomy enables an entirely new ability through both predictive and optimal trajectory planning and execution. Likewise extreme Short and Vertical Takeoff and Landing aircraft have key gust response sensitivities that could be greatly enhanced through degrees of autonomy within the control loop to achieve much faster response, and therefore new flight capabilities. Of particular interest is the ability to showcase how spiral development and rapid experimentation in aerial robotics can provide early lessons learned and guidance for future larger-scale technology investment. Such efforts could leverage the ability of dynamically-scaled sub-scaled vehicle testing to push very low high risk technology readiness levels to higher levels that more easily justify research investment.
- Autonomous Remote Sensing Measurement Technologies required to support Advanced Flight Testing, Earth Science, and Intelligence, Surveillance and Reconnaissance (ISR) Applications. NASA’s HYTHIRM project (AIAA-2010-241) has demonstrated an emerging capability to obtain quantitative global thermal surface temperatures associated with a hypersonic vehicle in flight. The available technology adequately measured the acreage surface temperature of the Shuttle lower surface during reentry. Future hypersonic cruise vehicles or advanced launcher configurations will challenge affordable human-in-the- loop remote imaging capability in terms of high speed tracking, spatial/spectral resolution and temperature sensitivity. A next generation system would entail a “smart payload” with a UAS optimally designed around it. The payload would ultimately permit autonomous long range target acquisition, tracking, image stabilization and enhancement, real-time sensor re-configuration and aircraft attitude/orientation to optimize the data collect thus significantly increasing mission flexibility while reducing operational costs. Phase I proposal should include an assessment of current imaging technology capabilities for spatially resolved thermal imagery along with requirements for a next generation autonomously controlled sensor/platform system. Proposals should consider Identification of technology gaps and lay out of a technology development roadmap. Software and hardware demonstrations are encouraged. Integration and autonomous control of the following technologies include: system simulation software; advanced high resolution focal plane array development including multi-color focal plane arrays; large apertures; miniaturization of high frame rate multi-waveband (i.e., visible, NIR, SWIR, MWIR, LWIR) including spectral/hyperspectral sensors; advanced radiometric simulation software; real time imaging processing and post processing deconvolution algorithms; adaptive optics; target recognition and low latency tracking algorithms; active feedback for platform command and control functions and local navigation and communication. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable of integrating with a UAS.

T8.03 Autonomous Navigation in GNSS-Denied Environments
Lead Center: LaRC

Current NASA research/development and mission capabilities for exploration of remote planetary surfaces are primarily focused on automated telerobotic systems dependent on human control. More fully autonomous systems will be required for future missions, particularly where communications with Earth may be limited, unavailable for extended periods of time and have significant delays.

This subtopic is to investigate the autonomous navigation capabilities required for land and possibly aerial vehicle operation in areas lacking GNSS and/or magnetic compass to expanded exploration roles within planetary environments. A specific area of interest is to investigate biologically inspired algorithms and capabilities, such as techniques us by insects, such as Honey Bees, to accomplish this goal. Optical flow, image motion across the field of vision, offers unique capabilities for hazard detection and avoidance, landmark navigation, distance judgment, cave navigation, speed regulation, and visual odometry. Current technology is very computationally intensive. It is desired that with hardware support, high speed optic flow measurements can be obtained to speed up and simplify the extraction of motion information from the visual scene, which would both enhance obstacle and hazard detection and avoidance, as well as speed up the navigation process. This will be very critical if VTOL flight [on Mars] can be achieved, as a fuel-limited, in-motion VTOL vehicle is ill positioned to wait for a complicated and time consuming image analysis to be accomplished. Additionally, current laser scanner/imaging technology used for generating terrestrial 3D maps have mass and power requirements that are excessive for smaller planetary robotic exploration systems. Low mass, low power 3D mapping systems accommodated on planetary missions could be employed to support autonomous vehicle navigation and maneuvering operations. One example would be a parent vehicle that could launch multiple smaller vehicles that would autonomously explore larger regions and then navigate back to the parent vehicle to transmit data and refuel. In addition to navigation, these vehicles could gather detailed, photorealistic 3D maps that can be fused with associated science data and used by scientists, students, and the general public for “participatory exploration” activities.

Initial activities would include an assessment of current technology capabilities that could be compared to requirements to identify technology gaps, lay out a technology development roadmap, and develop a software simulation of proposed system and operation. Subsequent activities would include component and system developments in accordance with the roadmap, leading to the development of a prototype system capable autonomous navigation in environments that do not allow GNSS or magnetic compass navigation and have limited or no communication between vehicles.

TOPIC: T9 Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing

Achieving NASA's exploration goals will hinge on continued development of improved capabilities in propulsion system design and manufacturing techniques. NASA is interested in innovative design and manufacturing technologies that enable sustained and affordable human and robotic exploration of the solar system. The development of and operation of these propulsion systems will benefit greatly from improvements in design and analysis tools and from improvements in manufacturing capabilities

T9.01 Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing
Lead Center: MSFC

This subtopic solicits partnerships between academic institutions and small businesses in the following specific areas of interest: Innovative design and analysis techniques, manufacturing, materials, and processes relevant to propulsion systems launch vehicles, crew exploration vehicles, orbiters, and landers. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components.

- Polymer Matrix Composites (PMCs) Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant, repairable, and self-healing technologies; advanced materials and manufacturing processes for both cryogenic and high-temperature applications.
- Ceramic Matrix Composite (CMCs) and Ablatives CMC materials and processes are projected to significantly increase safety and reduce costs simultaneously while decreasing system weight for space transportation propulsion.
- Solid-state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites, and high strength and high temperature or functionally graded materials.
- New advanced super alloys that resist hydrogen embrittlement and are compatible with high-pressure oxygen; innovative thermal-spray or cold-spray coating processes that substantially improve material properties, combine dissimilar materials, application of dense deposits of refractory metals and metal carbides, and coating on nonmetallic composite materials.
- Advanced NDE Methods Portable and lightweight NDE tools provide characterization of polymer, ceramic and metal-matrix composites, areas include, but are not limited to, microwaves, millimeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.
- Improvement in techniques for predicting the self-generated dynamics of space propulsion system when operated at off-design conditions.
- Improvement in techniques for predicting the acoustic field produced by the operation of a space propulsion system in near ground operation.
- Predictive capability of the performance and internal environment for systems, solid or liquid propellants, undergoing multi-phase combustion. Of special interest are systems utilizing nano-energetics solid fuels.
- Predictive capability improvements for the coupled fluid-structural problem with focus on accurate prediction of heat-transfer that occurs in the chamber of a nuclear thermal rocket.
- Design and analysis tools that accurately model small valves and turbopumps.
- Development of databases and instrumentation advances required for validation of previously mentioned predictive capabilities.

TOPIC: T10 Rocket Propulsion/Energy Conservation

NASA’s Stennis Space Center (SSC) seeks advanced technologies to support its testing of rocket engines including innovative approaches for component technologies, advanced rocket facility environment and health monitoring, new materials for rocket plume deflection and technologies for propellant conservation. Technologies are also sought to improve the Center’s energy conservation and sustainability.

T10.01 Test Area Technologies
Lead Center: SSC

Innovative Component Technologies
The focus of this topic is the development of innovative rocket test facility components (e.g., valves, flowmeters, actuators, tanks, etc.) for ultra high pressure (>8000 psi), high flow rate (>100 lbm/sec), and cryogenic environments. Robust and reliable component designs which are oxygen compatible and can operate efficiently in high vibro-acoustic, transient environments are being sought. Components which can also provide coupled high-speed (kHz-MHz) measurement and control of rocket propellant feed systems with minimum induced system losses are desirable. Proposals of innovative valve design concepts which will provide true linear performance for installed configurations and/or provide dynamically adjustable valve trimming are encouraged. Expected TRL at end of Phase I is 2, and at the end of Phase II is 4.

Advanced Rocket Facility Environment and Health Monitoring
Development of practical, industrial-grade, advanced flow/thermal diagnostics and smart sensors to monitor the near field environment (thermal, acoustic, emission) that a rocket test facility is exposed to during an engine/stage testing is requested. Examples of advanced rocket test environment diagnostics would include high-speed robust scanning or visualization of rocket exhaust plumes for simultaneous heat flux, species/temperature and/or near-field acoustics. In addition to the rocket test induced environments, infrastructure health monitoring and management for test facilities and for widely distributed support systems (WDSS) such as gas distribution and cooling water is needed. Capabilities being sought for WDSS include remote monitoring of vacuum lines, gas leaks, and fire, where the use of wireless technologies in order to eliminate running miles of power and data wires would be beneficial in this application. The proposed innovative systems must lead to improved safety and reduced test costs by allowing real-time analysis of data, information, and knowledge through efficient interfaces to enable integrated awareness of the system condition by users. Need for improved technologies are mid-term, and highly desirable. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

Development of New Materials for Rocket Plume Deflection
Refractory materials are commonly used to provide thermal protection of rocket plume deflectors on test facilities and launch pads. Advancement of refractory materials or development of new materials for the requirement of minimizing erosion (< 1 inch) when exposed to high heat (>1500 BTU/ft^2/sec) and shear/normal loads caused by the direct impingement of rocket exhausts is desired. Unlike launch facilities, test facilities are exposed to the plume environments for long durations (on the order of minutes) making the material requirements for minimum erosion even more stringent. The newly proposed material would need to be competitive to the material, installation and repair costs of current commercial grade high-temperature refractory materials. Also, the material development proposal should demonstrate the performance of the material in dynamically similar environments as would be present on the rocket test stand. Expected TRL at end of Phase I is 2, and at the end of Phase II is 4.

Technologies for Propellant Conservation
The objective is to minimize usage of costly gases (helium and hydrogen) through devices that can recover/recycle efflux from cryogenic test facilities (currently no recovery is done). This could include technologies such as real time gas sampling/contamination monitoring system for propellant and purge systems that could also help minimize use of non renewable resources such as Helium, or Helium reclamation carts for recapture of inert/purges. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

T10.02 Energy Conservation and Sustainability
Lead Center: SSC

John C Stennis Space Center (SSC) is a large rocket propulsion test facility located in southern Mississippi close to the Louisiana state line. Energy consumption is very large to sustain the static engine testing and supporting facilities. In an effort to conserve on energy and enhance the sustainability of these and other SSC facilities, interest exists in pursing innovative approaches to energy savings, water efficiency, CO_2 emission reductions, improved environmental quality. This includes the use of green technologies that support LEED certification. Technologies which have potential to support multiple centers or programs are highly desirable. The following listing includes some specific areas of interests for supporting SSC’s energy conservation goals:

Innovative Energy Conservation Technologies
SSC is interested in innovative technologies for reducing energy consumption and improving building sustainability through the use of alternative energy sources including of geothermal, natural gas and solar. Those using renewable sources of energy are highly desired. The goal is to reduce overall energy consumption and the Center's carbon footprint. Energy conservation technologies must also be cost effective to implement and maintain. Concepts will be evaluated based on their potential efficiency, ease of implementation and maintenance, and flexibility of applications (including, but not limited to, HVAC, preheating hot water heaters, and other means of extracting energy), as well as, applicability to the Center's mission. Proposals will also be evaluated based on the maturity level

to which the technology will be developed and innovative techniques. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Facility Sustainability Technologies

SSC is interested in innovative technologies for enhancing building and facility sustainability. The goal is to reduce the life-cycle costs for sustainability facilities and testing through the use of green or renewable products. Specific areas of interest include technologies which help sustain a healthy workplace including mold spore filtration, self-decontamination and air purification. Concepts will be evaluated on the innovativeness, maturity level of the technology and long-term viability of the concept. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Lighting Technology

Stennis Space Center is interested in developing innovative technologies, systems, or methodologies that will reduce the energy consumption and heat generation from facility lighting while maintaining the desired level of illumination for safety and effective work environments. SSC is interested in innovative lighting technologies for the test areas, office areas and parking lots. Innovative approaches for bringing natural lighting through skylights or other receptors are also of interest. These lighting technologies will need to reduce energy consumption while maintaining a comfortable and safe working environment. Technologies can be for replacement a technology or optimization of current facility lighting system. SSC is particularly interested in replacing costly lighting in the test area (test stands, hydrogen/oxygen environments, hazardous and potentially corrosive environments). The lighting should be in compliance with IESNA RP 7-01, Practice for Industrial Lighting. Proposals will be evaluated based on the maturity level to which the technology will be developed and innovative techniques that will provide a reasonable life expectancy. Proposals will also be evaluated on implementation strategy and ease of maintenance. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Innovative Solar Technology

Reduction in energy consumption and subsequent energy cost is a high priority at SSC. SSC is interested in developing new technologies for the efficient and effective use of photovoltaic/solar cell to reduce energy costs. Major issues in the development and use of solar panel include efficient system design and installation as well as effective maintenance. Innovative approaches and tools to facilitate the design of efficient solar cell systems, effective application of solar cells systems for building rooftops or a separate field area of solar cells are desired as well as innovative approaches to the monitor the health of the system and maintenance methods to insure the most effective and efficient operations of the system in an environment with high humidity, extensive rain showers, high pollen counts, rapid mold and fungal growth, etc. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Appendices

Appendix A: Example Format for Briefing Chart

NASA SBIR/STTR Technologies

Title of Proposal
Firm
City, ST
Proposal No.: _ _ . _ _ - _ _ _ _

Identification and Significance of Estimated TRL (1 – 9) at beginning and end of contract:	<Place graphic related to innovation here>
Technical Objectives and Work Plan	NASA and Non-NASA Applications Firm Contacts

NON-PROPRIETARY DATA

Appendix B: Technology Readiness Level (TRL) Descriptions

The Technology Readiness Level (TRL) describes the stage of maturity in the development process from observation of basic principals through final product operation. The exit criteria for each level documents that principles, concepts, applications or performance have been satisfactorily demonstrated in the appropriate environment required for that level. A relevant environment is a subset of the operational environment that is expected to have a dominant impact on operational performance. Thus, reduced-gravity may be only one of the operational environments in which the technology must be demonstrated or validated in order to advance to the next TRL.

TRL	Definition	Hardware Description	Software Description	Exit Criteria
1	Basic principles observed and reported.	Scientific knowledge generated underpinning hardware technology concepts/applications.	Scientific knowledge generated underpinning basic properties of software architecture and mathematical formulation.	Peer reviewed publication of research underlying the proposed concept/application.
2	Technology concept and/or application formulated.	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture. Basic properties of algorithms, representations and concepts defined. Basic principles coded. Experiments performed with synthetic data.	Documented description of the application/concept that addresses feasibility and benefit.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Analytical studies place the technology in an appropriate context and laboratory demonstrations, modeling and simulation validate analytical prediction.	Development of limited functionality to validate critical properties and predictions using non-integrated software components.	Documented analytical/experimental results validating predictions of key parameters.
4	Component and/or breadboard validation in laboratory environment.	A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments, and associated performance predictions are defined relative to the final operating environment.	Key, functionally critical, software components are integrated, and functionally validated, to establish interoperability and begin architecture development. Relevant Environments defined and performance in this environment predicted.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of relevant environment.
5	Component and/or brassboard validation in relevant environment.	A medium fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	End-to-end software elements implemented and interfaced with existing systems/simulations conforming to target environment. End-to-end software system, tested in relevant environment, meeting predicted performance. Operational environment performance predicted. Prototype implementations developed.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements.
6	System/sub-system model or prototype demonstration in a relevant environment.	A high fidelity system/component prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.	Prototype implementations of the software demonstrated on full-scale realistic problems. Partially integrate with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.	Documented test performance demonstrating agreement with analytical predictions.
7	System prototype demonstration in an operational environment.	A high fidelity engineering unit that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate performance in the actual operational environment and platform (ground, airborne, or space).	Prototype software exists having all key functionality available for demonstration and test. Well integrated with operational hardware/software systems demonstrating operational feasibility. Most software bugs removed. Limited documentation available.	Documented test performance demonstrating agreement with analytical predictions.

8	Actual system completed and "flight qualified" through test and demonstration.	The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment and platform (ground, airborne, or space).	All software has been thoroughly debugged and fully integrated with all operational hardware and software systems. All user documentation, training documentation, and maintenance documentation completed. All functionality successfully demonstrated in simulated operational scenarios. Verification and Validation (V&V) completed.	Documented test performance verifying analytical predictions.
9	Actual system flight proven through successful mission operations.	The final product is successfully operated in an actual mission.	All software has been thoroughly debugged and fully integrated with all operational hardware/software systems. All documentation has been completed. Sustaining software engineering support is in place. System has been successfully operated in the operational environment.	Documented mission operational results.

Definitions

Proof of Concept: Analytical and experimental demonstration of hardware/software concepts that may or may not be incorporated into subsequent development and/or operational units.

Breadboard: A low fidelity unit that demonstrates function only, without respect to form or fit in the case of hardware, or platform in the case of software. It often uses commercial and/or ad hoc components and is not intended to provide definitive information regarding operational performance.

Brassboard: A medium fidelity functional unit that typically tries to make use of as much operational hardware/software as possible and begins to address scaling issues associated with the operational system. It does not have the engineering pedigree in all aspects, but is structured to be able to operate in simulated operational environments in order to assess performance of critical functions.

Proto-type Unit: The proto-type unit demonstrates form, fit, and function at a scale deemed to be representative of the final product operating in its operational environment. A subscale test article provides fidelity sufficient to permit validation of analytical models capable of predicting the behavior of full-scale systems in an operational environment

Engineering Unit: A high fidelity unit that demonstrates critical aspects of the engineering processes involved in the development of the operational unit. Engineering test units are intended to closely resemble the final product (hardware/software) to the maximum extent possible and are built and tested so as to establish confidence that the design will function in the expected environments. In some cases, the engineering unit will become the final product, assuming proper traceability has been exercised over the components and hardware handling.

Mission Configuration: The final architecture/system design of the product that will be used in the operational environment. If the product is a subsystem/component, then it is embedded in the actual system in the actual configuration used in operation.

Laboratory Environment: An environment that does not address in any manner the environment to be encountered by the system, subsystem, or component (hardware or software) during its intended operation. Tests in a laboratory environment are solely for the purpose of demonstrating the underlying principles of technical performance (functions), without respect to the impact of environment.

Relevant Environment: Not all systems, subsystems, and/or components need to be operated in the operational environment in order to satisfactorily address performance margin requirements. Consequently, the relevant environment is the specific subset of the operational environment that is required to demonstrate critical "at risk" aspects of the final product performance in an operational environment. It is an environment that focuses specifically on "stressing" the technology advance in question.

Operational Environment: The environment in which the final product will be operated. In the case of space flight hardware/software, it is space. In the case of ground-based or airborne systems that are not directed toward space flight, it will be the environments defined by the scope of operations. For software, the environment will be defined by the operational platform.

Appendix C: NASA SBIR/STTR Technology Taxonomy

Aeronautics/Atmospheric Vehicles
Aerodynamics
Air Transportation & Safety
Airship/Lighter-than-Air Craft
Avionics (see also Control and Monitoring)
Analysis
Analytical Instruments (Solid, Liquid, Gas, Plasma, Energy; see also Sensors)
Analytical Methods
Astronautics
Aerobraking/Aerocapture
Entry, Descent, & Landing (see also Planetary Navigation, Tracking, & Telemetry)
Navigation & Guidance
Relative Navigation (Interception, Docking, Formation Flying; see also Control & Monitoring; Planetary Navigation, Tracking, & Telemetry)
Space Transportation & Safety
Spacecraft Design, Construction, Testing, & Performance (see also Engineering; Testing & Evaluation)
Spacecraft Instrumentation & Astrionics (see also Communications; Control & Monitoring; Information Systems)
Tools/EVA Tools
Autonomous Systems
Autonomous Control (see also Control & Monitoring)
Intelligence
Man-Machine Interaction
Perception/Vision
Recovery (see also Vehicle Health Management)
Robotics (see also Control & Monitoring; Sensors)
Biological Health/Life Support
Biomass Growth
Essential Life Resources (Oxygen, Water, Nutrients)
Fire Protection
Food (Preservation, Packaging, Preparation)
Health Monitoring & Sensing (see also Sensors)
Isolation/Protection/Radiation Shielding (see also Mechanical Systems)
Medical
Physiological/Psychological Countermeasures
Protective Clothing/Space Suits/Breathing Apparatus
Remediation/Purification
Waste Storage/Treatment
Communications, Networking & Signal Transport
Ad-Hoc Networks (see also Sensors)

Amplifiers/Repeaters/Translators
Antennas
Architecture/Framework/Protocols
Cables/Fittings
Coding & Compression
Multiplexers/Demultiplexers
Network Integration
Power Combiners/Splitters
Routers, Switches
Transmitters/Receivers
Waveguides/Optical Fiber (see also Optics)
Control & Monitoring
Algorithms/Control Software & Systems (see also Autonomous Systems)
Attitude Determination & Control
Command & Control
Condition Monitoring (see also Sensors)
Process Monitoring & Control
Sequencing & Scheduling
Telemetry/Tracking (Cooperative/Noncooperative; see also Planetary Navigation, Tracking, & Telemetry)
Teleoperation
Education & Training
Mission Training
Outreach
Training Concepts & Architectures
Electronics
Circuits (including ICs; for specific applications, see e.g., Communications, Networking & Signal Transport; Control & Monitoring, Sensors)
Manufacturing Methods
Materials (Insulator, Semiconductor, Substrate)
Superconductance/Magnetics
Energy
Conversion
Distribution/Management
Generation
Sources (Renewable, Nonrenewable)
Storage
Engineering
Characterization
Models & Simulations (see also Testing & Evaluation)
Project Management
Prototyping

Quality/Reliability
Software Tools (Analysis, Design)
Support
Imaging
3D Imaging
Display
Image Analysis
Image Capture (Stills/Motion)
Image Processing
Radiography
Thermal Imaging (see also Testing & Evaluation)
Information Systems
Computer System Architectures
Data Acquisition (see also Sensors)
Data Fusion
Data Input/Output Devices (Displays, Storage)
Data Modeling (see also Testing & Evaluation)
Data Processing
Knowledge Management
Logistics
Inventory Management/Warehousing
Material Handing & Packaging
Transport/Traffic Control
Manufacturing
Crop Production (see also Biological Health/Life Support)
In Situ Manufacturing
Microfabrication (and smaller; see also Electronics; Mechanical Systems; Photonics)
Processing Methods
Resource Extraction
Materials & Compositions
Aerogels
Ceramics
Coatings/Surface Treatments
Composites
Fluids
Joining (Adhesion, Welding)
Metallics
Minerals
Nanomaterials
Nonspecified

Organics/Biomaterials/Hybrids
Polymers
Smart/Multifunctional Materials
Textiles
Mechanical Systems
Actuators & Motors
Deployment
Exciters/Igniters
Fasteners/Decouplers
Isolation/Protection/Shielding (Acoustic, Ballistic, Dust, Radiation, Thermal)
Machines/Mechanical Subsystems
Microelectromechanical Systems (MEMS) and smaller
Pressure & Vacuum Systems
Structures
Tribology
Vehicles (see also Autonomous Systems)
Microgravity
Biophysical Utilization
Optics
Adaptive Optics
Fiber (see also Communications, Networking & Signal Transport; Photonics)
Filtering
Gratings
Lenses
Mirrors
Telescope Arrays
Photonics
Detectors (see also Sensors)
Emitters
Lasers (Communication)
Lasers (Cutting & Welding)
Lasers (Guidance & Tracking)
Lasers (Ignition)
Lasers (Ladar/Lidar)
Lasers (Machining/Materials Processing)
Lasers (Measuring/Sensing)
Lasers (Medical Imaging)
Lasers (Surgical)
Lasers (Weapons)
Materials & Structures (including Optoelectronics)

Planetary Navigation, Tracking, & Telemetry
Entry, Descent, & Landing (see also Astronautics)
GPS/Radiometric (see also Sensors)
Inertial (see also Sensors)
Optical
Ranging/Tracking
Telemetry (see also Control & Monitoring)
Propulsion
Ablative Propulsion
Atmospheric Propulsion
Extravehicular Activity (EVA) Propulsion
Fuels/Propellants
Launch Engine/Booster
Maneuvering/Stationkeeping/Attitude Control Devices
Photon Sails (Solar; Laser)
Spacecraft Main Engine
Surface Propulsion
Tethers
Sensors/Transducers
Acoustic/Vibration
Biological (see also Biological Health/Life Support)
Biological Signature (i.e., Signs Of Life)
Chemical/Environmental (see also Biological Health/Life Support)
Contact/Mechanical
Electromagnetic
Inertial
Interferometric (see also Analysis)
Ionizing Radiation
Optical/Photonic (see also Photonics)
Positioning (Attitude Determination, Location X-Y-Z)
Pressure/Vacuum
Radiometric
Sensor Nodes & Webs (see also Communications, Networking & Signal Transport)
Thermal
Software Development
Development Environments
Operating Systems
Programming Languages
Verification/Validation Tools
Spectral Measurement, Imaging & Analysis (including Telescopes)

Infrared
Long
Microwave
Multispectral/Hyperspectral
Non-Electromagnetic
Radio
Terahertz (Sub-millimeter)
Ultraviolet
Visible
X-rays/Gamma Rays
Testing & Evaluation
Destructive Testing
Hardware-in-the-Loop Testing
Lifetime Testing
Nondestructive Evaluation (NDE; NDT)
Simulation & Modeling
Thermal Management & Control
Active Systems
Cryogenic/Fluid Systems
Heat Exchange
Passive Systems
Vehicle Health Management
Diagnostics/Prognostics
Recovery (see also Autonomous Systems)

Appendix D: SBIR/STTR and the Space Technology Roadmaps

Funded at 2.5% of NASA's R&D budget, the Small Business Innovation Research (SBIR) Program was established by Congress in 1982 to provide increased opportunities for small businesses to participate in R&D, to increase employment, and to improve U.S. competitiveness. The program's specific objectives are to stimulate U.S. technological innovation, use small businesses to meet federal research and development needs, increase private-sector commercialization of innovations derived from federal R&D, and foster and encourage participation by socially disadvantaged businesses. Legislation enacted in 2000 extended and strengthened the SBIR program and increased its emphasis on pursuing commercial applications of SBIR project results.

Funded at 0.3% of NASA's R&D budget, the Small Business Technology Transfer (STTR) Program awards contracts to small business concerns for cooperative research and development with a non-profit research institution, such as a university. The goal of the Congress in establishing the STTR program is to facilitate the transfer of technology developed by an RI through the entrepreneurship of a small business.

The following statistics shows the extent of the effort associated with these two programs each year:

- Approximately 2,500 proposals per year from 1,000 small businesses throughout the Nation.
    - About 62,000 pages of technical, proprietary data.
    - 1/3 of the phase 1 contracts are with firms "new" to NASA.
- Approximately 500 new contracts per year.
    - 1/2 of NASA new contracts with for profit firms.
    - Up to 650 active contracts managed at any time.
- About 1,800 NASA employees participate in evaluation and oversight processes.

In the past few years, research and technology topics are for the SBIR program were identified annually by Mission Directorates and Center Programs. The Directorates identify high priority research and technology needs for respective programs and projects. Research and technology topics for the STTR Program are aligned with needs associated with the research interest and core competencies across NASA Centers. Both programs support a broad range of technologies defined by a list of topics and subtopics that vary in content within each annual solicitation.

The following table relates these SBIR/STTR topics and subtopics to the Technology Area Breakdown Structure (TABS) in the Space Technology Roadmaps (STR). The table is organized by Technology Area (first column), with the related SBIR/STTR topics (third column) and subtopics (fourth column) listed as well. For completeness, the Aeronautics area is included for completeness, though this was beyond the scope of the STR.

TA	STR Technology Area (TA) Level 1 Description	FY 11 SBIR/STTR Topic	FY11 SBIR/STTR Sub-topic Description	FY 11 SBIR / STTR Sub-topic
TA01	Launch Propulsion Systems	Propulsion	Low Cost Heavy Lift Propulsion	X2.01
TA01	Launch Propulsion Systems	Space Transportation	Nano/Small Sat Launch Vehicle Technology	O2.01
TA01	Launch Propulsion Systems	Space Transportation	Propulsion Technologies	O2.02
TA02	In-Space Propulsion Technologies	Spacecraft and Platform Subsystems	Propulsion Systems	S3.04

TA02	In-Space Propulsion Technologies	Propulsion	High Thrust In Space Propulsion	X2.02
TA02	In-Space Propulsion Technologies	Propulsion	Electric Propulsion Systems	X2.03
TA03	Space Power and Energy Storage	Spacecraft and Platform Subsystems	Power Generation and Conversion (for Science Spacecraft)	S3.03
TA03	Space Power and Energy Storage	Spacecraft and Platform Subsystems	Power Electronics and Management and Energy Storage (for Science Spacecraft)	S3.05
TA03	Space Power and Energy Storage	High-Efficiency Space Power Systems	Fuel Cells and Electrolyzers for Space Applications	X8.01
TA03	Space Power and Energy Storage	High-Efficiency Space Power Systems	Advanced Space-Rated Batteries	X8.02
TA03	Space Power and Energy Storage	High-Efficiency Space Power Systems	Space Nuclear Power Systems	X8.03
TA03	Space Power and Energy Storage	High-Efficiency Space Power Systems	Advanced Photovoltaic Systems	X8.04
TA04	Robotics, Telerobotics and Autonomous Systems	Robotic Exploration Technologies	Sample Collection, Processing, and Handling	S5.02
TA04	Robotics, Telerobotics and Autonomous Systems	Robotic Exploration Technologies	Surface and Subsurface Robotic Exploration	S5.03
TA04	Robotics, Telerobotics and Autonomous Systems	Robotic Exploration Technologies	Spacecraft Technology for Sample Return Missions	S5.04
TA04	Robotics, Telerobotics and Autonomous Systems	Autonomous Systems and Avionics	Spacecraft Autonomy and Space Mission Automation	X6.01
TA04	Robotics, Telerobotics and Autonomous Systems	Autonomous Systems and Avionics	Intelligent System Health Management for Flexible Exploration	X6.03
TA04	Robotics, Telerobotics and Autonomous Systems	Human-Robotic Systems	Human Robotic Systems - Human Robot Interfaces	X7.01
TA04	Robotics, Telerobotics and Autonomous Systems	Human-Robotic Systems	Human-Robotic Systems - Mobility Subsystems	X7.02
TA04	Robotics, Telerobotics and Autonomous Systems	Processing and Operations	Remotely Operated Mobile Sensing Technologies for inside ISS	O3.01

TA04	Robotics, Telerobotics and Autonomous Systems	Spacecraft and Platform Subsystems	Unmanned Aircraft and Sounding Rocket Technologies	S3.08
TA05	Communication and Navigation	Space Communications	Antenna Technology	O1.01
TA05	Communication and Navigation	Space Communications	Reconfigurable/Reprogrammable Communication Systems	O1.02
TA05	Communication and Navigation	Space Communications	Game Changing Technologies	O1.03
TA05	Communication and Navigation	Space Communications	Long Range Optical Telecommunications	O1.04
TA05	Communication and Navigation	Space Communications	Long Range Space RF Telecommunications	O1.05
TA05	Communication and Navigation	Space Communications	CoNNeCT Experiments	O1.06
TA05	Communication and Navigation	Navigation	Metric Tracking of Launch Vehicles	O4.01
TA05	Communication and Navigation	Navigation	PNT (Positioning, Navigation, and Timing) Sensors and Components	O4.02
TA05	Communication and Navigation	Spacecraft and Platform Subsystems	Guidance, Navigation and Control	S3.06
TA06	Human Health, Life Support and Habitation Systems	Radiation Protection	Radiation Shielding Materials Systems	X11.01
TA06	Human Health, Life Support and Habitation Systems	Radiation Protection	Integrated Advanced Alert/Warning Systems for Solar Proton Events	X11.02
TA06	Human Health, Life Support and Habitation Systems	Exploration Crew Health capabilities	Crew Exercise Systems	X12.01
TA06	Human Health, Life Support and Habitation Systems	Exploration Crew Health Capabilities	Portable Load Sensing Systems	X12.02
TA06	Human Health, Life Support and Habitation Systems	Exploration Medical Capability	Smart Phone Driven Blood-Based Diagnostics	X13.01
TA06	Human Health, Life Support and Habitation Systems	Exploration Medical Capability	Non-Wet Prep Electrodes	X13.02
TA06	Human Health, Life Support and Habitation Systems	Behavioral health and Performance	Virtual Reality and World Technologies for Team Training Approaches	X14.01

TA06	Human Health, Life Support and Habitation Systems	Space Human Factors and Food Systems	A New Technique for Automated Analyses of Raw Operational Videos	X15.01
TA06	Human Health, Life Support and Habitation Systems	Space Human factors and Food Systems	Advanced Food Technologies	X15.02
TA06	Human Health, Life Support and Habitation Systems	Space Radiation	Radiation measurement Technologies	X16.01
TA06	Human Health, Life Support and Habitation Systems	Inflight Biological Sample Preservation and Analysis	Alternative Methods for Ambient Preservation of Human Biological Samples During Extended Spaceflight and Planetary Operations	X17.01
TA06	Human Health, Life Support and Habitation Systems	Life Support and Habitation Systems	Enabling Technologies for Biological Life Support	X3.01
TA06	Human Health, Life Support and Habitation Systems	Life Support and Habitation Systems	Crew Accommodations and Waste Processing for Long Duration Missions	X3.02
TA06	Human Health, Life Support and Habitation Systems	Life Support and Habitation Systems	Environmental Monitoring and Fire Protection for Spacecraft Autonomy	X3.03
TA06	Human Health, Life Support and Habitation Systems	Life Support and Habitation Systems	Spacecraft Cabin Ventilation and Thermal Control	X3.04
TA07	Human Exploration Destination-Systems	Processing and Operations	ISS Utilization	O3.02
TA07	Human Exploration Destination-Systems	Processing and Operations	ISS Demonstration & Development of Improved Exploration Technologies	O3.03
TA07	Human Exploration Destination-Systems	In Situ Resource Utilization	In-Situ Resource Characterization, Extraction, Transfer, and Processing	X1.01
TA07	Human Exploration Destination-Systems	Extra Vehicular Activity Technologies	Space Suit Pressure Garment and Airlock Technologies	X4.01
TA07	Human Exploration Destination-Systems	Extra Vehicular Activity Technologies	Space Suit Life Support Systems	X4.02
TA07	Human Exploration Destination-Systems	Extra Vehicular Activity Technologies	Space Suit Radio, Sensors, Displays, Cameras, and Audio	X4.03

TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Lidar and Laser System Components	S1.01
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Active Microwave Technologies	S1.02
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Passive Microwave Technologies	S1.03
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter	S1.04
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments	S1.05
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Particles and Field Sensors and Instrument Enabling Technologies	S1.06
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Cryogenic Systems for Sensors and Detectors	S1.07
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	In Situ Airborne, Surface, and Submersible Instruments for Earth Science	S1.08
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	In Situ Sensors and Sensor Systems for Planetary Science	S1.09
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Atomic Interferometry	S1.10
TA08	Science Instruments, Observatories and Sensor Systems	Sensors, Detectors and Instruments	Planetary Orbital Sensors and Sensor Systems (POSSS)	S1.11
TA08	Science Instruments, Observatories and Sensor Systems	Advanced Telescope Systems	Precision Spacecraft Formations for Telescope Systems	S2.01
TA08	Science Instruments, Observatories and Sensor Systems	Advanced Telescope Systems	Proximity Glare Suppression for Astronomical Coronagraphy	S2.02
TA08	Science Instruments, Observatories and Sensor Systems	Advanced Telescope Systems	Advanced Optical Component Systems	S2.04
TA08	Science Instruments, Observatories and Sensor Systems	Robotic Exploration Technologies	Extreme Environments Technology	S5.05
TA08	Science Instruments, Observatories and Sensor Systems	Robotic Exploration Technologies	Planetary Protection	S5.06

TA08	Science Instruments, Observatories and Sensor Systems	Spacecraft and Platform Subsystems	Terrestrial and Planetary Balloons	S3.07
TA08	Science Instruments, Observatories and Sensor Systems	Low-Cost Small Spacecraft and Technologies	Unique Mission Architectures Using Small Spacecraft	S4.01
TA09	Entry, Descent and Landing Systems	Robotic Exploration Technologies	Planetary Entry, Descent and Landing Technology	S5.01
TA09	Entry, Descent and Landing Systems	Planetary Entry, Descent and Landing (EDL) Technology	Advanced Integrated Hypersonic Entry Systems	X9.02
TA10	Nanotechnology	N/A	N/A	N/A
TA10	Nanotechnology	N/A	N/A	N/A
TA11	Modeling, Simulation, Information Technology and Processing	Navigation	Flight Dynamics Software and Technologies	O4.03
TA11	Modeling, Simulation, Information Technology and Processing	Spacecraft and Platform Subsystems	Command, Data Handling, and Electronics (for Science Spacecraft)	S3.01
TA11	Modeling, Simulation, Information Technology and Processing	Information Technologies	Technologies for Large-Scale Numerical Simulation	S6.01
TA11	Modeling, Simulation, Information Technology and Processing	Information Technologies	Earth Science Applied Research and Decision Support	S6.02
TA11	Modeling, Simulation, Information Technology and Processing	Information Technologies	Algorithms and Tools for Science Data Processing, Discovery and Analysis, in State-of-the-Art Data Environments	S6.03
TA11	Modeling, Simulation, Information Technology and Processing	Information Technologies	Integrated Mission Modeling for Opto-mechanical Systems	S6.04
TA11	Modeling, Simulation, Information Technology and Processing	Information Technologies	Fault Management Technologies	S6.05
TA11	Modeling, Simulation, Information Technology and Processing	Autonomous Systems and Avionics	Radiation Hardened/Tolerant and Low Temperature Electronics and Processors	X6.02
TA12	Materials, Structures, Mechanical Systems and Manufacturing	Space Transportation	Advanced Tank Technology Development	O2.04

TA12	Materials, Structures, Mechanical Systems and Manufacturing	Advanced Telescope Systems	Precision Deployable Optical Structures and Metrology	S2.03
TA12	Materials, Structures, Mechanical Systems and Manufacturing	Advanced Telescope Systems	Optics Manufacturing and Metrology for Telescope Optical Surfaces	S2.05
TA12	Materials, Structures, Mechanical Systems and Manufacturing	Lightweight Spacecraft Materials and Structures	Expandable Structures	X5.01
TA12	Materials, Structures, Mechanical Systems and Manufacturing	Lightweight Spacecraft Materials and Structures	Advanced Fabrication and Manufacturing of Metallic and Polymer Matrix Composite Materials for Lightweight Structures	X5.02
TA12	Materials, Structures, Mechanical Systems and Manufacturing	Lightweight Spacecraft Materials and Structures	Spaceflight Structural Sensor Systems and NDE	X5.03
TA13	Ground and Launch Systems Processing	Space Transportation	Propulsion Technologies	O2.02
TA13	Ground and Launch Systems Processing	Space Transportation	21st Century Spaceport Ground Systems Technologies	O2.03
TA13	Ground and Launch Systems Processing	Processing and Operations	Vehicle Integration and Ground Processing	O3.04
TA13	Ground and Launch Systems Processing	Processing and Operations	Advanced Motion Imaging	O3.05
TA13	Ground and Launch Systems Processing	Processing and Operations	Environmental Control Systems & Technologies for NR & Cubesats	O3.06
TA13	Ground and Launch Systems Processing	Space Transportation	Advanced Propulsion Testing Technologies	O2.05
TA14	Thermal Management Systems	Spacecraft and Platform Subsystems	Thermal Control Systems (for Science Spacecraft)	S3.02
TA14	Thermal Management Systems	Cryogenic Propellant Storage and Transfer	Cryogenic Fluid Management Technologies	X10.01
TA14	Thermal Management Systems	Entry, Descent and Landing (EDL) Technology	Ablative Thermal Protection Systems	X9.01
		Aviation Safety	Aviation External Hazard Sensor Technologies	A1.01
		Aviation Safety	Inflight Icing Hazard Mitigation Technology	A1.02
		Aviation Safety	Durable Propulsion Components	A1.03
		Aviation Safety	Airframe Design and Sustainment	A1.04
		Aviation Safety	Sensing and Diagnostic Capabilities for Degradation in Aircraft Materials and Structures	A1.05

		Aviation Safety	Propulsion Health State Assessment and Management	A1.06
		Aviation Safety	Avionics Health State Assessment and Management	A1.07
		Aviation Safety	Crew Systems Technologies for Improved Aviation Safety	A1.08
		Aviation Safety	Integrated Vehicle Dynamics Modeling Methods for LOC Conditions	A1.09
		Aviation Safety	Advanced Dynamic Testing Capability for Abnormal Flight Conditions	A1.10
		Aviation Safety	Transport Aircraft Simulator Motion Fidelity For Abnormal Flight Conditions	A1.11
		Aviation Safety	Propulsion System Performance Prediction for Integrated Flight and Propulsion Control	A1.12
		Aviation Safety	Advanced Upset Protection System	A1.13
		Aviation Safety	Detection, Identification, and Mitigation of Sensor Failures	A1.14
		Aviation Safety	Unmanned Vehicle Design for Loss-of-Control Flight Research	A1.15
		Aviation Safety	Validation Methods for Safety-Critical Systems Operating under LOC Conditions	A1.16
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