National Aeronautics and Space Administration

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

Fiscal Year 2014 General Solicitation

Opening Date: November 14, 2013
Closing Date: January 29, 2014

Fiscal Year 2014SBIR/STTR Solicitation Noteworthy Changes

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

1.3 Program Management

The solicitation includes topic and subtopics from NASA's newly-established Space Technology Mission Directorate. See section 9.

1.4 Three-Phase Program

The description for the Phase II Enhancement (Phase II-E) and Phase II eXpanded (Phase II-X) contract options have changed.

1.5.2 (1.3.2 in the Phase II instruction) Place of Performance

Proposals must clearly indicate if any work will be performed outside the United States, **including subcontractor performance**.

1.5.5 Restrictions on Venture Capital-owned Businesses

As set forth in the SBIR Reauthorization Act of 2011, small businesses owned in majority part by multiple venture capital operating companies, hedge funds, or private equity firms may be eligible for SBIR awards. SBA's regulations of 13 CFR part 121 sets forth the eligibility criteria for SBIR applicants that are owned in majority part by multiple venture capital operating companies, hedge funds, or private equity firms. **At the current time, NASA is considering this change. Currently, such firms are not eligible to submit proposals to the NASA SBIR, STTR, and SBIR Select solicitations.**

1.5.6 Required Benchmark Transition Rate

The required benchmark Transition Rate (Number of Phase II awards/ Number of Phase I awards) is 0.25 over a five year period.

1.7 (1.5 in the Phase II instructions) Commercialization Technical Assistance

NASA will authorize the recipient of a Phase I SBIR award to purchase technical assistance services, such as access to a network of scientists and engineers engaged in a wide range of technologies, or access to technical and business literature available through on-line data bases, for the purpose of assisting such concerns in:

1. Making better technical decisions concerning such projects.
2. Solving technical problems which arise during the conduct of such projects.
3. Minimizing technical risks associated with such projects.
4. Developing and commercializing new commercial products and processes resulting from such projects.

You must provide the vendor name and contact information, the proposed amount not to exceed $5,000, and a detailed explanation of the services to be provided. You must also upload a price quote from the vendor. Approval of technical assistance is not guaranteed and is subject to review by the contracting officer. Please note that this commercialization assistance does not count toward the maximum award size in either Phase I or Phase II.

2.0 Definitions

Definitions that relate to NASA New Technology Reporting have been added (these definitions are labeled 2.16 through 2.19).

3.2.4 (2.2.4 in the Phase II instructions) Technical Content, Part 8: Facilities/Equipment

Failure to provide a written letter of availability from the Government official authorized to approve such use of the Federal laboratory and the letter of justification from the SBC shall invalidate any proposal selection.

5.12 Required Registrations and Submissions

5.12.1 (4.10.1 in the Phase II Instructions) Firm SBA Firm Registry

The SBA SBIR policy directive requires each small business concern (SBC) applying for a Phase I or Phase II award to register in the SBA Company Registry prior to submitting an application. Proof of registration is required to be submitted with each firm's proposal.

5.12.2 (4.10.2 in the Phase II Instructions) Central Contractor Registration

Offerors should be aware of the requirement to register in the System for Award Management (SAM) 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.**

5.12.3 (4.10.3 in the Phase II Instructions) 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 SAM website (https://www.sam.gov/).

8.0 Submission Forms and Certifications

In an effort to reduce the length of this solicitation, all example forms and certifications have been removed from Section 8 of this solicitation. **Previews of all forms and certifications are available via the NASA SBIR/STTR Firm Library, located at: (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).**

Specific Phase I Changes:

Phase I STTR Period of Performance

The period of performance for NASA STTR Phase I contracts is now 6 months. The period of performance had previously been 12 months.

Part 1: Phase I Proposal Instructions and Evaluation Criteria for the NASA Fiscal Year 2014 SBIR/STTR Solicitation

2014 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 are contained herein. The fiscal year 2014Solicitation period for Phase I proposals begins November 14, 2013 and ends January 29, 2014.

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 in approximately April 2014. Historically, the percentage of Phase I proposals to awards is approximately 13-15% for SBIR and STTR, and approximately 35-40% of the selected Phase I contracts are competitively selected for Phase II follow-on efforts.

Under this Solicitation NASA will not accept more than 10 proposals to either program from any one firm 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, P.L. 97-219 (codified at 15 U.S.C. 638) as amended by the Small Business Innovation Research (SBIR) Program, Extension, P.L. 99-443 which extended the program through September 30, 1993. On October 28, 1992, through the Small Business Innovation Research and Development Act of 1992 (P.L. 102-564), Congress reauthorized and extended the SBIR Program for another seven years (2000). Subsequently, on December 21, 2000, through the Small Business Reauthorization Act of 2000 (P.L. 106-554) Congress again reauthorized the SBIR Program. With the approval of H.R. 2608, Continuing Appropriations Act 2012, the SBIR Program was authorized through December 31, 2011. On December 31, 2011, the President signed into law the National Defense Reauthorization Act of 2012 (Defense Reauthorization Act), P. L. 112-81, Section 5001, Division E of the Defense Reauthorization Act contains the SBIR/STTR Reauthorization Act of 2011 (SBIR/STTR Reauthorization Act)), which extends both the SBIR and Small Business Technology Transfer (STTR) programs through September 30, 2017.

1.3 Program Management

The Space Technology Mission Directorate 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 the Agency's 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 for the SBIR Program.

The STTR Program is aligned with the priorities of NASA's Space Technology Roadmaps, as well as the associated core competencies of the NASA Centers as described in section 9.2.

As technological innovation is at the core of the SBIR/STTR program it is critical to NASA's Technology Transfer efforts that any new innovation derived from an SBIR/STTR award is reported to NASA in accordance with its New Technology Reporting Requirements.

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

Space Technology	
Space Technology Roadmaps	http://www.nasa.gov/offices/oct/home/roadmaps/index.html

NASA Mission Directorates	
Aeronautics Research	http://www.aeronautics.nasa.gov/
Human Exploration and Operations	http://www.nasa.gov/directorates/heo/home/
Science	http://nasascience.nasa.gov
Space Technology	http://www.nasa.gov/directorates/spacetech/home/index.html

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.

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	6months
Phase II Contracts	**SBIR**	**STTR**
Maximum Contract Value	$750,000	$750,000
Maximum Period of Performance	24 months	24 months

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 a Phase I contract are eligible to submit a proposal for a Phase II funding agreement. Phase II projects are chosen as a result of competitive evaluations and based on selection criteria provided in the Phase II Proposal Instructions and Evaluation Criteria.

Opportunities for Continued Technology Development Post-Phase II

Phase II Enhancement (Phase II-E) and Phase II eXpanded (Phase II-X)

The purpose of the Phase II-E Option is to further encourage the advancement of innovations developed under Phase II via an extension of R/R&D efforts underway on current Phase II contracts. Under a Phase II-E option, the NASA SBIR/STTR Program will match, on a dollar-to-dollar basis, a minimum of $25,000 and a maximum of $150,000 of non-NASA-SBIR/STTR investments in a small business by an eligible third party to extend a project from 6-to-12 months. New work proposed under a Phase II-E effort must build upon and demonstrably advance the R/R&D conducted during Phase II, and should therefore lead to new outcomes not achievable with Phase II funding alone. Eligible third parties include a NASA project, NASA contractor, or any commercial investor. The total cumulative award for the Phase II contract plus the Phase II-E match is not expected to exceed $900,000 of SBIR/STTR funding. The non-SBIR/non-STTR contribution is not limited since it is regulated under the guidelines for Phase III awards.

	Minimum non-SBIR/STTR Funding Required for Eligibility for Matching in Phase II-E	**Corresponding SBIR/STTR Program Contribution**	**Anticipated Period of Additional Performance**
Phase II Enhancement	$25,000	$25,000	6-12 Months
	Maximum non-SBIR/STTR Funding to be Matched by SBIR/STTR Program in Phase II-E	**Corresponding SBIR/STTR Program Contribution**	**Anticipated Period of Additional Performance**
	$150,000	$150,000	6-12 Months

The purpose of the Phase II-X Option is to establish a strong and direct partnership between the NASA SBIR/STTR Program and other NASA projects undertaking the development of new technologies of innovations for future use. Under a Phase II-X option, innovations developed in Phase II are to be advanced via an extension of R/R&D efforts to the current Phase II contract. There are two specific requirements to be met for firms to be eligible for a Phase II-X option.

- First, eligible firms must secure a NASA program or project (other than the NASA SBIR/STTR Program) as a partner to invest in enhancing their technology for further research or infusion.
- Second, there is a minimum funding requirement for Phase II-X, as eligible firms must secure at least $75,000 in NASA program or project funding.

Under a Phase II-X option, the NASA SBIR/STTR Program will match, on a 2-for-1 basis, up to $250,000 of NASA program or project funding, thus enabling a maximum of $500,000 of SBIR/STTR award funds to be added from the NASA SBIR/STTR Program. The total cumulative award for the Phase II contract plus the Phase II-X match is not expected to exceed $1,250,000 of SBIR/STTR funding. Contributions from other NASA programs or projects are not limited since it is regulated under the guidelines for Phase III awards.

Phase II eXpanded	Minimum Funding Required from non-SBIR/STTR NASA Source for Eligibility for Matching in Phase II-X	Corresponding SBIR/STTR Program Contribution	Anticipated Period of Additional Performance
	$75,000	$150,000	12-24 Months
	Maximum Funding Amount from non-SBIR/STTR NASA Source to be Matched in Phase II-X	**Corresponding SBIR/STTR Program Contribution**	**Anticipated Period of Additional Performance**
	$250,000	$500,000	12-24 Months

All Phase II award recipients will have the Phase II-E and Phase II-X options written into their contract. Please refer to the NASA SBIR/STTR website (http://sbir.gsfc.nasa.gov/content/post-phase-ii-initiatives) for additional information.

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 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 2.26, 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 2.31). 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, including subcontractor performance. 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. For further information on ITAR visit http://www.pmddtc.state.gov/regulations_laws/itar.html. For additional assistance, refer to http://sbir.nasa.gov/content/training-resources or contact the NASA SBIR helpdesk at sbir@reisystems.com.

1.5.3 Principal Investigator (PI) Employment Requirement

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-Principle Investigators are not allowed.

Note: NASA considers a fulltime workweek to be nominally 40 hours and we consider 19.9-hour or more workweek elsewhere to be in conflict with this rule. In rare occasions, minor deviations from this requirement may be necessary; however, any minor deviation must be approved in writing by the contracting officer after consultation with the NASA SBIR/STTR Program Manager/Business Manager.

Requirements	SBIR	STTR
Primary Employment	PI must be employed 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-PIs	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

1.5.4 Restrictions on Funding Activity with the People's Republic of China

No funds can be used to participate, collaborate or coordinate bilaterally in any way with China or any Chinese-owned firm at either the prime contract level or any tier of subcontracting. This restriction on the use of funds appropriated to NASA is found in Section 1340(a) of The Department of Defense and Full-Year Appropriations Act, Public Law 112-10, Section 539 of the Consolidated and Further Continuing Appropriation Act of 2012, PL 112-55, and Section 535 of the Consolidated and Further Continuing Appropriations Act, 2013, PL113-6. NASA anticipates this restriction will be contained in future appropriation acts.

1.5.5 Restrictions on Venture Capital-owned Businesses

As set forth in the SBIR Reauthorization Act of 2011, small businesses owned in majority part by multiple venture capital operating companies, hedge funds, or private equity firms may be eligible for SBIR awards. SBA's regulations of 13 CFR part 121 sets forth the eligibility criteria for SBIR applicants that are owned in majority part by multiple venture capital operating companies, hedge funds, or private equity firms. Please note that SBIR agencies must submit a written determination (to the SBA, the Senate Committee on Small Business and Entrepreneurship, the House Committee on Small Business, and the House Committee on Science, Space, and Technology) at least 30 calendar days before it begins making awards to SBCs that are owned in majority part by multiple venture capital operating companies, hedge funds, or private equity firms. **At the current time, NASA is considering this change. Currently, such firms are not eligible to submit proposals to the NASA SBIR, STTR, and SBIR Select solicitations.**

1.5.6 Required Benchmark Transition Rate

The Phase I to Phase II Transition benchmark requirement applies to SBIR and STTR Phase I applicants that have received more than 20 Phase I awards over the past 5 fiscal years, excluding the most recently-completed fiscal year. For these companies, this benchmark rate establishes a minimum number of Phase II awards the SBC must have received for a given number of Phase I awards received during the 5-year time period. The required benchmark Transition Rate is 0.25.

SBA calculates company Phase I - Phase II Transition Rates once a year, on June 1st, using SBIR and STTR award information across all agencies in its TechNet database. A company's transition rate is the total number of SBIR and STTR Phase II awards it received during the past 5 years divided by the total number of SBIR and STTR Phase I awards it received during the past 5 years excluding the most recently-completed year. The 5-year period over which Phase I awards are counted excludes the most recently completed fiscal year because not all Phase II awards can occur within the same year as the Phase I award.

Companies with more than 20 Phase I awards during the past 5 years can view their Transition Rate if they log onto their Company Registry account at SBIR.gov. Companies that do not meet the benchmark rate on June 1st are notified by SBA that they are ineligible for an SBIR or STTR Phase I award until the following June 1st.

1.6 NASA SBIR/STTR Technology Available (TAV)

All subtopics have the option of using Technology Available (TAV) with NASA IP (defined below), which may also include NASA non-patented software technology requiring a Software Usage Agreement (SUA) or similar permission for use by others. All subtopics 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 commercial product development in any of its intramural research areas. Additional work is often necessary to exploit these NASA technologies for either infusion or commercial viability and likely requires innovation on behalf of the private sector. NASA provides these technologies "as is" and makes no representation or guarantee that additional effort will result in infusion or commercial viability.

The NASA technologies identified in a subtopic or via the IP search tool (http://technology.nasa.gov): (1) are protected by NASA-owned patents (NASA Patents), (2) are non-patented NASA-owned or controlled software (NASA software), or (3) are otherwise available for use by the public. In the event offeror requests to use NASA owned or controlled technologies, which are not NASA patents or NASA software, NASA shall consider such request and permit such uses as NASA, in its sole discretion, deems appropriate and permissible. If a proposer elects to use a NASA patent, a non-exclusive, royalty-free research license will be required to use the NASA IP during the SBIR/STTR performance period.

Similarly, if a proposer wishes to use NASA software, the parties will be required to enter into a Software Usage Agreement on a non-exclusive, royalty-free basis in order to use such NASA software for government purposes and "Government-Furnished Computer Software and Related Technical Data" will apply to the contract. As used herein, "NASA IP" refers collectively to NASA patents and NASA software. Disclaimer: All subtopics include an opportunity to license or otherwise use NASA IP on a non-exclusive, royalty-free basis, for research use under the contract. 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. NASA software release is governed by NPR 2210.1C.

Use of NASA Software

Software identified and requested under a SBIR/STTR contract shall be treated as Government Purpose Rights. Government purpose releases includes releases to other NASA Centers, Federal government agencies, and recipients who have a government contract. The software may be used for "government purposes" only. The recipients of such software releases are typically U.S. citizens. Non U.S. citizens will not be allowed access to NASA software under the SBIR/STTR contract.

A Software Usage Agreement (SUA) shall be requested after contract award from the appropriate NASA Center Software Release Authority (SRA). The SUA request shall include the NASA software title, version number, requesting firm contract info including recipient name, and SBIR/STTR contract award info. The SUA will expire when the contract ends.

Use of NASA Patent

All offerors submitting proposals citing a NASA patent must submit a non-exclusive, royalty-free license application if the use of a NASA patent is desired. The NASA license application is available on the NASA SBIR/STTR website: http://sbir.gsfc.nasa.gov/sites/default/files/research_license_app.doc. NASA only will grant research licenses to those SBIR/STTR offerors who submitted a license application and whose proposal resulted in an SBIR/STTR award under this solicitation. Such grant of non-exclusive research license will be set forth in the successful offeror's SBIR/STTR contract. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 CFR Part 404.

SBIR/STTR offerors are notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NASA patent will be granted unless an SBIR/STTR offeror applies for and receives such a license in accordance with the Federal patent licensing regulations at 37 CFR Part 404. Awardees with contracts that identify a specific NASA patent will be given the opportunity to negotiate a non-exclusive commercialization license or, if available, an exclusive commercialization license to the NASA patent.

An SBIR/STTR awardee that has been granted a non-exclusive, royalty-free research license to use a NASA patent under the SBIR/STTR award may, if available and on a non-interference basis, also have access to NASA personnel knowledgeable about the NASA patent. The NASA Intellectual Property Manager (IPM) located at the appropriate NASA Center will be available to assist awardees requesting information about a patent that was identified in the SBIR/STTR contract and, if available and on a non-interference basis, provide access to the inventor or surrogate for the purpose of knowledge transfer.

Note: Access to the inventor for the purpose of knowledge transfer, will require the requestor to enter into a Non-Disclosure Agreement (NDA), the awardee "may" be required to reimburse NASA for knowledge transfer activities.

1.7 Commercialization Technical Assistance

In accordance with the Small Business Act (15 U.S.C. 632), NASA will authorize the recipient of a Phase I SBIR award to purchase technical assistance services, such as access to a network of scientists and engineers engaged in a wide range of technologies, or access to technical and business literature available through on-line data bases, for the purpose of assisting such concerns in:

1. Making better technical decisions concerning such projects.
2. Solving technical problems which arise during the conduct of such projects.
3. Minimizing technical risks associated with such projects.
4. Developing and commercializing new commercial products and processes resulting from such projects.

If you are interested in proposing use of a vendor for technical assistance, you must complete the "Technical Assistance" section located under Other Direct Costs (ODCs) in the Budget Summary (Form C). You must provide the vendor name and contact information, the proposed amount not to exceed $5,000, and a detailed explanation of the services to be provided. You must also upload a price quote from the vendor. Approval of technical assistance is not guaranteed and is subject to review by the contracting officer. Please note that this commercialization assistance does not count toward the maximum award size in either Phase I or Phase II.

1.8 General Information

1.8.1 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@reisystems.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

1.8.2 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 Awardee

The organizational entity receiving an SBIR/STTR Phase I, Phase II, or Phase III award.

2.3 Commercialization

The process of developing products, processes, technologies, or services and the production and delivery (whether by the originating party or others) of the products, processes, technologies, or services for sale to or use by the Federal government or commercial markets.

2.4 Cooperative Research or Cooperative 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 firm must:

(1) Be a Women Owned Small Business (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 $750,000 (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

Work that is substantially the same research, which is proposed for funding in more than one contract proposal or grant application submitted to the same Federal agency or submitted to two or more different Federal agencies for review and funding consideration; or work where a specific research objective and the research design for accomplishing the objective are the same or closely related to another proposal or award, regardless of the funding source.

2.7 Feasibility

The practical extent to which a project can be performed successfully.

2.8 Federal Laboratory

As defined in 15 U.S.C. §3703, means any laboratory, any federally funded research and development center, or any center established under 15 U.S.C. §§ 3705 & 3707 that is owned, leased, or otherwise used by a Federal agency and funded by the Federal Government, whether operated by the Government or by a contractor.

2.9 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.

2.10 Funding Agreement Officer

A contracting officer, a grants officer, or a cooperative agreement officer.

2.11 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.

2.12 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.

2.13 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.

2.14 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 2.23), 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.

2.15 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.

2.16 New Technology Reporting Requirements

Anyone performing experimental, developmental, or research work under a NASA funding agreement, including SBIR/STTR Awardees, is required to disclose any new technology, invention or innovation as a result of the work performed under the contract. Any improvement, regardless of how big or small, should be reported via the New Technology Report (NTR) process defined below. Reportable items include a discovery, an invention, an innovation, or simply an advance in the state of the art. More detail on NASA’s New Technology Reporting requirements can be found at: https://invention.nasa.gov.

2.17 New Technology Report (NTR)

NASA's New Technology Report (NTR), also known as a NASA Form 1679, is the method by which new technologies (inventions and/or innovations) are disclosed. The NTR captures essential information about the technology /innovation, including its purpose, features, benefits and uses. NTR's should be submitted within two months after the inventor discloses it in writing to the Awardee's personnel responsible for patent matters. NTRs may be submitted via NASA's e-NTR system, by way of a link in the EHB.

2.18 New Technology Summary Reports (NTSR): Interim and Final

The New Technology Summary Report is a required deliverable in all research contracts. It is used to summarize any and all technologies (inventions and/or innovations) developed during the performance of the contract. If no new technologies were developed under the contract, the Awardee shall submit an NTSR which contains a certification stating no new technology was developed. NTSRs may be submitted via NASA's e-NTR system, by way of a link in the EHB.

2.19 electronic NASA's New Technology Reporting System (e-NTR)

NASA's e-NTR system is an on-line system used to submit NTRs, Interim NTSRs and Final NTSRs. The system may be found at URL: https://invention.nasa.gov. In addition, for SBIR/STTR awardees, the e-NTR system link may be found within the SBIR/STTR EHB.

2.20 Principal Investigator (PI)

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

2.21 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.

2.22 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).

2.23 SBIR/STTR Technical Data

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

2.24 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.

2.25 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).

2.26 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).

2.27 Socially and Economically Disadvantaged Individual

See 13 C.F.R. § 124.103 & 124.104 (http://www.sbir.gov/about/sbir-policy-directive).

2.28 Socially and Economically Disadvantaged Small Business Concern

See 13 CFR part 124, Subpart B (http://www.sbir.gov/about/sbir-policy-directive).

2.29 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.

2.30 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 A.

2.31 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.

2.32 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).

2.33 Women-Owned Small Business (WOSB)

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. An offeror 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 under this solicitation.

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 research agreement with a Research Institution. This agreement must be completed online through the form provided in the submissions handbook.

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. For SBIR Phase I and STTR Phase I contracts, a final NTSR is due at the end of the contract, prior to submission of the final invoice. 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 or MS Word format.

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

<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 I proposal shall not exceed a total of 23 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 23-page limit.
(2) Proposal Summary (Form B), counts as 1 page towards the 23-page limit (and must not contain proprietary data).
(3) Budget Summary (Form C), counts as 1 page towards the 23-page limit.
(4) Technical Content (11 parts in order as specified in section 3.2.4, **not to exceed 20 pages for SBIR and 19 pages for STTR**), including all graphics, with a table of contents.
(5) R/R&D Agreement between the SBC and RI **(STTR only)**, counts as 1 page towards the 23-page limit.
(6) Briefing Chart, is not included in the 23-page limit (and must not contain proprietary data).
(7) NASA Research License Application is not included in the 23-page limit (only if TAV is being proposed).

Note: Letters of general endorsement are not required or desired and will not be considered during the review process. However, if submitted, such letter(s) will count against the page limit.

In addition to the above items, each offeror must submit the following firm level forms, which must be filled out once during each submission period and are applicable to all firm proposals submissions:

(8) Firm Level Certifications, are not included in the 23-page limit.
(9) Audit Information, is not included in the 23-page limit.
(10) Prior Awards Addendum, is not included in the 23-page limit.
(11) Commercial Metrics Survey, is not included in the 23-page limit.

Previews of all forms and certifications are available via the NASA SBIR/STTR Firm Library, located at: (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).

Please note: Website references, relevant technical papers, product samples, videotapes, slides, or other ancillary items will not be considered during the review process.

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

All form submissions shall be done electronically, with each form counting as 1 page towards the 23-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 A) is provided in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html). 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 23-page limit.

3.2.3.2 Proposal Summary (Form B)

A sample Proposal Summary (Form B) is provided in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html). 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 23-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 C) is provided in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html). 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 23-page limit.

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

3.2.4 Technical Proposal

This part of the submission should 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 proposal 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.

TAV Note: All offerors submitting proposals who 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 23-page limit (See paragraph 1.6).

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 offeror may use this section to include bibliographic references.

Please note:
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. Provide a brief explanation of how it is related to energy efficiency and alternative and renewable energy.**

Part 6: Key Personnel and Bibliography of Directly Related Work
Identify all 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 Fiscal Year 2014 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 (this should include physical location [where the work is to be performed], square footage, and major equipment) 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 Federal facilities or equipment: 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. When a proposed project or product demonstration requires the use of a unique Federal facility that is not designated as a Federal laboratory to be funded by the SBIR/STTR Program, 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. 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. These letters should be uploaded in Form C of your proposal. **Failure to provide this explanation and a written letter of availability from the Government official authorized to approve such use may invalidate any proposal selection.**

When a proposed project or product demonstration requires the use of a Federal laboratory then the offeror must provide a letter justifying the use of a Federal laboratory from the SBC official, as well as, a letter from the Government agency that verifies the availability. These letters should be uploaded in Form C of your proposal. **Failure to provide a written letter of availability from the Government official authorized to approve such use of the Federal laboratory and the letter of justification from the SBC shall invalidate any proposal selection.**

Additionally, any proposer requiring the use of Federal laboratory, property, or facilities must, within ten (10) business 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 Federal 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.

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 and supporting documentation should be uploaded for each (appropriate documentation is specified 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 Subcontracts/Consultants	STTR Phase I Subcontracts/Consultants
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 minimum of 30 percent must be performed by the RI. Any subcontracted business effort other than that performed by the RI, shall 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 have been identified as an area of abuse and possibly fraud. 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 Research Agreement (Applicable for STTR proposals only)

The Research 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 Research Agreement should be submitted as required in section 6. This agreement counts as one page toward the 23-page limit.

3.2.6 Briefing Chart

An electronic form will be provided during the submissions process. The one-page briefing chart is required to assist in the ranking and advocacy of proposals prior to selection. It is not counted against the 23-page limit, and must not contain any proprietary data or ITAR restricted data.

3.2.7 Firm Level 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. An example of the certification can be found in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).

Note: The designated Firm Admin, typically the first person to register your firm, is the only individual authorized to update the certifications.

3.2.8 Audit Information

The SBC shall complete the questions regarding the firm's rates and upload the Federal agency audit report or related information that is available from the last audit. If your firm has never been audited by a federal agency, then answer "No" to the first question and you do not need to complete the remainder of the form. The "Audit Information" will be used to assist the contracting officer with negotiations if the proposal is selected for award. If the audit provided is not acceptable, they will be advised by the contracting officer on what is required to determine reasonable cost and/or rates. There is a separate "Audit Information" section in Forms C that must also be completed. The audit information is not included in the 23-page limit. An electronic form will be provided during the submissions process.

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update the audit information.

3.2.9 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. If your firm has received any SBIR or STTR Phase II awards, even if it has received fewer than 15 in the last 5 years, it is still recommended that you complete this form for those Phase II awards your firm did receive. This information will be useful when completing the Commercialization Metrics Survey, and in tracking the overall success of the SBIR and STTR programs. Any NASA Phase II awards your firm has received will be automatically populated in the electronic form, as are any Phase II awards previously entered by the SBC during prior submissions (you may update the information for these awards). The addendum is not included in the 23-page-limit. An electronic form will be provided during the submissions process.

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update the addendum information.

3.2.10 Commercial Metrics Survey

NASA has instituted a comprehensive commercialization survey/data gathering process for firms with prior 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, and period of performance. The survey will also ask for firm sales and ownership information, as well as any commercialization success the firm has had as a result of Phase II SBIR or STTR awards. This information will allow firms to demonstrate their ability to carry SBIR/STTR research through to achieve commercial success, and allow agencies to track the overall commercialization success of their SBIR and STTR programs. The survey is not included in the 23-page limit and content should be limited to information requested above. An electronic form will be provided during the submissions process.

Note: Information received from SBIR/STTR awardees completing the survey is kept confidential, and will not be made public except in broad aggregate, with no firm-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 Contractor Responsibility Information

No later than 10 business days after the notification of selection for negotiations the offeror shall provide a signed statement from your financial institution(s), on its letterhead, 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.

3.2.12 Allocation of Rights Agreement (STTR awards only)

No more than 10 business days after the notification of selection 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 the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html) of this Solicitation.

If the ARA form is completed and available at the time of submission, offers should upload it in Form C, which will help to expedite contract negotiations.

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, part 8).

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/non-STTR 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 announcement of selection for negotiation. If you have not received your debriefing by this time, contact the SBIR/STTR Program Support Office at ARC-SBIR-PMO@mail.nasa.gov.Telephone requests for debriefings will not be accepted. Debriefings are not opportunities to reopen selection decisions. 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.

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. If changes have occurred since submittal of your proposal, notify contracting officer immediately.
(2) Your firm is registered with System for Award Management (SAM). NASA has transitioned to SAM. It is the Official U.S. Government system that consolidated the CCR/FedReg, ORCA, and EPLS systems.
(3) The VETS 100 report submitted by your firm to the Department of Labor is current and submitted to the contracting officer within 10 business days of the notification of selection for negotiation.
(4) Your firm HAS NOT proposed a Co-Principal Investigator.
(5) STTR selectees should execute their Allocation of Rights Agreement within 10 business days of the notification of selection for negotiation.
(6) Your firm has a timely response to all communications from the NSSC Contracting Officer.

Please note: NASA will be transitioning to the DOD system, Wide Area WorkFlow (WAWF). During the duration of the contract your firm may be required to register with the WAWF system. It is a secure web based system for electronic invoicing, receipt, and acceptance. The WAWF website is located at: (https://wawf.eb.mil/).

From the time of proposal notification of 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 notification of selection for negotiation is not to be misconstrued as an award notification to commence work.

Phase I Model Contract
An example of the Phase I contracts can be found in the NASA SBIR/STTR Firm Library: https://sbir.gsfc.nasa.gov/sbir/firm_library/index.html. **Note: Model contracts are subject to change.**

5.2 Phase I Reporting

The technical reports and other deliverables 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 required reports and other deliverables shall 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 the Phase I will be included in the contract.

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 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 the 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 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 B.

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

If the contractor desires to continue protection of proprietary data, it shall deliver form, fit, and function data and shall not deliver the proprietary data. Data is considered to be "proprietary" when the data is developed at a private expense and (1) embodies trade secrets or contains commercial, financial and confidential, privileged information, or (2) is computer software.

5.7.3 Non-Disclosure Period

As part of SBIR contracts, 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.

Per the NASA FAR Supplement 1852.227-11 Patent Rights--Retention by the Contractor (Short Form) 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 NASA Form 1679 and the NTSR shall also be uploaded to the SBIR/STTR EHB at https://ehb8.gsfc.nasa.gov/contracts/public/firmHome.do.

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 2.22. 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 23-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 with every invoice 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 Additional Information

5.11.1 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.

5.11.2 Evidence of Contractor Responsibility

In addition to the information required to be submitted in section 3.2.11, 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.

5.11.3 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/content/training-resources or contact the NASA SBIR helpdesk at sbir@reisystems.com.

5.11.4 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 Required Registrations and Submissions

5.12.1 Firm SBA Firm Registry

SBA maintains and manages a Company Registry at www.SBIR.gov to track ownership and affiliation requirements for all companies applying to the SBIR Program. The SBIR policy directive requires each small business concern (SBC) applying for a Phase I or Phase II award to register in the Company Registry prior to submitting an application. A PDF document with the SBC registration information is available for download by the SBC upon successful registration. This PDF document must be saved by the SBC for inclusion in applications submitted to SBIR agencies. All SBCs must report and/or update ownership information to SBA prior to each SBIR application submission or if any information changes prior to award.

From the NASA SBIR/STTR Proposal Submission Electronic Handbook (EHB), the SBC must provide their unique SBC Control ID that gets assigned by SBA upon completion of the Company Registry registration, as well as upload the PDF document validating their registration. This information is submitted to NASA via a Firm level form in the Activity Worksheet and is applicable across all proposals submitted by the SBC for that specific solicitation.

5.12.2 Central Contractor Registration

Offerors should be aware of the requirement to register in the System for Award Management (SAM) 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.**

SAM 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 SAM, all mandatory information, which includes the DUNS or DUNS+4 number, and a CAGE code, must be validated in SAM. 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 SAM registration process.

The DoD has established a goal of registering an applicant in SAM within 48 hours after receipt of a complete and accurate application via the Internet. Offerors that are not registered should consider applying for registration immediately upon receipt of this solicitation. Offerors and contractors may obtain information on SAM registration and annual confirmation requirements via the Internet at (https://www.sam.gov/) or by calling 866-606-8220

5.12.3 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 SAM website (https://www.sam.gov/). 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.

5.12.4 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. 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 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.

5.12.5 1852.225-72 Restriction on funding Activity with China – Representation

(a) Definition - “China” or “Chinese-owned” means the People’s Republic of China, any firm owned by the People’s Republic of China or any firm incorporated under the laws of the People’s Republic of China.
(b) Public Laws 112-10, Section 1340(a) 112-55, Section 536, and Section 535, PL 113-6 restrict NASA from contracting to participate, collaborate, or coordinate bilaterally in any way with China or a Chinese-owned firm with funds appropriated on or after April 25, 2011. NASA anticipates this restriction will be in future appropriation acts. Contracts for commercial and non-developmental items are excepted from the prohibition as they constitute purchase of goods or services that would not involve participation, collaboration, or coordination between the parties.
(c) Representation. By submission of its offer, the offeror represents that the offeror is not China or a Chinese-owned firm.

5.12.6 Software Development Standards

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

5.12.7 Human and/or Animal Subject

Due to the complexity of the approval process, use of human and/or animal subjects is not allowed for Phase I contracts.

5.12.8 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.

5.13 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. Firms are encouraged to start the proposal process early, to allow for sufficient time to complete the submissions 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.

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update and change the firm level forms.

For successful proposal submission, SBCs must complete all forms online, upload their technical proposal in an acceptable format, and have the Business Official and Principle Investigator 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 Research 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 other firm level forms must be submitted 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) STTR proposers must submit the Research Agreement between the SBC and RI **(STTR only)**.
(4) Firms must submit a briefing chart online, which is not included in the page count (see section 3.2.6).
(5) NASA Research License Application (only if the use of TAV is proposed).
(6) The certifications, audit information, prior awards addendum, commercialization metrics survey are required and to be completed online. These are not included in the page count.

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 or MS Word. **Note: Embedded animation or video, as well as reference technical papers for "further reading" 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 supporting documentation, as reviewers may not be able to open and read the files. An e-mail will be sent acknowledging each successful technical proposal upload. Please verify the file name and file size in the confirmation email to ensure the correct proposal was uploaded.

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 Wednesday, January 29, 2014 via the NASA SBIR/STTR website (http://sbir.nasa.gov). The EHB will not be available for Internet submissions after this deadline, so firms are also advised to print all forms prior to the deadline since the EHB will not be available. 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 and Principal Investigator), Form B, Form C, the uploaded technical proposal, firm-level forms, 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.

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@reisystems.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 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.sbir.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

Please note: Previews of all forms and certifications are available via the NASA SBIR/STTR Firm Library, located at: (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).

Firm Certifications
Offerors must complete the “Certifications” section of the Proposal Submission Electronic Handbook, answering Yes or No to certifications as applicable.

Firms should carefully read each of the certification statements. The Federal government relies on the information to determine whether the business is eligible for a Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) Program award. A similar certification will be used to ensure continued compliance with specific program requirements during the life of the funding agreement. The definitions for the terms used in this certification are set forth in the Small Business Act, SBA regulations (13 C.F.R. Part 121), the SBIR Policy Directive and also any statutory and regulatory provisions referenced in those authorities.

If the funding agreement officer believes that the business may not meet certain eligibility requirements at the time of award, they are required to file a size protest with the U.S. Small Business Administration (SBA), who will determine eligibility. At that time, SBA will request further clarification and supporting documentation in order to assist in the verification of any of the information provided as part of a protest. If the funding agreement officer believes, after award, that the business is not meeting certain funding agreement requirements, the agency may request further clarification and supporting documentation in order to assist in the verification of any of the information provided.

Even if correct information has been included in other materials submitted to the Federal government, any action taken with respect to this certification does not affect the Government’s right to pursue criminal, civil or administrative remedies for incorrect or incomplete information given in the certification. Each person signing this certification may be prosecuted if they have provided false information.

In submitting the proposals including the certifications, each offeror understands 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.

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 23 8.5 x 11 inch pages and follow the format requirements (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. A letter of commitment from the facility manager, if the research or R&D effort requires use of federal facilities (section 3.2.4).

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 6 months (sections 1.4).

9. Entire proposal including Forms A, B, and C submitted via the Internet.

   a) All firm-level forms most also be submitted, including: 1) all certifications, 2) audit information, 3) prior awards addendum, and 4) the commercialization metrics survey.

10. Form A electronically endorsed by the SBC Official and the PI.

11. **Proposals must be received no later than 5:00 p.m. EDT on 29 January 2014 (section 6.3).**

STTR 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 23 8.5 x 11 inch pages, including the Research Agreement, and follow the format requirements (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. A letter of commitment from the facility manager, if the research or R&D effort requires use of federal facilities (section 3.2.4).

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 6months (sections 1.4).

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

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

    a) All firm-level forms most also be submitted, including: 1) all certifications, 2) audit information, 3) prior awards addendum, and 4) the commercialization metrics survey.

11. Form A electronically endorsed by the SBC Official and the PI.

12. **Proposals must be received no later than 5:00 p.m. EDT on 29 January 2014 (section 6.3).**

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

National Aeronautics and Space Administration

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

Part 2: General Phase II Proposal Instructions and Evaluation Criteria

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

Fiscal year 2014 NASA SBIR/STTR Program Solicitations

1. Phase II Program Description

1.1 Introduction

This document provides a general description of the NASA SBIR/STTR Phase II Program and proposal submission requirements. 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 contract completion date.

Proposals must be submitted online via the Proposal Submissions Electronic Handbook at http://sbir.nasa.gov and include all relevant documentation.

1.2 Phase II Description

Phase II
The purpose of Phase II is the development, demonstration and delivery of the innovation. Only SBCs awarded a Phase I contract are eligible to submit a proposal for a Phase II funding agreement. Phase II projects are chosen as a result of competitive evaluations and based on selection criteria provided in the Phase II Proposal Instructions and Evaluation Criteria.

Maximum value and period of performance for Phase II contracts:

Phase II Contracts	SBIR	STTR
Maximum Contract Value	$750,000	$750,000
Maximum Period of Performance	24 months	24 months

1.3 Eligibility Requirements

1.3.1 Small Business Concern

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

1.3.2 Place of Performance

R/R&D must be performed in the United States. 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., including subcontractor performance. 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. 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/content/training-resources or contact the NASA SBIR helpdesk at sbir@reisystems.com.

1.3.3 Principal Investigator (PI) Employment Requirement

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-Principle Investigators are not allowed.

Note: NASA considers a fulltime workweek to be nominally 40 hours and we consider 19.9-hour or more workweek elsewhere to be in conflict with this rule. In rare occasions, minor deviations from this requirement may be necessary; however, any minor deviation must be approved in writing by the contracting officer after consultation with the NASA SBIR/STTR Program Manager/Business Manager.

Requirements	SBIR	STTR
Primary Employment	PI must be employed 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-PIs	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

1.4 NASA SBIR/STTR Technology Available (TAV)

All subtopics have the option of using Technology Available (TAV) with NASA IP (defined below), which may also include NASA non-patented software technology requiring a Software Usage Agreement (SUA) or similar permission for use by others. All subtopics 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 commercial product development in any of its intramural research areas. Additional work is often necessary to exploit these NASA technologies for either infusion or commercial viability and likely requires innovation on behalf of the private sector. NASA provides these technologies "as is" and makes no representation or guarantee that additional effort will result in infusion or commercial viability.

The NASA technologies identified in a subtopic or via the IP search tool (http://technology.nasa.gov): (1) are protected by NASA-owned patents (NASA Patents), (2) are non-patented NASA-owned or controlled software (NASA software), or (3) are otherwise available for use by the public. In the event offeror requests to use NASA owned or controlled technologies, which are not NASA patents or NASA software, NASA shall consider such request and permit such uses as NASA, in its sole discretion, deems appropriate and permissible. If a proposer elects to use a NASA patent, a non-exclusive, royalty-free research license will be required to use the NASA IP during the SBIR/STTR performance period.

Similarly, if a proposer wishes to use NASA software, the parties will be required to enter into a Software Usage Agreement on a non-exclusive, royalty-free basis in order to use such NASA software for government purposes and "Government-Furnished Computer Software and Related Technical Data" will apply to the contract. As used herein, "NASA IP" refers collectively to NASA patents and NASA software disclaimer: All subtopics include an opportunity to license or otherwise use NASA IP on a non-exclusive, royalty-free basis, for research use under the contract. 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. NASA software release is governed by NPR 2210.1C.

Use of NASA Software

Software identified and requested under a SBIR/STTR contract shall be treated as Government Purpose Rights. Government purpose releases includes releases to other NASA Centers, Federal government agencies, and recipients who have a government contract. The software may be used for "government purposes" only. The recipients of such software releases are typically U.S. citizens. Non U.S. citizens will not be allowed access to NASA software under the SBIR/STTR contract.

A Software Usage Agreement (SUA) shall be requested after contract award from the appropriate NASA Center Software Release Authority (SRA). The SUA request shall include the NASA software title, version number, requesting firm contract info including recipient name, and SBIR/STTR contract award info. The SUA will expire when the contract ends.

Use of NASA Patent
All offerors submitting proposals citing a NASA patent must submit a non-exclusive, royalty-free license application if the use of a NASA patent is desired. The NASA license application is available on the NASA SBIR/STTR website: http://sbir.gsfc.nasa.gov/sites/default/files/research_license_app.doc. NASA only will grant research licenses to those SBIR/STTR offerors who submitted a license application and whose proposal resulted in an SBIR/STTR award under this solicitation. Such grant of non-exclusive research license will be set forth in the successful offeror's SBIR/STTR contract. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 CFR Part 404.

SBIR/STTR offerors are notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NASA patent will be granted unless an SBIR/STTR offeror applies for and receives such a license in accordance with the Federal patent licensing regulations at 37 CFR Part 404. Awardees with contracts that identify a specific NASA patent will be given the opportunity to negotiate a non-exclusive commercialization license or, if available, an exclusive commercialization license to the NASA patent.

An SBIR/STTR awardee that has been granted a non-exclusive, royalty-free research license to use a NASA patent under the SBIR/STTR award may, if available and on a non-interference basis, also have access to NASA personnel knowledgeable about the NASA patent. The NASA Intellectual Property Manager (IPM) located at the appropriate NASA Center will be available to assist awardees requesting information about a patent that was identified in the SBIR/STTR contract and, if available and on a non-interference basis, provide access to the inventor or surrogate for the purpose of knowledge transfer.

Note: Access to the inventor for the purpose of knowledge transfer, will require the requestor to enter into a Non-Disclosure Agreement (NDA), the awardee "may" be required to reimburse NASA for knowledge transfer activities.

1.5 Commercialization Technical Assistance

In accordance with the Small Business Act (15 U.S.C. 632), NASA will authorize the recipient of a Phase I SBIR award to purchase technical assistance services, such as access to a network of scientists and engineers engaged in a wide range of technologies, or access to technical and business literature available through on-line data bases, for the purpose of assisting such concerns in:

1. Making better technical decisions concerning such projects.
2. Solving technical problems which arise during the conduct of such projects.
3. Minimizing technical risks associated with such projects.
4. Developing and commercializing new commercial products and processes resulting from such projects.

If you are interested in proposing use of a vendor for technical assistance, you must complete the "Technical Assistance" section located under Other Direct Costs (ODCs) in the Budget Summary (Form C). You must provide the vendor name and contact information, the proposed amount not to exceed $5,000, and a detailed explanation of the services to be provided. You must also upload a price quote from the vendor. Approval of technical assistance is not guaranteed and is subject to review by the contracting officer. Please note that this commercialization assistance does not count toward the maximum award size in either Phase I or Phase II.

2. Proposal Preparation Instructions and Requirements

2.1 Fundamental Considerations

The object of Phase II is to continue the R/R&D effort from the completed Phase I.

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, 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. For SBIR Phase II and STTR Phase II contracts, an Interim NTSR report is required every 12 months from the effective date of the contract as well as a final NTSR due at the end of the contract, prior to submission of the final invoice.

2.2 Phase II Proposal Requirements

2.2.1 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, 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.

2.2.2 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 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 (and must not contain proprietary data).
(3) Budget Summary (Form C), counts as 1 page towards the 50-page limit.
(4) Technical Content (11 Parts in order as specified in section 2.2.4, **not to exceed 47 pages for SBIR and 46 pages for STTR)**, including all graphics, and starting with a table of contents.
(5) R/R&D Agreement between the SBC and RI **(STTR only)**, counts as 1 page towards the 50-page limit.
(6) Capital Commitments Addendum Supporting Phase II and Phase III.
(7) Briefing Chart (Not included in the 50-page limit and must not contain proprietary data).
(8) NASA Research License Application is not included in the 50-page limit (only if TAV is being proposed).

Note: Letters of general endorsement are not required or desired and will not be considered during the review process. However, if submitted, such letter(s) will count against the page limit.

In addition to the above items, each offeror must submit the following firm level forms, which must be filled out once during each submission period and are applicable to all firm proposals submissions:

(9) Firm Level Certifications, are not included in the 50-page limit.
(10) Audit Information, is not included in the 50-page limit.
(11) Prior Awards Addendum, is not included in the 50-page limit.
(12) Commercial Metrics Survey, is not included in the 50-page limit.

Previews of all forms and certifications are available via the NASA SBIR/STTR Firm Library, located at: (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).

Please note: Website references, relevant technical papers, product samples, videotapes, slides, or other ancillary items will not be considered during the review process.

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.

2.2.3 Forms

All form submissions shall be 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.

2.2.3.1 Cover Sheet (Form A)

A sample Cover Sheet (Form A) is provided in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html). The offeror shall provide complete information for each item and submit the form, as required in section 5. 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.

2.2.3.2 Proposal Summary (Form B)

A sample Proposal Summary (Form B) is provided in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html). The offeror shall provide complete information for each item and submit Form B as required in section 5. 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.

2.2.3.3. Budget Summary (Form C)

A sample of the Budget Summary (Form C) is provided in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html). 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 $750,000. 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 firm before award of any contract.

2.2.4 Technical Proposal

This part of the submission should 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
The technical proposal 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 the subtopic;
(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.

TAV Note: All offerors submitting proposals who 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 50-page limit (See section 1.4).

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.

Please note:
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. Provide a brief explanation of how it is related to energy efficiency and alternative and renewable energy.**

Part 6: Key Personnel and Bibliography of Directly Related Work
Identify all 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 Phase I 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 (this should include physical location [where the work is to be performed], square footage, and major equipment) 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 Federal facilities or equipment: 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/STTR policies restrict the use of any SBIR/STTR funds for the use of Federal equipment and facilities (except for those facilities designated as a Federal laboratory). This does not preclude an SBC from utilizing a Federal facility or Federal equipment, but any charges for such use may not be paid for with SBIR/STTR funds. In rare and unique circumstances, SBA may issue a case-by-case waiver to this provision after review of an agency's written justification. Federal facilities designated as Federal laboratories are exempt from this waiver requirement (see 15 U.S.C. § 3710a(d) and the SBA SBIR/STTR Policy Directive). Any NASA facility generally would be considered a Federal laboratory; however, requests for things such as office space would be deemed to be a Federal facility requiring a waiver. Additionally, NASA may not and cannot fund the use of the Federal facility (including Federal laboratories) or personnel for the SBIR/STTR project with NASA program or project money.

When a proposed project or product demonstration requires the use of a unique Federal facility that is not designated as a Federal laboratory to be funded by the SBIR/STTR Program, 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. 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. These letters should be uploaded in Form C of your proposal. **Failure to provide this explanation and the site manager's written availability of use may invalidate any proposal selection.**

When a proposed project or product demonstration requires the use of a Federal laboratory then the offeror must provide a letter justifying the use of a Federal laboratory from the SBC official, as well as, a letter from the Government agency that verifies the availability. These letters should be uploaded in Form C of your proposal. **Failure to provide the site manager's written availability of use of the Federal laboratory and the letter of justification from the SBC shall invalidate any proposal selection.**

Additionally, any proposer requiring the use of Federal laboratory, property, or facilities must, within ten (10) business 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 Federal 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.

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 and supporting documentation should be uploaded for each (appropriate documentation is specified in Form C). Subcontractors' and consultants' work has the same place of performance restrictions as stated in Phase I section 1.5.2.

The following restrictions apply to the use of subcontracts/consultants:

SBIR Phase II Subcontracts/Consultants	STTR Phase II Subcontracts/Consultants
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 minimum of 30 percent must be performed by the RI. Any subcontracted business effort other than that performed by the RI, shall 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 2.2.4, 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 have been identified as an area of abuse and possibly fraud. 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”, 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.

2.2.5 Research Agreement (Applicable for STTR proposals only)

The Research Agreement (different from the Allocation of Rights Agreement) 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 Research Agreement should be submitted as required in section 5. This agreement counts as one page toward the 50-page limit.

2.2.6 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.

2.2.7 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 electronic form will be provided during the submissions process.

2.2.8 Firm Level 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. An example of the certification can be found in the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update the certifications.

2.2.9 Audit Information

The SBC shall complete the questions regarding the firm’s rates and upload the Federal agency audit report or related information that is available from the last audit. If your firm has never been audited by a federal agency, then answer "No" to the first question and you do not need to complete the remainder of the form. The “Audit Information” will be used to assist the contracting officer with negotiations if the proposal is selected for award. If the audit provided is not acceptable, they will be advised by the Contracting Officer on what is required to determine reasonable cost and/or rates. There is a separate “Audit Information” section in Forms C that must also be completed. The audit information is not included in the 50-page limit. An electronic form will be provided during the submissions process.

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update the audit information.

2.2.10 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. If your firm has received any SBIR or STTR Phase II awards, even if it has received fewer than 15 in the last 5 years, it is still recommended that you complete this form for those Phase II awards your firm did receive. This information will be useful when completing the Commercialization Metrics Survey, and in tracking the overall success of the SBIR and STTR programs. Any NASA Phase II awards your firm has received will be automatically populated in the electronic form, as are any Phase II awards previously entered by the SBC during prior submissions (you may update the information for these awards). The addendum is not included in the 50-page limit. An electronic form will be provided during the submissions process.

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update the addendum information.

2.2.11 Commercial Metrics Survey

NASA has instituted a comprehensive commercialization survey/data gathering process for firms with prior 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, and period of performance. The survey will also ask for firm sales and ownership information, as well as any commercialization success the firm has had as a result of Phase II SBIR or STTR awards. This information will allow firms to demonstrate their ability to carry SBIR/STTR research through to achieve commercial success, and allow agencies to track the overall commercialization success of their SBIR and STTR programs. The survey 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.

Note: Information received from SBIR/STTR awardees completing the survey is kept confidential, and will not be made public except in broad aggregate, with no firm-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

2.2.12 Contractor Responsibility Information

No later than 10 business days after the notification of selection for negotiations the offeror shall provide a signed statement from your financial institution(s), on its letterhead, stating whether or not your firm is in good standing and how long you have been with the institution.

2.2.13 Allocation of Rights Agreement (STTR awards only)

No more than 10 business days after the notification of selection 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 the NASA SBIR/STTR Firm Library (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html)of this Solicitation.

If the ARA form is completed and available at the time of submission, offers should upload it in Form C, which will help to expedite contract negotiations.

3. Method of Selection and Evaluation Criteria

3.1 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.

3.1.1 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.

3.1.2 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 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 2.2.4, part 8).

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 acceptable numerical scores 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.

3.1.3 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.

3.2 Debriefing of Unsuccessful Offerors

After selection for negotiations have been announced, debriefings for 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. To request debriefings on proposals, offerors must request via e-mail to the SBIR/STTR Program Support Office at ARC-SBIR-PMO@mail.nasa.gov within 60 days after the announcement of selection for negotiation. Late requests will not be honored.

4. Considerations

4.1 Awards

4.1.1 Availability of Funds

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

SBIR Contracts	STTR Contracts
NASA anticipates that approximately 35-40 percent of the successfully completed Phase I projects from the SBIR fiscal year 2014 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 $750,000.	NASA anticipates that approximately 35-40 percent of the successfully completed Phase I projects from the STTR fiscal year 2014 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 $750,000.

4.1.2 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. If changes have occurred since submittal of your proposal, notify contracting officer immediately.
(2) Your firm is registered with System for Award Management (SAM). NASA has transitioned to SAM. It is the Official U.S. Government system that consolidated the CCR/FedReg, ORCA, and EPLS systems.
(3) The VETS 100 report submitted by your firm to the Department of Labor is current and submitted to the contracting officer within 10 business days of the notification of selection for negotiation.
(4) Your firm HAS NOT proposed a Co-Principal Investigator.
(5) STTR selectees should execute their Allocation of Rights Agreement within 10 business days of the notification of selection for negotiation.
(6) Your firm has a timely response to all communications from the NSSC Contracting Officer.

Please note: NASA will be transitioning to the DOD system, Wide Area WorkFlow (WAWF). During the duration of the contract your firm may be required to register with the WAWF system. It is a secure web based system for electronic invoicing, receipt, and acceptance. The WAWF website is located at: (https://wawf.eb.mil/).
From the time of proposal notification of 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 notification of selection for negotiation is not to be misconstrued as an award notification to commence work.

Phase II Model Contract
An example of the Phase II contracts can be found in the NASA SBIR/STTR Firm Library: https://sbir.gsfc.nasa.gov/sbir/firm_library/index.html. Note: **Model contracts are subject to change.**

4.2 Phase II Reporting

The technical reports are required as described in the contract and are to be provided to NASA. All required reports shall be submitted electronically via the EHB.

4.3 Release of Proposal Information

In submitting a proposal, the offeror agrees to permit the Government to disclose publicly the information contained on 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).

4.4 Access to Proprietary Data by Non-NASA Personnel

4.4.1 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.

4.4.2 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.

4.5 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 the 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 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 B.

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

4.6 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.

4.7 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.

4.8 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as an SBC. 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.

4.9 Addition Information

4.9.1 Evidence of Contractor Responsibility

In addition to the information required to be submitted in section 2.2.12, 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.

4.10 Required Registrations and Submissions

4.10.1 Firm SBA Firm Registry

SBA maintains and manages a Company Registry at www.SBIR.gov to track ownership and affiliation requirements for all companies applying to the SBIR Program. The SBIR policy directive requires each small business concern (SBC) applying for a Phase I or Phase II award to register in the Company Registry prior to submitting an application. A PDF document with the SBC registration information is available for download by the SBC upon successful registration. This PDF document must be saved by the SBC for inclusion in applications submitted to SBIR agencies. All SBCs must report and/or update ownership information to SBA prior to each SBIR application submission or if any information changes prior to award.

From the NASA SBIR/STTR Proposal Submission Electronic Handbook (EHB), the SBC must provide their unique SBC Control ID that gets assigned by SBA upon completion of the Company Registry registration, as well as upload the PDF document validating their registration. This information is submitted to NASA via a Firm level form in the Activity Worksheet and is applicable across all proposals submitted by the SBC for that specific solicitation.

4.10.2 Central Contractor Registration

Offerors should be aware of the requirement to register in the System for Award Management (SAM) 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.**

SAM 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 SAM, all mandatory information, which includes the DUNS or DUNS+4 number, and a CAGE code, must be validated in SAM. 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 SAM registration process.

The DoD has established a goal of registering an applicant in SAM within 48 hours after receipt of a complete and accurate application via the Internet. Offerors that are not registered should consider applying for registration immediately upon receipt of this solicitation. Offerors and contractors may obtain information on SAM registration and annual confirmation requirements via the Internet at (https://www.sam.gov/) or by calling 866-606-8220.

4.10.3 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 SAM website (https://www.sam.gov/). 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.

4.10.4 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. 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 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.

4.10.5 Software Development Standards

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

4.10.6 Human and/or Animal Subject

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 prior to the initiation of any human and/or animal subject research. 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.

4.10.7 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.

4.11 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.

5. Submission of Proposals

5.1 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.

5.2 Submission Process

SBCs must register in the EHB to begin the submission process. Firms are encouraged to start the proposal process early, to allow for sufficient time to complete the submissions 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.

Note: The designated firm admin, typically the first person to register your firm, is the only individual authorized to update and change the firm level forms (see Phase I section 6.2.1).

For successful proposal submission, SBCs must complete all forms online, upload their technical proposal in an acceptable format, and have the Business Official and Principle Investigator 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 2.2.4.

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

5.2.1 What Needs to Be Submitted

The entire proposal including Forms A, B, C, the briefing chart, and other firm level forms must be submitted 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) STTR proposers must submit the Research Agreement between the SBC and RI (STTR only).
(4) Firms must submit a briefing chart online, which is not included in the page count (see sections 3.2.6).
(5) NASA Research License Application (only if the use of TAV is proposed).
(6) The certifications, audit information, prior awards addendum, commercialization metrics survey are required and to be completed online. These are not included in the page count.

5.2.2 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 or MS Word. **Note: Embedded animation or video, as well as reference technical papers for "further reading" 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.

5.2.3 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 supporting documentation, as reviewers may not be able to open and read the files. An e-mail will be sent acknowledging each successful technical proposal upload. Please verify the file name and file size in the confirmation email to ensure the correct proposal was uploaded.

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.

5.3 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. Receipt of Phase II proposals are due on the last day of performance under SBIR/STTR Phase I contracts. The EHB will not be available for Internet submissions after this deadline, so firms are also advised to print all forms prior to the deadline since the EHB will not be available. Any proposal received after that date and time shall be considered late and handled according to NASA FAR Supplement 1815.208.

5.4 Acknowledgment of Proposal Receipt

The final proposal submission includes successful completion of Form A (electronically endorsed by the SBC Official and Principal Investigator), Form B, Form C, the uploaded technical proposal, firm-level forms, 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.

5.5 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@reisystems.com.

5.6 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.

6. Submission Forms and Certifications

Please note: Previews of all forms and certifications are available via the NASA SBIR/STTR Firm Library, located at: (https:/sbir.gsfc.nasa.gov/sbir/firm_library/index.html).

Firm Certifications
Offerors must complete the "Certifications" section of the Proposal Submission Electronic Handbook, answering Yes or No to certifications as applicable.

Firms should carefully read each of the certification statements. The Federal government relies on the information to determine whether the business is eligible for a Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program award. A similar certification will be used to ensure continued compliance with specific program requirements during the life of the funding agreement. The definitions for the terms used in this certification are set forth in the Small Business Act, SBA regulations (13 C.F.R. Part 121), the SBIR Policy Directive and also any statutory and regulatory provisions referenced in those authorities.

If the funding agreement officer believes that the business may not meet certain eligibility requirements at the time of award, they are required to file a size protest with the U.S. Small Business Administration (SBA), who will determine eligibility. At that time, SBA will request further clarification and supporting documentation in order to assist in the verification of any of the information provided as part of a protest. If the funding agreement officer believes, after award, that the business is not meeting certain funding agreement requirements, the agency may request further clarification and supporting documentation in order to assist in the verification of any of the information provided.

Even if correct information has been included in other materials submitted to the Federal government, any action taken with respect to this certification does not affect the Government's right to pursue criminal, civil or administrative remedies for incorrect or incomplete information given in the certification. Each person signing this certification may be prosecuted if they have provided false information.

In submitting the proposals including the certifications, each offeror understands 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.

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 and the format requirements (section 2.2.2).**

2. The proposal and innovation is submitted for one subtopic only.

3. The entire proposal is submitted consistent with the requirements and in the order outlined in section 2.2.

4. The technical proposal contains all eleven parts in order (section 2.2.4).

5. A letter of commitment from the facility manager, if the research or R&D effort requires use of federal facilities (section 2.2.4).

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

7. Proposed funding does not exceed $750,000 (sections 1.2, 4.1.1).

8. Proposed project duration does not exceed 24 months (sections 1.2, 4.1.1).

9. Entire proposal including Forms A, B, and C submitted via the Internet.

   a) All firm-level forms most also be submitted, including: 1) all certifications, 2) audit information, 3) prior awards addendum, and 4) the commercialization metrics survey.

10. Form A electronically endorsed by the SBC Official and the PI.

11. **Phase II proposal submissions will be due after the last day of the Phase I contract (section 5.3).**

STTR 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 25 8.5 x 11 inch pages, including the Research Agreement, and follow the format requirements (sections 2.2.2, 2.2.5).**

2. The proposal and innovation is submitted for one subtopic only.

3. The entire proposal is submitted consistent with the requirements and in the order outlined in section 2.2.

4. The technical proposal contains all eleven parts in order (section 2.2.4).

5. A letter of commitment from the facility manager, if the research or R&D effort requires use of federal facilities (section 2.2.4).

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

7. Proposed funding does not exceed $750,000 (section 1.2, 4.1.1).

8. Proposed project duration does not exceed 24 months (section 1.2, 4.1.1).

9. Research Agreement has been electronically endorsed by both the SBC Official and the RI (sections 2.2.5, 5.2).

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

    a) All firm-level forms most also be submitted, including: 1) all certifications, 2) audit information, 3) prior awards addendum, and 4) the commercialization metrics survey.

11. Form A electronically endorsed by the SBC Official and the PI.

12. **Phase II proposal submissions will be due after the last day of the Phase I contract (section 5.3).**

13. Signed Allocation of Rights Agreement, available for the Contracting Officer at the 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 Mission Directorates (MDs):

Aeronautics Research
Human Exploration and Operations
Science
Space Technology

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 at the fundamental level and integrated systems level to support current and emerging applications as well as revolutionary concepts and technologies that could one day 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 is also directly addressing fundamental research challenges that must be overcome in order to implement the Next Generation Air Transportation System (NextGen). NextGen is the name given to a new National Airspace System that proposes to transform America's air traffic control system from an aging ground-based system to a satellite-based system. NextGen technology will provide advanced levels of automated support to air navigation service providers and aircraft operators enabling shortened routes for time and fuel savings, reduced traffic delays, increased capacity, and permitting controllers to monitor and manage aircraft with greater safety margins. This transformation has the aim of reducing gridlock, both in the sky and at airports. 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.

In 2012, ARMD started issuing more focused solicitations by rotating subtopics every other year. The reduction in the scope of the solicitation does not imply a change in interest in a given area. For example, in 2012 we solicited proposals for airframe noise reduction and efficiency improvement (through drag reduction). In 2014 we are soliciting proposals for engine efficiencies and noise reduction. Then in 2015 we plan to return to airframe noise and efficiency improvement.

(http://www.aeronautics.nasa.gov/)

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 Precursors to Safety Incidents
- Assuring Safe Human-Systems Integration
- Prognostic Algorithm Design for Safety Assurance
- Maintain Vehicle Safety Between Major Inspections
- Improve Crew Decision-Making and Response in Complex Situations
- Assure Safe and Effective Aircraft Control under Hazardous Conditions
- Engine Icing Characterization and Simulation Capability
- Airframe Icing Simulation and Engineering Tool Capability
- Atmospheric Hazard Sensing and Mitigation Technology Capability

AvSP includes three research projects:

- The System-wide Safety Assurance Technologies Project identifies risks and provides knowledge required to safely 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.
- By addressing important issues related to past accidents and considering emerging potential hazards associated with future operations, the Vehicle Systems Safety Technologies Project provides enhanced vehicle design, structure, systems, and operating concepts to enable a reduction in accidents and incidents.
- 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): DFRC, GRC

NASA is concerned with the prevention of encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. Hazardous flight conditions of particular interest are: wake vortices, clear-air turbulence, in-flight icing, lightning, and low visibility. NASA is interested in new and innovative methods for detection, identification, evaluation, and monitoring of in-flight hazards to aviation. In the case of lightning, interest is centered on the mitigation and in-flight measurement of lightning damage, particularly to composite aircraft.

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. Proposed products may be for retrofit into current aircraft or for installation in future aircraft. Both manned and unmanned aircraft are of interest.

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). Additional information is available at (http://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. Approaches that use multiple sensors in combination to improve hazard detection and quantification of hazard levels are also of interest. With regard to hazardous lightning conditions, the emphasis is not on remote detection, but rather on developing systems that make aircraft more robust in a lightning environment or provide in-flight damage assessment or other hazard mitigating benefits. The design and development of composite materials and composite construction methods are not included in this subtopic. The scope of this subtopic does not include human factors and focused development of human interfaces, including displays and alerts. Primary emphasis is on airborne applications, but in some cases the development of ground-based sensor technology may be supported.

Areas of particular interest to NASA at this time are described in more detail below. The list and details are provided as encouragement but are not intended to exclude other proposals that fit the scope of this subtopic.

Lightning

- *Lightning Strike Protection* - NASA is investigating means for mitigating damage to aircraft, with a particular interest in protecting composite aircraft. Currently, an electrically-conductive screen protects composite aircraft by functioning as a Faraday shield and is intended to confine lightning and electromagnetic effects to the outside or outermost skin of the aircraft. The lightning strike protection system, hereafter referred to as the LSP, is incorporated in the coatings, layers, and structure that comprise the skin of the aircraft. NASA is most interested in LSP solutions that will be cost effective and light-weight. The design and development of composite materials and construction methods is out of scope for this subtopic.
- *Mitigation of Lightning Strike Damage* - NASA is seeking solutions that will provide better protection from lightning damage by directing attachment points or lightning currents to safe or less hazardous areas and by reducing the susceptibility of the aircraft to thermal or other damage due to strikes.
- *In-flight Lightning Damage Measurement and Assessment* - A typical commercial aircraft is struck by lightning about once per year. At this time, composite aircraft that are struck in-flight are inspected upon landing for a damage assessment. Such assessments may be time-consuming and difficult. Innovations that will provide a measurement or damage detection system in the LSP are solicited. The objective would be to achieve a capability to have damage detection and assessment in the aircraft that will provide immediate information to the flight crew after a lightning attachment.

Polarimetric Radar Technology

- *Polarimetric Antennas* - Recent investigations indicate that polarimetric capability would provide a substantial advancement in airborne weather radar. Flat plate, slot antenna (single polarity) arrays currently in use are cost-effective, light-weight, and rugged. An innovative polarimetric antenna design that meets the same criteria would be a major step toward implementation of polarimetric radar. Existing commercial aircraft dictate the antenna system requirements, and new antenna designs should be suitable for retrofit. Innovative techniques, designs, or developments that lead to polarimetric antennas that are affordable and effective and can be retrofit to existing commercial aircraft are solicited.

Turbulence and Wake Vortex

- *Remote Detection of Kinetic Air Hazards* - The class of hazards including wake vortices, turbulence, and other hazards associated with air motion is referred to as kinetic air hazards. Within this class, wakes and turbulence are the highest priorities; however, NASA is particularly interested in sensor systems that can detect multiple hazards and thus provide greater utility. For example, air data systems are at times disabled by icing, and a multi-function, multi-hazard sensor that includes a robust alternative air data source would be a great asset in such conditions.

- *Airborne Detection of Wake Vortices* - 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. In particular, NASA is interested in the ability to detect and measure wake vortex hazards for arbitrary viewing angles.
- *Airborne Detection of Turbulence* - 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.

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 research tools and 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 super-cooled liquid water clouds and flight into regions of high mass concentrations of ice crystal.

Areas of particular interest include:

- Technology to measure the phase (ice or liquid), size, and mass concentration of ice and liquid density of water particles as they are ingested into a turbofan engine core flow path and in upstream wind tunnel ducts.
- Technology to measure the mass of water that impinges on the leading edge of airframe components for droplet spectra having median volumetric diameters from 20 to 1000 microns. Past measurement methods using dye-tracers and blotter paper have demonstrated limitations, particularly for larger drop sizes. More advanced methods are sought that can improve accuracy and measurement time.
- Non-destructive 3-D ice density measurements of ice accretions on wind tunnel models. NASA has a need for non-optical methods to digitize ice shapes with rough external surfaces and internal voids as can occur with accretions on highly swept wings. Technologies proposed must be compatible with working within a wind tunnel testing environment.

A1.03 Real-Time Safety Assurance under Unanticipated and Hazardous Conditions
Lead Center: LaRC

Assuring safety of flight under uncertain, unanticipated, and multiple hazards is a core requirement for aircraft loss of control prevention and for safety-assured autonomous aircraft operations. Sources of hazards include adverse onboard conditions (e.g., system failures, vehicle impairment or damage), external disturbances (e.g., turbulence, inclement weather, wake vortices), and abnormal flight conditions (e.g., abnormal attitudes/rates, unsafe/abnormal flight trajectories, stall/departure). Research is sought that supports real-time flight safety assurance in either of the following critical areas:

- *Real-time Flight Safety Management* - Assuring flight safety requires the real-time ability to assess impacts and risks of current or impending hazards, and to enforce minimum flight safety margins. Research in this area includes:
    - Definition of flight safety and its core components.
    - Development of methodologies and algorithms for predicting impacts and risks to flight safety (or one or more key components) of uncertain, unanticipated, and multiple hazards.
    - Development of a supervisory control system that ensures a minimum margin of flight safety under uncertain, unanticipated, and multiple hazards.
    - Evaluation of flight safety prediction and supervisory control algorithms using analysis, simulation, and/or experimental testing under a variety of hazardous conditions.

- *Real-time Sensor Integrity Management* - Assuring the integrity of information required for aircraft control is a core requirement in assuring flight safety. Research in this area focuses on assuring the integrity of flight dynamics and control parameters and includes:
  - Development of a methodology to utilize all available information from diverse physical and virtual sensors in order to rapidly detect, isolate, and mitigate erroneous behavior within a sensor or sensor suite in real time.
  - Utilization of information fusion across multiple sensors (physical and virtual) and algorithmic redundancy to estimate lost information from failed sensor(s).
  - Assurance of information integrity under turbulence, noise, and abnormal and highly nonlinear flight conditions associated with aircraft loss of control.
  - Evaluation of sensor integrity management algorithms and the integrated system using analysis, simulation, and/or experimental testing under a variety of hazardous conditions.

A1.04 Prognostics and Decision Making
Lead Center: ARC

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:

- Remaining Useful Life (RUL) prediction techniques that address a set of fault modes for a device or component, for example by modeling the physics of the most critical fault modes and using (typically less accurate) data-driven methods for the remainder.
- Physics-based damage propagation models for one or more relevant aircraft subsystems such as airframe structures, avionics, electrical power systems, and electronics. Methods for damage propagation in composite structures are of a particular interest. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.
- Uncertainty quantification and management for prognostics. Proposers are encouraged to quantify prognostic uncertainty by accounting for the effects of modeling uncertainty, measurement errors, algorithmic uncertainties, as well as uncertainties stemming from estimation of future loads and environmental conditions. Methods for reducing prognostic uncertainty estimates are of particular interest. Proposals can consider the fusion of different techniques for uncertainty quantification and management but must demonstrate (using the appropriate metrics) the direct benefits of using such an approach in improving uncertainty estimates.
- Aircraft-relevant test beds that can generate aging and degradation datasets for the development and validation of prognostic techniques.
- Verification and validation methods for prognostic algorithms.

If prognostic algorithms are being developed, 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.

A1.05 Identification of Sequences of Atypical Occurrences in Massive Heterogeneous Datasets Representing the Operation of a System of Systems
Lead Center: ARC

The fulfillment of the SSAT project's goal requires the ability to transform vast amounts of data produced by 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. For this topic, we are especially interested in automated discovery of previously unknown precursors to aviation safety incidents involving human - automation interaction. We expect to gain knowledge on latent deficiencies in crew training, communication, and operations that is of paramount importance to future SSAT project goals and objectives. The incorporation of human performance will be invaluable to the success of this effort, and as such it will be important to use heterogeneous data from varied sources that are matched on a per-flight basis with flight-recorded data, such as radar track data, airport information, weather data, flight crew schedule information, maintenance information, and Air Safety Reports. This topic will develop revolutionary and first-of-a-kind methods and tools that incorporate the limitations of human performance throughout the design lifecycle of human-automation systems to increase safety and reduce validation costs in NextGen.

The focus of this effort will be from the aircraft-level to fleet level and above. As such, the successful proposal will develop validated predictive analytics to uncover systemic human-automation interaction issues that manifest at a much broader level than those incidents that occur within a single flight or for a single aircraft. Real data from a defunct airline will be made available as GFE (government furnished equipment), representing the interactions between humans and automation found on flight systems, data from aircraft as well as supporting ground-based systems. As such, a deep knowledge of algorithmic development across multiple heterogeneous data sources and the ability to address recent developments in the growing area of "big data" should be clearly demonstrated. The successful proposer will have a proven track record of deploying groundbreaking, innovative approaches in a real-world setting to similar "big data" challenges.

TOPIC: A2 Unmanned Aircraft Systems

The Integrated Systems Research Program (ISRP) conducts research at an integrated system-level on promising concepts and technologies and explores, assesses and/or demonstrates 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 Aeronautics Research Mission Directorate’s other research programs, as well as efforts within other Federal Government agencies. As the NextGen air transportation system 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 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 existing projects – the Environmentally Responsible Aviation (ERA) Project and the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project, and one new project starting in Fiscal year 2014, the Advanced Composites Project. The UAS Integration in the NAS Project, specifically, seeks to reduce or eliminate critical technical barriers of integrating UAS in to the national Airspace system through integrated system-level testing in relevant environments. At present, the project has four main focuses:

- *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.

A2.01 Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Research
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 the Integrated Systems Research Program (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. The UAS Integration in the NAS Project is structured under the following technical challenges:

- *Airspace Integration* - Validate technologies and procedures for UAS to remain an appropriate distance from other aircraft, and to safely and routinely interoperate with NAS and NextGen Air Traffic Services (ATS).
- *Standards/Regulations* - Validate minimum system and operational performance standards and certification requirements and procedures for UAS to safely operate in the NAS.
- *Relevant Test Environment* - Develop an adaptable, scalable, and schedulable relevant test environment for validating concepts and technologies for UAS to safely operate in the NAS. The Federal Aviation Administration (FAA) regulations are built upon the condition of a pilot being in an 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 provide research findings to reduce technical barriers associated with integrating UAS into the NAS utilizing integrated system level tests in a relevant environment. The project is currently broken down into five subprojects:

- Separation Assurance/Sense and Avoid Interoperability (SSI)
- Communications
- Human Systems Integration
- Certification
- Integrated Test and Evaluation

The fifth subproject, Integrated Test and Evaluation, is responsible for developing a live, virtual, and constructive test environment for the other four subprojects. During the first phase, (May-2011 to September-2013) the project has:

- Conducted initial modeling, simulation, and flight testing.
- Completed early subproject-focused deliverables (spectrum requirements, comparative analysis of certification methodologies, etc.).
- Validated the key technical elements identified by the project.

The plan for the second phase includes the following:

- Conduct systems-level, integrated testing of concepts and/or capabilities that address barriers to routine access to the NAS.
- Develop a body of evidence (including validated data, algorithms, analysis, and recommendations) to support key decision makers in establishing policy, procedures, standards and regulations, enabling routine UAS access in the NAS.

This solicitation seeks proposals, but is not limited, to develop concepts that can reduce the technical barriers related to the safety and operational challenges of routine UAS operations in the NAS.

- *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 High power C-band amplifiers and highly linear C-band power amplifiers/linearization of high power C-band amplifiers.
  - Miniaturization of C-band terrestrial radio components/systems and C- Ku- and Ka-Band satellite communications components/systems.
  - Conformal steerable antennas for satellite communications links in C-, Ku- and Ka Band.

- *Weather Information Systems for GCS* - On-board, real-time graphic aviation weather information products have been developed and successfully implemented for manned cockpits. Their use is now widespread and their safety impact widely recognized. The applicability of such products for operators and ground control pilots to enhance situation awareness and improve mission planning and execution is of interest to NASA. Systems such as the NASA developed Aviation Weather Information (AWIN) system that included software, data and data-link applications, color weather graphics such as composite-radar mosaic, lightning-strike data, wind data, satellite images and forecasts could be integrated into a ground control station to provide pilots with weather awareness before and during mission execution. Improved weather awareness should allow aircrews to avoid most weather-related problems through both pre-flight and en-route planning. While the use of these systems has been explored for military UAS operations, their applicability to civil and public operations has not yet been explored.
- *Safety Analysis and Methodologies* - UAS operations are untried in the civil NAS. Unlike other aircraft, there is not an extensive record of civil operations upon which to forecast the safety of UAS operations in the NAS. The introduction of UAS into the NAS raises many safety issues and concerns. Typically, anytime a new capability is added into the NAS, an Operational Safety Assessment (OSA) is performed by the FAA, to determine whether that introduction of new capability will enhance or detract from the safety of the NAS. As these UAS represent a wholly new operational system, traditional approaches cannot suffice. Research is needed to identify and develop new safety analysis approaches, as well as prognostic indicators and potential new safety metrics.
- *Autonomous Operations* - As vehicle capabilities and machine intelligence continue to evolve, it is expected that future air vehicles, especially unmanned vehicles, will assume an increasing level of independent decision-making, flight monitoring and management, and trajectory management. As the Next-Generation Air Traffic Management System (NextGen) continues to evolve and expand, the future system will need to concurrently develop operational accommodations for these aircraft that manifest increasing levels of autonomy. Thus, autonomous vehicles and NextGen must evolve in complementary ways to accommodate these future operational considerations. At a minimum, future autonomous systems must demonstrate successfully the following characteristics:
  - Collision/hazard avoidance.
  - Autonomous navigation under uncertain conditions.
  - Cooperative task completion (if more than one aircraft is needed for a particular operation).
  - Recognition of anomalies.
  - Long term system diagnostics, failure prediction and correction.
- *Development of a UAS Flight Inspection and Cargo Aircraft Capability Concept* - Currently the FAA conducts flight inspections of the ground based air navigational aids and guidance systems (MLS, TACAN, VASI) in Antarctica using a CL-601 Challenger corporate executive jet type of aircraft, not certified for operations from ice and gravel runways. The risk for damage to these costly aircraft is high and no flights are made to remote areas, like Antarctica, without the inclusion of maintenance personnel among the crew. A UAS, RPV equipped for flight inspection work in Antarctica and other remote areas utilizing a simple rugged STOL type of vehicle, ski or wheel equipped, (thus capable of operating from rough snow, ice and short gravel runways) would greatly reduce the risks and costs of flight inspecting and light air logistics in Antarctica. The environment in Antarctica is a perfect venue to demonstrate an efficient, practical and environmental friendly use of unmanned aircraft technologies to a worldwide audience. Basic requirements for a drone utilized in this type of operation include:
  - Ability to carry a 1000-pound payload 800 nautical miles and return with no need for additional fuel.
  - Be TCAS responsive and “visible” to other traffic.

- o Be equipped with bubble observation windows and mounts for various surveillance and photography systems.
- o Have the capability to operate from the short gravel runways.

TOPIC: A3 Air Vehicle Technology

The Air Vehicle Technology topic solicits cutting-edge research in aeronautics to overcome technology barriers and challenges in developing highly efficient aircraft systems of the future, with reduced impact to the environment. The primary objective is the development of innovative design tools, capabilities and technologies that provide design and system solutions and capabilities to meet the national goals in cleaner environment, reduced noise and highly energy efficient and revolutionary aircraft for the next generation (NextGen) air transportation system.

This topic solicits tools, technologies, and concepts to enable revolutionary air vehicles of the future as well as having near-term application. Innovative ideas are sought in general areas of airframe structural efficiency, quiet performance, low emissions/clean power, aerodynamic efficiency, propulsion efficiency, rotorcraft, and physics-based conceptual design tools. Each of these general subtopic areas has a more specific focus that is detailed in the subtopic descriptions to follow. The research will contribute to enabling the best design solutions and technology innovations to meet performance and environmental requirements and challenges of future air vehicles that will operate in the NextGen air transportation system.

Beginning in FY14, this topic covers aircraft technologies covered by the Fundamental Aeronautics Program. This topic will emphasize development of tools, technologies, and knowledge to meet metrics derived from a definitive set of Technical Challenges responsive to the goals of the National Aeronautics Research and Development Plan (2010) and the NASA Strategic Plan (2011).

- *Fixed Wing Vehicles* - Technologies and concepts for subsonic transport aircraft, propulsion system energy efficiency and environmental compatibility supported by enabling tools and methods. Targeted challenges include drag and weight reduction for fuselages and high aspect ratio wings, quiet high performance high-lift and propulsion systems, high performance clean, alternative-fuel burning gas generators, paradigm-changing hybrid-electric propulsion systems, innovative propulsion-airframe integration concepts.
- *Rotary Wing Vehicles* - Advanced Efficient Propulsion (multi-speed lightweight rotorcraft drive trains and variable speed efficient engines), Advanced Concepts and Configurations (aerodynamically efficient rotorcraft, NextGen configurations, and multi-fidelity design and analysis tools), and Community and Passenger Acceptance (NextGen operations and standards, and comfort and safety).
- *High Speed* - Focused on supersonic research, design, and boom mitigation techniques to achieve low boom strength and other elements that will help enable a low-boom experimental aircraft; System Integration Assessment.
- *Supersonic Cruise Efficiency* - Propulsion; Supersonic Cruise Efficiency-Airframe; Sonic Boom Modeling; and Jet Noise Research.
- *Aeronautical Sciences* - Broad, cross-cutting discipline research (e.g., some CFD and structures & materials research) that is pervasive across flight regimes, helps develop some low-level concepts and ideas, and provides program-level systems analysis capability to assess balance and impact of program-wide investments.

A3.01 Structural Efficiency-Aeroservoelasticity
Lead Center: LaRC
Participating Center(s): DFRC

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. The Fundamental Aeronautics Program's work on Structural Efficiency for the FY 2014 NASA SBIR solicitation is focused on aeroservoelasticity active structural control for lightweight flexible structures, specifically related to load redistribution, flutter prediction and suppression, and gust load prediction and alleviation. Of interest are:

- Aeroservoelastic analyses at the appropriate level of fidelity for the problem at hand.
- Aeroservoelastic experiments to validate methodologies and to gain valuable insights available only through testing.
- Development of computational-aeroservoelastic analysis tools that advance the state of the art in aeroelasticity through novel and creative application of aeroelastic knowledge.

Specific subjects to be considered include:

- Development of design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of efficient methods to generate mathematical models of wind-tunnel models and flight vehicles for performing aeroservoelastic studies. Example: CFD-based methods (reduced-order models) for aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, flight dynamics stability and control issues, and flutter.
- 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 aeroservoelastic phenomena.

A3.02 Quiet Performance
Lead Center: GRC
Participating Center(s): LaRC

To reduce noise emissions from aircraft, tools and technologies are needed to design aircraft that are both efficient and low-noise. In support of several Aeronautics Research Mission Directorate projects, developments/ improvements in noise reduction technology, noise prediction tools, and flow & noise diagnostic methods are needed for subsonic and supersonic aircraft. In this call, innovations with an emphasis on aircraft propulsion are solicited in the following areas:

Noise Reduction

- Advanced liners including broadband liners (i.e., liners capable of appreciable sound absorption over at least two octaves), and low-frequency liners (i.e., liners with optimum absorption frequencies half of the current ones but without increasing the liner depth).
- Low-noise propulsor concepts that is quieter than current generation fans and open rotors.
- Concepts for active control of propulsion broadband noise sources including fan, open rotor, jet, compressor, combustor, and turbine.
- Adaptive flow and noise control technologies including smart structures for inlets, nozzles, and low-drag liners.
- Concepts to mitigate the effects of distorted inflow on fan noise.

Noise Prediction

- High-fidelity fan and turbine noise prediction models including Large Eddy Simulation of broadband noise, 3-D fan and turbine acoustic transmission models for tone and/or broadband noise.
- Accurate models for prediction of installed noise for jet surface interaction, fan inlet distortion, and open rotors.

Noise Diagnostics

- Tools/Techniques for quantitative characterization of fan in-duct broadband noise in terms of its spatial and temporal content.
- Phased array and acoustic holography techniques to measure source noise in low signal-to-noise ratio wind tunnel environments.
- Characterization of fundamental jet noise sources and structures.
- Innovative measurement of radiated acoustic fields from aeroacoustics sources.

A3.03 Low Emissions/Clean Power
Lead Center: GRC
Participating Center(s): LaRC

Achieving low emissions and finding new pathways to cleaner power are critical for the development of future air vehicles. Vehicles for subsonic and supersonic flight regimes will be required to operate on a variety of certified aircraft fuels and emit extremely low amounts of gaseous and particulate emissions to satisfy increasingly stringent emissions regulations. Future vehicles will be more fuel-efficient which will result in smaller engine cores operating at higher pressures. Fundamental combustion research coupled with associated physics based model development of combustion processes will provide the foundation for technology development critical for these vehicles. Combustion involves multi-phase, multi-component fuel, turbulent, unsteady, 3-D, 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. Low emissions combustion concepts require very rapid mixing of the fuel and air with a minimum pressure loss to achieve complete combustion in the smallest volume. Areas of specific interest where research is solicited include:

- Development of laser-based diagnostics for quantitative spatially and temporally resolved measurements of fuel/air ratio in reacting flows at elevated pressure.
- Development of ultra-sensitive instruments for determining the size-dependent mass of combustion generated particle emissions.
- Low emissions combustor concepts for small high pressure engine cores.
- Chemical kinetics mechanisms with approximately 20 species for Jet-A fuel suitable for use with 3-D Combustion CFD Codes.

A3.04 Aerodynamic Efficiency
Lead Center: ARC
Participating Center(s): DFRC, LaRC

NASA is conducting fundamental aeronautics research to develop innovative ideas that can lead to next generation aircraft design concepts with improved aerodynamic efficiency. Innovative vehicle concepts are being studied with emphasis on MDAO methods that can simultaneously address complex interactions among aerodynamics, aeroelasticity, propulsion, dynamics, and controls. Modern aircraft development is a tightly coupled multi-disciplinary process designed to achieve as much efficiency as possible. There is an increasing interest in flight control technologies that can improve aerodynamic efficiency. Concepts such as performance adaptive aeroelastic wing shape control for drag reduction and circulation control for lift augmentation are potential aviation technologies that can contribute to the goal of aerodynamic efficiency. To realize the full potential of these technologies, tight coupling with vehicle dynamics and control should be emphasized. The vehicle-centric flight control perspective will enable an integrated approach that ensures complex vehicle interactions with new technologies are addressed. Areas of interest are performance adaptive aeroelastic wing shape control concepts that can:

- Tailor the spanwise lift distribution for optimal L/D throughout the flight envelope.
- Enable high-aspect ratio wing design with relaxed stiffness to reduce weight and drag penalties of non-lifting structures.
- Improve aerodynamic performance by enabling more efficient designs.

Specific subjects to be considered include but are not limited to:

- Novel control systems that can potentially reduce size, weight, and drag relative to the existing state-of-the-art, including concepts that can improve aerodynamic performance by exploring design options with relaxed static stability.
- Control laws and associated architectures that blend wing shape control for optimal L/D with performance, command tracking, and suitable handling and ride quality in all flight phases, taking into account aeroelasticity and flow physics as necessary.
- Measurement and instrumentation required to enable the control laws and architectures.
- Measurement, instrumentation, and/or estimation techniques for real-time identification of vehicle drag or L/D.
- Techniques to ensure robustness relative to measurement, estimation, and control uncertainty.

A3.05 Physics-Based Conceptual Design Tools
Lead Center: LaRC
Participating Center(s): GRC

NASA continues to investigate the potential of advanced, innovative propulsion and aircraft concepts to improve fuel efficiency and reduce the environmental footprint of future generations of commercial transports across the subsonic and supersonic flight regimes. Conceptual design and analysis of unconventional vehicle concepts and technologies is used for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts. The agency's systems analysts need to have the best conceptual design/analysis tools possible to support these efforts. Substantial progress has been recently made in incorporating more physics-based analysis tools in the conceptual design process and NASA has developed a capability that integrates several analysis tools and models in engineering frameworks, such as ModelCenter and OpenMDAO. The current focus is instead on filling remaining capability gaps in specific design disciplines. As such, the purpose of this subtopic is to solicit proposals for innovative solutions which address the problem of rapidly obtaining reasonably accurate airframe weight and center of gravity estimates during the conceptual design of unconventional configurations.

Historically, empirical and semi-empirical weight estimation methods have been utilized during the conceptual design phase. These methods work well for the conceptual design of conventional vehicles with parameters that reside within the historical databases used to develop the methodologies. These methods are not well suited, however, for unconventional vehicle concepts, or even conventional concepts which reside outside of the database (for example, very high aspect ratio swept wings). Developing higher order, more accurate tools suitable for conceptual design is a difficult challenge. The first issue is analysis turnaround time. To perform the configuration trades and optimization typical of conceptual design, runtimes measured in seconds or minutes, instead of hours or days, are required. However, rapid analysis turnaround time alone is insufficient. To be suitable for conceptual design, tools and methods are needed which accurately predict the "as-built" characteristics. Because it is not possible to model every detail of the design and account for all the underlying physics in the problem formulation, it is difficult to predict the "as-built" characteristics with physics-based methods alone. What is usually required is a combination of these methods with some semi-empirical corrections. A final challenge in conceptual design is a lack of detailed design information. Lower order, empirical-based methods often require only gross design parameters as inputs. High-order, physics-based methods currently require detailed design knowledge to be useful. For example, whereas semi-empirical weight prediction tools provide estimates for wing weight without needing a structural layout, such detail is necessary to successfully utilize finite-element analysis tools. This gap between the analysis capability and the maturity of the design being analyzed currently limits the usefulness of high order analysis in conceptual design. Physics-based tools for conceptual design are needed which are consistent with the amount of design knowledge that is available at the conceptual design stage.

Specifically for FY 2014, desired capabilities include the following:

- New weight estimation relationships valid for wing and/or fuselage geometries outside of current historical databases.
- Increased fidelity loads generation.
- Engineering based weight estimation techniques for systems, equipment, and operational items.

A3.06 Rotorcraft
Lead Center: ARC
Participating Center(s): GRC, LaRC

The challenge of the Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles. Technologies of particular interest are as follows:

- The use of small vertical lift UAVs has increased in recent times with many civilian applications missions being proposed, including autonomous surveillance, mapping, etc. Much of the current research associated with these vehicles has been in the areas of electric propulsion, batteries, small sensors and autonomous control laws, while very little attention has been paid to their acoustic characteristics. The generation and propagation of noise associated with this small class of vertical lift UAVs are not well understood and prediction tools have not been developed or validated for this class of vehicles. The objective of a proposed effort is to develop design and analysis tools for the prediction of acoustics for small vertical lift UAVs, such as quad-copters, coaxial rotor UAVs, ducted fan rotors, etc. Proposals are also sought that include measurement and characterization of noise associated with this class of small vertical lift UAVs.
- A transition to low-carbon propulsion has the promise of dramatically reducing the emissions from full-scale rotorcraft, as well as reducing overall fuel consumption and operating cost. All-electric and hybrid electric propulsion systems could be beneficial to rotorcraft due to high power requirements of hover and integrated motor-drive systems designs that could be realized. The objective of a proposed effort is to investigate, develop and/or demonstrate all-electric and hybrid electric architectures specific to full-scale rotorcraft drive and propulsion system applications. Validated modeling and analysis tools for all-electric and hybrid electric propulsions systems are also sought in this solicitation, as are system studies of various hybrid/electric architectures to show their relative benefits in-terms of weight, efficiency, emissions and fuel consumption for full-scale rotorcraft applications.

Proposals on other rotorcraft technologies will also be considered but the primary emphasis of the solicitation will be on the above two identified technical areas.

A3.07 Propulsion Efficiency - Propulsion Materials and Structures
Lead Center: GRC
Participating Center(s): DFRC

Research and development of both materials and structures is essential to the NASA Aeronautics Programs, Fundamental Aeronautics and Aviation Safety, contributing to their ability to achieve their long-term goals in developing advanced propulsion systems. Responding to this call will require a proposal describing the intent to conduct novel research in materials and structures linked to enhancing aircraft propulsion efficiency. Reductions in vehicle weight, fuel consumption and increased component durability/life will increase propulsion efficiency. The extreme temperature and environmental stability requirements of advanced aircraft propulsion systems demand development of new, reliable, higher performance materials. Research in the areas of high-temperature metals, alloys, ceramics, polymers and their composites provides the fundamental understanding of the underlying process-structure-property relationships of these materials. Study of material systems interactions with harsh environmental conditions and their modes of failure are of particular importance to developing more advanced materials for future aircraft propulsion systems, which will be operating at higher temperatures than todays turbine engines. Heat transport, diffusion, oxidation and corrosion, deformation, creep, fatigue and fracture are among the complex phenomena that can occur in the component materials in the extreme environment of turbine engines propulsion systems. Many of the significant advances in aircraft propulsion have been enabled by improved materials and materials manufacturing processes. Additional advances in the performance and efficiency of jet propulsion systems will be strongly dependent on the development of lighter, more durable high-temperature materials.

The specific topics of interest include:

- Advanced High Temperature Materials Technologies Including Fundamental Materials Development, Processing and Characterization. Innovative approaches to enhance the durability, processability,

performance and reliability of advanced materials including advanced blade and disk alloys, ceramics and CMCs, polymers and PMCs, nanostructured materials, hybrid materials and coatings to improve environmental durability. In particular, proposals are sought in:
    - Disk materials and concepts such as innovative joining methodologies for bonding powder metallurgy disk material to directionally solidified/single crystal rim alloy.
    - Corrosion/oxidation resistant coatings for turbine disk materials operating at temperatures in excess of 1400 °F.
    - High strength fibers for ceramic matrix composites and environmental barrier coatings to enable a CMC temperature capability greater than 2700 °F.
    - Innovative methods for the evaluation of advanced materials and structural concepts under simulated operating conditions, including combinations of thermal loads, mechanical loads during environmental (application) exposure.
    - Innovative processing methods that enhance high temperature material and coating properties and reliability.
    - Development and evaluation of shape memory alloys for applications across the lower temperature range of the subsonic aircraft flight path, i.e., experiencing shape changing phase transitions between 0° to -50 °C.
    - Using the unique properties of nanomaterials to tailoring composite properties using nanocomposites, nano-engineered, thermally-conductive composites and micro-engineered porous structures with metals, polymer and ceramic composites.
- Advanced Structural Concepts. New concepts for propulsion components incorporating new lightweight concepts as well as smart structural concepts to reduce mass and improve durability.
- 3-D additive fabrication of complex structures/subelements demonstrating mechanical properties and environmental durability for propulsion system applications.
- Multifunctional materials and structural concepts for gas turbine engine structures, such as novel approaches to power harvesting, thermal management, self-sensing, and materials for actuation.
- Fabrication of unique structures (such as lattice block) using shape memory alloys for lightweight multifunctional/adaptive structures for engine component applications.
- Innovative approaches for use of shape memory alloys for actuation of components in gas turbine engines.
- Computational Materials and Multiscale Modeling Tools. Including methods to predict properties, and/or durability of propulsion materials based upon chemistry and processing for conventional as well as functionally-graded, nanostructured, multifunctional and adaptive materials. And 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 tools. In particular proposals are sought in:
    - Development of physics-based models of the various failure mechanisms of the EBC, particularly those associated with environmental degradation (e.g., oxidation, diffusion, cracking, crack + oxygen interaction, creep, etc.).
    - Multiscale design tools for aircraft engine structures that integrate novel materials, mechanism design, and structural subcomponent design into systems level designs.
    - Use of multiscale modeling tools to design multifunctional and adaptive structures.
    - Robust and efficient methods/tools to design advanced high temperature materials based on first principles and microstructural models that can be used in a multi-scale framework.
    - Development of models to predict degradation of CMCs due to combined effect of environment and mechanical loading at high temperatures.

TOPIC: A4 Ground and Flight Test Techniques and Measurement

The Aeronautics Test Program (ATP) supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate from takeoff speeds through Mach 10. It ensures the long-term availability and health of NASA's major wind tunnels/ground test facilities and flight operations/test infrastructure, providing support for 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 is divided into the Flight Test and the Ground Test Projects with facilities are located at four NASA Centers, including the Ames Research Center, Dryden Flight Research Center, Glenn Research Center and Langley Research Center. Classes of facilities 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. This year the primary emphasis is on ground testing requirements. 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 is available at (http://www.aeronautics.nasa.gov/atp/index.html).

A4.01 Ground Test Techniques and Measurement Technologies
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

The Ground and Flight Test Techniques and Measurements topic supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate from takeoff speeds to Mach 10, as well as the testing requirements of other government and commercial entities. The primary objective is to develop innovative tools and technologies that enhance measurement capabilities, improve ground and flight resource utilization, and provide capability sustainment. This year the primary emphasis is on ground testing requirements.

Wind tunnel vehicle design databases have traditionally included the foundational measurements of forces, discrete surface pressures, and discrete surface temperatures. However, designing and testing future vehicles with highly integrated and possibly distributed propulsion and flow control systems will require enhanced, remotely sensed global surface measurements to accurately define the vehicle performance and acoustic levels covering a wide range of operational conditions. Enhanced optical systems are required to visualize the flow interactions both on and off the surface. Non-intrusive measurement systems offering multi-component velocities, density, and pressure in the tunnel stream are required to routinely quantify and baseline the test environment and to establish boundary conditions for advanced computational simulations. Non-intrusive measurements of off-body and near-body flow parameters both at a point and globally (i.e., planar or volumetric) are necessary to examine fluid-fluid and fluid-structure interactions for computational solution validation. In all cases, significant measurement accuracy enhancements are required to achieve the revolutionary aircraft systems of the future. Measurement systems must be robust and user-friendly to achieve the level of utility required for practical and routine application. Clean seeding methods that do not contaminate anti-turbulence screens are required in the wind tunnel testing environment; seedless methods for velocity measurements are particularly desired. Compact measurement systems and analysis techniques with dual use capability in both ground and flight test environments are valuable, enabling smooth transition between each. Since wind tunnel test data must ultimately represent free-air conditions, techniques and/or analysis methods that can demonstrate and articulate novel ground to flight extrapolation methodologies are sought. In all cases, measurement methods that can significantly increase data capture per test point are desired, including the simultaneous measurement of multiple flow parameters. Accordingly, the topic solicits cutting-edge enhancements that significantly improve existing test and measurement capabilities, and enabling tools that provide new opportunities for aerodynamic and aerothermodynamic discovery for NextGen and high-speed transportation systems.

The contraction of the Nation's ground-based testing resources emphasizes the technological need to improve wind tunnel utilization. Advanced methods that aid pre-test planning, improve data collection, enhance visual display in a data rich environment, and provide rapid analysis are solicited.

With an aging and reduced workforce comes the challenge of capability sustainment. Tools and technologies are solicited that enable knowledge capture, offer ubiquitous training, and provide workforce agility.

9.1.2 HUMAN EXPLORATION AND OPERATIONS

The Human Exploration and Operations Mission Directorate (HEOMD) is chartered with the development of the core transportation elements, key systems, and enabling technologies required for beyond-Low Earth Orbit (LEO) human exploration that will provide the foundation for the next half-century of American leadership in space exploration. This new deep space exploration era starts with increasingly challenging test missions in cis-lunar space, including flights to the Lagrange points, followed by human missions to near-Earth asteroids (NEAs), Earth's moon, the moons of Mars, and Mars itself as part of a sustained journey of exploration in the inner solar system. HEOMD was formed in 2011 by combining the Space Operations Mission Directorate (SOMD) and the Exploration Systems Mission Directorate (ESMD) to optimize the elements, systems, and technologies of the precursor Directorates to the maximum extent possible. HEOMD accomplishes its mission through the following goals:

- Development and use of launch systems and in-space transport capabilities permitting exploration of various regions of space.
- Development of space habitats that permit the processing and operation of physical and life science experiments in the space environment.
- Development of means to return data and explorers to Earth from these in-space operations.

HEOMD encapsulates several key technology areas, including Space Transportation, Space Communications and Navigation, Human Research and Health Maintenance, Radiation Protection, Life Support and Habitation, High Efficiency Space Power Systems, and Ground Processing/ISS Utilization. These areas of focus, along with enabling technologies and capabilities, will continue to evolve synergistically as the directorate guides their development and enhancement to meet future needs. In addition, operational capacity will continue to grow by including these enhancements as other NASA programs develop new mission capabilities and requirements. To generate new capabilities and contribute to the knowledge required for humans to explore in-space destinations, HEOMD is responsible for:

- 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 Operations and research to prepare for long-duration missions in deep space.
- Enabling U.S. commercial human spaceflight capabilities.
- Developing communication and navigation technologies.
- Maximizing ISS utilization.

HEOMD looks forward to incorporating SBIR-developed technologies into current and future systems to contribute to the expansion of humanity across the solar system while providing continued cost effective space access and operations for its customers, with a high standard of safety, reliability, and affordability.

(http://www.nasa.gov/directorates/heo/home/index.html)

TOPIC: H1 In-Situ Resource Utilization

The purpose of In-Situ Resource Utilization (ISRU) is to harness and utilize resources (both natural and discarded material) at the site of exploration to create products and services which can enable new approaches for exploration 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 provide significant benefits for sustained human activities beyond Earth very early in exploration architectures. Since ISRU can be performed wherever resources may exist, ISRU systems will need to operate in a variety of environments and gravities and need to consider a wide variety of potential resource physical and mineral characteristics. 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, atmosphere, 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 gas, water, and Mars atmosphere processing.

H1.01 In-Situ Resource Utilization - Mars Atmosphere/Gas Chemical Processing
Lead Center: JSC
Participating Center(s): ARC, GRC, JPL, KSC, MSFC

In-Situ Resource Utilization (ISRU) involves collecting and converting local resources into products that can reduce mission mass, cost, and/or risk of human exploration. ISRU products that provide significant mission benefits with minimal infrastructure required are propellants, fuel cell reactants, and life support consumable. Innovative technologies and approaches are sought related to ISRU processes associated with collecting, separating, pressurizing, and processing gases collected from in-situ resources including the Mars atmosphere, trash processing, and volatiles released from in-situ soil/regolith resources, into oxygen, methane, and water. State of the art (SOA) technologies for these ISRU processes either do not exist or are too complex, heavy, inefficient, or consume too much power. The innovative technologies and process sought must operate in low and micro-gravity environments, must be scalable from low demonstration processing and production flow rates of 0.045 kg/hr of carbon dioxide (CO_2) and 0.015 kg/hr of oxygen (O_2) to utilization flow rates of 2.25 kg/hr for CO_2 and 0.75 kg/hr for O_2. Chemical processing technologies must operate between 15 to 75 psia.

Technologies of specific interest include:

- Regenerative dust filtration, especially Mars dust, that is: scalable, has minimum pressure drop, can operate at low inlet pressures, and provides 99% @ 0.3 um collection efficiency, with >95% regeneration capability for multiple cleaning cycles. SOA filters are replaced by the crew or sized for the complete mission. Since Mars ISRU operations will occur without a crew present and between 100 and 480 days in duration, cleaning and regeneration of filtration approaches is required.
- Dust/particle measurement device that allows for size and particle density measurements before and after filtration. Optional additional capabilities including electrostatic and or mineral characterization are also of interest. Dust measurement devices must integrate into limited volume areas and interface with atmosphere-inlets/trash processing outlet tubing.
- Lightweight, low-power device to deliver fresh Mars 'air' (0.1 psia) to the plant with small head pressure capability (10's torr). SOA blowers currently do not exist which can effectively move the low pressure Mars atmosphere efficiently (power and mass) for long-periods of time. Thermal management and/or use must be clearly defined for proposed devices.
- Lightweight, lower power device to collect and pressurize CO_2 from 0.1 psia to >15 psia; maximum 75 psia. SOA mechanical compressors are heavy, power intensive, and have limited life. Mars atmosphere CO_2 collection devices will need to operate for a minimum of 100 days and up to 480 days. Thermal management and/or use must be clearly defined for proposed devices.
- High throughput water separation from gas streams. SOA devices utilize water tanks and chillers which are potentially large, heavy, and power intensive. Highly efficient, low power, and compact membrane and adsorption based separation devices allowing for very low dew point exhaust are sought.

- High throughput carbon monoxide/carbon dioxide separation and recycling concepts for processes with only partial conversion of CO_2 into usable products. Highly efficient, low power, and compact membrane and adsorption based separation devices are sought with minimum pressure drop.
- Highly efficient chemical reactors and heat exchangers based on modular/stackable microchannel plate architectures. SOA catalyst bed type reactors are inefficient in mass and volume and are not easily scalable to higher processing rates without reactor bed redesigns and thermal management changes. Thermal management and/or use must be clearly defined for proposed devices.

Proposals must identify and provide clear benefits compared to state of the art technologies and processes in the areas of mass, volume, and/or power reduction as well as define the expected impact of changing gravity orientation and strength. SOA for most processing technologies are terrestrial applications or space life support systems. Phase I proposals for innovative technologies and processes must include the design and test of critical attributes or high risk areas associated with the proposed technology or process. Phase II proposals must further Phase I efforts leading to the design, build, test, and delivery of hardware (at rates specified above) that can be integrated into breadboard ISRU systems for testing with other technologies and processes (Technology Readiness Level 4 to 6).

TOPIC: H2 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. Human Exploration requires advances in operations, testing, and propulsion for transport to the earth orbit, the moon, Mars, and beyond. NASA is interested in making space transportation 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. 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 vehicles. 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 acquisition, reusability, reliability, and operability of space transportation systems.

H2.01 High Power Electric Propulsion
Lead Center: GRC
Participating Center(s): JPL, MSFC

The goal of this subtopic is to develop innovative technologies that can lead to high-power (>50 kW to MW-class) electric propulsion systems. High-power (high-thrust) electric propulsion (>50kW per thruster) 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.

Innovations and advancements leading to improvements in the end to end performance of high power electric propulsion systems are of interest. Technologies are sought that increase system efficiency; increase system and/or component life or durability; reduce system and/or component mass, complexity, or development issues; or provide other definable benefits. In general, thruster system efficiencies exceeding 60% and providing total impulse values greater than 10^7. Desired specific impulses range from a value of 2000 s for Earth-orbit transfers to over 6000 s for planetary missions.

Specific technologies of interest in addressing these challenges include:

- Electric propulsion systems and components for alternate fuels such as the use of in-situ resources, condensable or metal propellants, and alternatives to Xenon.
- Novel methods for fabricating large refractory metal parts with complex shapes, with integrated heat pipes. Particular figures of merit include low cost, rapid turnaround, and ability to incorporate internal flow passages.

- Long life cathodes for high power electrostatic or electromagnetic thrusters capable of extended operation at required temperature and current levels for appropriate mission durations.
- Innovative plasma neutralization concepts.
- Highly accurate flow controllers and fast acting valves for pulsed thruster systems High current (MA), high repetition rate (up to 1-kHz), long life (greater than 10^9 pulses) solid state switches for high power inductive pulsed plasma thrusters.
- High-temperature permanent magnets and/or electromagnets; low-voltage, high-temperature wire for electromagnets; superconducting magnets.

Note to Proposer: Subtopic S3.02 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.02.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II demonstration, and delivering a demonstration package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables - Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a demonstration. Bench or lab-level demonstrations are desirable. The technology concept at the end of Phase I should be at a TRL range of 3-4.

Phase II Deliverables - Emphasis should be placed on developing and demonstrating the technology under simulated mission conditions. The proposal shall outline a path showing how the technology could be developed into mission-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. The technology concept at the end of Phase II should be at a TRL range of 4-5.

H2.02 In-Space Chemical Propulsion
Lead Center: GRC
Participating Center(s): JSC, MSFC

This solicitation intends to examine a range of key technology options associated with non-toxic storable liquid propulsion systems for use in future exploration missions. Efficient propulsive performance and long duration storage attributes have made the use of hydrazine widespread across the aerospace community. However, hydrazine is highly corrosive and toxic, creating a need for non-toxic, high performance propellants for NASA, other government agencies, academia, and the commercial space industry.

Non-toxic engine liquid mono- and bi-propellants technologies are desired for use in lieu of the currently operational hydrazine based engine technologies. Handling and safety concerns with the current toxic chemical propellants can lead to more costly propulsion systems. The use of new non-toxic propellants has the potential to reduce the cost of access to space by lowering overall life cycle costs.

Demonstrations of a hydrazine alternative in a storable liquid mono- or bi-propellant chemical propulsion system implementation relevant to at least one of the following applications are desired: in-space reaction control propulsion, in-space primary propulsion, and launch vehicle reaction control propulsion. Non-toxic technologies could range from pump fed or pressure fed thruster systems from 1 to 1000 lbf.

Specific technologies of interest to meet proposed engine requirements include:

- Non-toxic mono- and bi-propellants 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.
- Alternate catalysts, ignition technologies to ignite advanced monopropellants.
- Advanced materials capable of withstanding hot and corrosive combustion environment of advanced mono- and bi-propellants.
- Techniques that lower the cost of manufacturing complex components such as injectors, catalysts, and combustion chambers. Examples include, but are not limited to, development and demonstration of rapid

prototype techniques for metallic parts, powder metallurgy techniques, and application of nano-technology for near net shape manufacturing.

Note to Proposer: Subtopic S3.02 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.02.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II demonstration, and delivering a demonstration package for NASA testing at the completion of the Phase II contract.

Phase I Deliverables - Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a demonstration. Bench or lab-level demonstrations are desirable. The technology concept at the end of Phase I should be at a TRL range of 3-4.

Phase II Deliverables - Emphasis should be placed on developing and demonstrating the technology under simulated mission conditions. The proposal shall outline a path showing how the technology could be developed into mission-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. The technology concept at the end of Phase II should be at a TRL range of 4-6.

H2.03 Nuclear Thermal Propulsion (NTP)
Lead Center: MSFC
Participating Center(s): GRC, JSC

This subtopic seeks to develop innovative NTP technologies supporting the needs of future space exploration.

Solid core NTP has been identified as an advanced propulsion concept which could provide the fastest trip times with fewer SLS launches than other propulsion concepts for human missions to Mars over a variety of mission years. The current NASA Strategic Space Technology Investment Plan states NTP is a high priority technology needed for future human exploration of Mars. NTP had major technical work done between 1955-1973 as part of the Rover and Nuclear Engine for Rocket Vehicle Application (NERVA) programs. A few other NTP programs followed including the Space Nuclear Thermal Propulsion (SNTP) program in the early 1990's. The NTP concept is similar to a liquid chemical propulsion system, except instead of combustion in the thrust chamber, a monopropellant is heated with a fission reactor (heat exchanger) in the thrust chamber. In addition, the engine components and surrounding structures are exposed to a radiation environment formed by the reactor during operation.

This solicitation will examine a range of modern technologies associated with NTP using solid core nuclear fission reactors. The engines are pump fed ~15,000-35,000 lbf with a specific impulse goal of 900 seconds (using hydrogen), and are used individually or in clusters for the spacecraft's primary propulsion system. The NTP can have multiple start-ups (>4) with cumulative run time >100 minutes in a single mission, which can last a few years.

Specific technologies of interest to meet the proposed requirements include:

- High temperature (> 2600K), low burn-up composite, carbide, and/or ceramic-metallic (cermet) based nuclear fuels with improved coatings and/or claddings to maximize hydrogen propellant heating and to reduce fission product gas release and particulates into the engine's hydrogen exhaust stream.
- Long life, lightweight, reliable turbopump modeling, designs and technologies including seals, bearing and fluid system components. Throttle ability is also considered. Zero net positive suction head (NPSH) hydrogen inducers have been demonstrated that can ingest 20-30% vapor by volume. The goal would be to develop inducers that can ingest 55% vapor by volume for up to 8 hours with less than 10 percent head fall off at the design point. Develop the capability to model (predict) turbopump cavitation dynamics. This includes first order rotating and alternating cavitation (1.1X 2X) and higher (6X-10X) order cavitation dynamics.
- Highly-reliable, long-life, fast-acting propellant valves with ultra-low hydrogen leakage that tolerate long duration space mission environments with reduced volume, mass, and power requirements are also desirable. Large propellant tank bottom valves can be expected to leak in the order of 1cc per minute of hydrogen measured at standard temperature and pressure (STP). For deep space missions valve leakage will need to be <.01 cc per minute at STP. Demonstrate a large tank bottom valve that can maintain a .01 cc per minute at

STP. The valve should be able to cycle 10 times and maintain that leak rate. Valve cycle time can be on the order of one minute or more.

- 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. Robonaut type inspections for prototype flight test considered.
- Concepts to cool down the reactor decay heat after shutdown to minimize the amount of open cycle propellant used in each engine shutdown. Depending on the engine run time for a single burn, cool-down time can take many hours.
- Technology needed to store the NTP propellant for multiple years in-space as liquid hydrogen with almost zero boil-off for 900 days (includes time from first launch to final trans earth injection burn). Innovations are needed in thermal control materials and design, mechanical refrigeration systems, and vehicle design.

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 (TRL 2-3). 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 component and/or breadboard validation measurements, including populated verification matrix from Phase I (TRL 4-5). Opportunities and plans should also be identified and summarized for potential commercialization.

H2.04 Nuclear Thermal Propulsion (NTP) Ground Test Technologies
Lead Center: SSC
Participating Center(s): MSFC

A nuclear rocket engine uses a nuclear reactor to heat hydrogen to very high temperatures, which expands through a nozzle to generate thrust. This topic area seeks to develop advanced technology components and system level ground test systems that support Nuclear Thermal Propulsion (NTP) technology development and certification.

Solid core NTP has been identified as an advanced propulsion concept which could provide the fastest trip times with fewer SLS launches than other propulsion concepts for human missions to Mars over a variety of mission years. The current NASA Strategic Space Technology Investment Plan states NTP is a high priority technology needed for future human exploration of Mars. The NTP concept is similar to a liquid chemical propulsion system, except instead of combustion in the thrust chamber, a monopropellant is heated with a fission reactor (heat exchanger) in the thrust chamber. In addition, the engine components and surrounding structures are exposed to a radiation environment formed by the reactor during operation. The NTP had ground testing done between 1955-1973 as part of the Rover and Nuclear Engine for Rocket Vehicle Application (NERVA) programs. The Rover/NERVA ground tested a variety of engine sizes, for a variety of burn durations and start-ups. These ground tests were mostly exhausted in the open air. Information on the NERVA program can be found at (http://history.nasa.gov/SP-4533/Plum%20Brook%20Complete.pdf).

Current regulations require exhaust filtering of any radioactive noble gases and particulates released to stay within the current environmental regulations. The NTP ground testing requires the development of robust materials, advanced instruments and monitoring systems capable of operating in extreme temperature, pressure and radiation environments. This topic area will investigate large scale engine exhaust scrubber technologies and options for integrating it to the NTP engine for ground tests. The NTP engines are pump fed ~15,000-35,000 lbf with a specific impulse goal of 900 seconds (using hydrogen). The NTP primary test requirements can have multiple start-ups (>8) with the longest single burn time ~50 minutes.

This subtopic seeks innovative technologies in the following areas to facilitate NTP ground testing:

- Advanced high-temperature and hydrogen embrittlement resistant materials for use in a hot hydrogen environment (<4400 °F).
- Efficient non-nuclear generation of high temperature, high flowrate hydrogen (<60 lb/sec).
- Devices for measurement of radiation, pressure, temperature and strain in a high temperature and radiation environment.
- Effluent scrubber technologies for efficient filtering and management of high temperature, high flow hydrogen exhausts.
- Innovative refractory materials which use nano-particle additives and/or unconventional non-cement based refractories that can withstand the extreme plume heating environments experienced during rocket propulsion testing.

Specific interests include:

- Filtering of radioactive particles and debris from exhaust stream having an efficiency rating greater than 99.9%.
- Removal of radioactive halogens, noble gases and vapor phase contaminants from a high flow exhaust stream with an efficiency rating greater than 99.5%.
- Applicable Integrated System Health Monitoring and autonomous test operations control systems.
- Modern robotics which can be used to inspect the ground test system exposed to a radiation environment.

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 (TRL 2-3). 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 component and/or breadboard validation measurements, including populated verification matrix from Phase I (TRL 4-5). Opportunities and plans should also be identified and summarized for potential commercialization.

TOPIC: H3 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 atmosphere revitalization, environmental monitoring and fire protection systems, crew accommodations, water recovery systems and thermal control. 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. 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.

H3.01 Thermal Control for Future Human Exploration Vehicles
Lead Center: JSC
Participating Center(s): GRC, GSFC, JPL, KSC, LaRC, MSFC

Future human spacecraft will require more sophisticated thermal control systems that can operate in severe environments ranging from full sun to deep space and can dissipate a wide range of heat loads. The systems must perform their function while using fewer spacecraft resources, including mass, volume and power. Advances are sought for microgravity thermal control in the following areas:

- Heat rejection systems and/or radiators that can operate at low fractions of their design heat load in the cold environments that are required for deep space missions. Systems that can maintain setpoint control and operate stably at 25% of their design heat load in a deep space (0 K) environment are sought. Innovative components, working fluids, and systems may be needed to achieve this goal.
- Lightweight non-venting phase change heat exchangers are sought to ameliorate the environmental transients that would be seen in planetary (or lunar) orbit. Heat exchangers that have minimal structural mass and good thermal performance are sought. The goal is a ratio exceeding 2/3 phase change material mass and 1/3 structural mass.
- Two-phase heat transfer components and system architectures that will allow the acquisition, transport, and rejection of waste heat loads in the range of 100 kW to 10 megawatts are sought.
- Nontoxic working fluids are needed that are compatible with aluminum components and combine low operating temperature limits (<250K) and favorable thermophysical properties - e.g., viscosity and specific heat.

Technologies are expected to be raised from TRL2 to TRL 3/4 during Phase I. Minimum deliverables at the end of Phase I are analysis/test reports, but delivery of development hardware for further testing is desirable. In addition, the necessity and usefulness of a follow-on Phase II should be demonstrated.

Technologies would be expected to be matured from TRL 3/4 to TRL 5 during a potential Phase II effort. Expected deliverables for a Phase II effort are analysis/test reports and prototypic hardware.

For more detailed relevant information: (http://www.nasa.gov/pdf/501320main_TA14-Thermal-DRAFT-Nov2010-A.pdf).

H3.02 Atmosphere Revitalization and Fire Recovery for Future Exploration Missions
Lead Center: MSFC
Participating Center(s): ARC, GRC, JSC, KSC

This topic seeks to develop targeted process technologies and equipment to advance the operability and reliability of atmosphere revitalization (AR) subsystems that enable crewed deep space exploration objectives.

Highly reliable AR subsystem equipment and process technologies, supplemented by atmosphere decontamination equipment and methods, are necessary components to crewed deep space exploration mission success. While the International Space Station (ISS) AR subsystem equipment approaches many of the functional goals necessary for deep space exploration mission success, flight operational experience has identified areas for improvement in resource recovery and rapid atmosphere decontamination capabilities. Technologies related to resource recovery include gas compression and management as well as gas separations. Rapid atmosphere decontamination capabilities are needed to remove the functional burden for recovering from a contamination event, such as a fire or chemical spill, from the primary AR subsystem equipment. Details in each functional area of interest are provided by the following:

- *Gas Compression and Management* - NASA is seeking safe, compact, quiet, long-lived, and efficient ways to compress, store, and deliver gaseous oxygen and carbon dioxide within an AR subsystem. Also, methods to store, condition, and deliver reactant gases, primarily carbon dioxide, to carbon dioxide reduction process equipment are sought. Present AR equipment aboard ISS consists of power-intensive, noisy compressors that have service lives less than 2 years. Significant acoustic treatment is necessary to achieve NC-40 criteria. Applications for deep space exploration missions include but are not limited to production of high pressure oxygen for EVA use, and compression and storage of carbon dioxide for use in carbon dioxide reduction systems. Improvements in service life, reliability, and mechanical compression for atmospheric gas recharge to pressures up to 3,600 psia, including long life and reliability, and novel methods to increase tank storage capacity at lower pressures are of particular interest.

- *Hydrogen Purification for Resource Recovery* - Resource recovery and recycling is an enabling functional area for the AR subsystems needed for long-duration missions. For this purpose, NASA is interested in a regenerative separation technology to enable maximum hydrogen recovery from a stream containing water vapor (saturated), carbon monoxide (CO), and hydrocarbons including methane, acetylene, ethane, and ethylene, among others. While a high quantity of methane in the hydrogen product stream is acceptable, and even desirable, the presence of CO, water, and other hydrocarbons is highly undesirable. Final gas composition must be >99% hydrogen with some allowable methane and the dewpoint must be less than -60 °C. System concepts must strive to minimize power, mass, and consumable requirements while maximizing efficiency, operational life, and reliability.
- *Post-Fire Cabin Atmosphere Cleanup* - A portable, self-contained fire and toxic atmosphere cleanup system is desired that can rapidly remove contaminants from a spacecraft volume, to quickly and effectively decontaminate cabin atmosphere after a fire. The capability to reduce starting concentrations by >80% within 15 minutes for a 100-m^3 volume is desired. Methods have involved either deploying a filter assembly to the commode after a fire and using the commode fan as the source of airflow or attaching a series of filters to a portable fan using an adapter kit. Both methods result in low atmospheric scrubbing flow rates and significant time for deployment as well as limited capacity and non-specific scrubbing. Russian-provided portable equipment aboard the ISS provides 65 m^3 /h flow through a replaceable cartridge. The equipment's mass is 17 kg and the power consumption is 150 W. Filter service life is 7.5 hours. The dimensions are approximately 33 cm diameter and 35 cm tall. Future equipment must provide the rapid contamination reduction within the characteristic size and performance envelope of the Russian-developed portable scrubbing device.

For each technical area, projects are sought to research and demonstrate technical feasibility during Phase I that will develop a clear technical maturation path towards Phase II hardware development and demonstration. Phase II products must include a demonstration unit suitable for testing by NASA.

Phase I Deliverables - Documentation, data, and feasibility assessment proving the proposed approach is suitable to develop the proposed product (at least TRL 3 at completion according to NPR 7123.1 TRL definition). A breadboard developmental unit is desirable.

Phase II Deliverables - Functional engineering development unit at a minimum high fidelity breadboard (brassboard fidelity preferred), defined by NPR 7120.8, and technical maturity level 4 (TRL 4 defined by NPR 7123.1) of the proposed product, along with a full report of developmental and performance results, including drawings, analyses, and models as applicable. Opportunities and plans should also be identified and summarized for potential commercialization.

H3.03 Human Accommodations and Habitation Systems for Future Exploration Missions
Lead Center: JSC
Participating Center(s): ARC, KSC, MSFC

Habitation systems that are dispersed throughout a spacecraft volume need to be investigated as a system to improve future human accommodations. Current spacecraft interiors exceed acoustic limits from a wide range of equipment; have manual inventory tracking and no capability for assistance of lost items; and require substantial crew time and wipes for cleaning common crew surfaces (hand rails and panels) and water/solids hygiene surfaces. Future spacecraft interiors will need to be reconfigurable to meet changing crew needs as a mission moves from launch, transit, and exploration-destination phases. Adaptable distributed habitation technologies are needed in the following areas.

- *Quiet Crew Cabin Environments* - Smaller future vehicles will unlikely have dedicated quiet volumes for crew rest so maintaining a quiet cabin is required. Crew cabin acoustic noise mitigation needs to control noise levels to enable improved voice communication, alarm signal to noise ratio, and reduce crew fatigue from long duration noise exposure. There is need for non-wearable active and passive noise cancellation/reduction strategies for open crew cabin environment that do not impede voice or alarms. Need for adaptive broad coverage area to accommodate changing crew cabin layout and volume.

- *Crew Item Location Capability* - Significant crew time is lost in tracking or locating items at the piece part level in space habitat environment that serves both as living quarters and laboratory. Items are sometimes misplaced or simply float away in the microgravity environment. Innovative approaches are sought for automatic location and tracking of a large number of individual crew items as they move from their original launch configuration to any area in the crew cabin. Crew items range in size from pill size, hand tools, clothing, and spare equipment and vary in material composition from non-metallic, metallic, to fluid containing. There is a need for low-power, and miniature Radio Frequency Identification (RFID) readers for dense storage and sparse tag environments. Flexible reader deployment that allows individual item autonomous logistics management tracking and precise 3-D locating are desired. Solutions providing enhanced localization utilizing the EPCglobal UHF reader-tag protocols (Class 1 Gen2 or advanced classes) are of high interest. Similar types of reader-tag communication protocols at higher frequencies that enable more accurate spatial localization are also of interest. Innovative algorithmic solutions for finding lost items, based on RFID or similar sensory information, are also of interest. All solutions must accommodate a highly reflective and complex scattering environment such as a conductive habitat cylindrical volume of ~ 3.5 m diameter ~6 m in length.
- *Crew Cabin Surfaces* - Crew activity and surface contact of fabric and solid surfaces result in generation and accumulation of particulate, moisture, organic, and salt. Surface treatments for fabrics and solid surfaces to prevent this accumulation of contaminants are needed to reduce crew time and the large number of wipes used for cleaning. Innovative low out gassing, super hydrophobic, super hydrophilic, antistatic, and antimicrobial treatments are needed for crew hygiene areas and waste collection hardware is needed. Non-mechanical fastener/non-particle generating removable physical connections are needed for repeated reconfiguring of interior volumes on longer missions. Examples of the types of temporary and reversible physical connections include crew restraints (e.g., hand rails), close out panels, and the hook-and-loop type fasteners present on most crew items.

Phase I Deliverables - Detailed analysis, proof of concept test data, material test coupons, key algorithms/ subroutines, and predicted performance comparison to industry state of the art.

Phase II Deliverables - Comparison of analysis to prototype test data in representative environment, sufficient material samples/components for independent evaluation, functional software, functional breadboard component hardware and/or system, and operations documentation.

H3.04 Development of Treatment Technologies and Process Monitoring for Water Recovery
Lead Center: JSC
Participating Center(s): ARC, KSC, JPL, MSFC

The capability to recover potable water from wastewater is critical to enable space exploration missions beyond low Earth orbit. A major focus of technology development is to increase reliability of water recovery systems, so these systems require less crew intervention and a lower risk of failure with longer operational lifetimes. With these goals in mind, two areas of interest have been identified for further focus:

- *Water Recovery Post-Processing Systems* - Technologies are needed to increase the reliability of systems for polishing of partially-treated wastewater. The current state of the art uses catalytic oxidation to remove dissolved organic carbon contaminants. Technologies that operate below 100 °C or ambient pressure are desirable. Examples of these technologies include low-temperature catalytic oxidation, photolysis, or photocatalysis.
- *Monitoring Systems for Mineral Species in Water & Wastewater* - A capability is needed to measure dissolved mineral ions in water and wastewater, including polyatomic ions (could encompass organic ions) and the alkaline, alkaline-earth and transition metals. Multi-analyte capability is needed, such as that available from ion chromatography and plasma spectroscopy. Potential applications include measurement of typical ionic species in humidity condensate, potable water, wastewater, byproducts of water treatment such as brines, and biomedical and science samples. Desirable attributes should include minimal sample preparation, minimal consumables, in situ calibration, and operation in microgravity and partial gravity.

At the completion of Phase I, the technology should be TRL 3. The expected deliverable for Phase I is a detailed report describing experimental methods and results, with a clear feasibility demonstration of critical technology components.

The equivalent system mass, including consumables, power, volume and mass, should be estimated for the technology and be included in the report. Phase II deliverables should have completed TRL 4 and be approaching TRL 5. The Phase II deliverable should include a prototype system suitable for additional testing at a NASA center as well as a detailed report of testing and development demonstrating TRL 4.

TOPIC: H4 Extra-Vehicular Activity Technology

Extra-Vehicular Activity (EVA) system technology advancements are required to enable forecasted microgravity and planetary human exploration mission scenarios and to support potential extension of the International Space Station (ISS) mission beyond 2020. Advanced EVA systems include the space suit pressure garment systems; the portable life support system (PLSS); the power, avionics and software systems including communications, controls, and informative displays; the common suit system interfaces; and airlock alternatives in varying host vehicles. More durable, longer-life and higher-reliability technologies for Lunar and Martian environment service as well as those suitable for working on and around near earth asteroids (NEAs) are needed, as are technologies that enable the range and difficulty of tasks beyond those experienced to date to encompass those anticipated for exploration, with improved comfort and productivity, less fatigue and lower injury risk. Reductions in commodity and life-limited part consumption rates and the size/weight/power of worn systems are needed. All proposed Phase I research must lead to specific Phase II experimental development that could be integrated into a functional EVA system.

H4.01 Space Suit Pressure Garment and Airlock Technologies
Lead Center: JSC

Space suit pressure garment and airlock technology advancements are needed to accomplish future human space exploration missions and support ISS operations. EVA and crew survival pressure garments are addressed in this subtopic. Exploration destinations include deep-space microgravity objectives such as near-earth asteroids and Mars moons as well as lunar and Martian surface objectives involving gravitational forces and local environments. Innovative space suit technologies that improve performance and prevent injuries, extend service life and eliminate or reduce overhead, provide better environmental protection, and reduce suit system mass are required to enable a robust and flexible exploration capability. Innovative airlock technologies that protect habitable environments and reduce operational and logistical overhead are required to integrate with deep space and surface EVA-hosting systems to enable and operationally optimize achievement of exploration objectives. Key innovations sought include, in priority order:

- Reduction of suit mass, emphasizing light-weight structural components and bearings and the use of multi-function materials to reduce environmental protection layers.
- Improved mobility for enhanced task performance that also reduces injury risk.
- Improved material durability and extended service life (time and cycles).
- Improved accommodation of crew size variations for a suit system and an individual crew member.
- Reduction of crew time for maintenance and logistical support.
- Improved protection from natural and induced environments including vacuum/atmosphere, thermal, loads and dynamics, radiation, plasma and conventional shock hazards.
- Includes thin atmosphere thermal protection.
- Elimination/reduction of dust-caused failure or degradation and intrusion/contamination of habitable volumes.
- Innovative data collection techniques to define and improve methods for the human-to-suit interface.
- Improved occupant thermal comfort management.
- Improved ability to don and doff pressurized rear-entry suits.
- Self-diagnosing and repair technologies for suit wear and damage.
- Long-duration (week or longer) suited survival concepts, including nutrition delivery and hygiene maintenance.
- Low power, consumable, overhead and light-weight airlocks.
- Suitport designs reduce the impact to the pressure garment and crewmember (on-back mass during EVA).

TOPIC: H5 Lightweight Spacecraft Materials and Structures

The SBIR topic area of Lightweight Spacecraft Materials and Structures centers on developing lightweight structures and advanced materials technologies for enabling launch vehicles and spacecraft for the Human Exploration Missions. Lightweight structures and advanced materials have been identified as a critical need since the reduction of structural mass translates directly to additional up and down mass capability in exploration missions. The technology drivers are:

- Lower mass.
- Improve efficient packaging of launch volume.
- Improve performance to reduce risk and extend life.
- Improve manufacturing and processing to reduce costs.

Applications are expected to include space exploration vehicles including launch vehicles, crewed vehicles and habitat systems, and in-space transfer vehicles. The focus areas targeted in this topic are:

- Additive Manufacturing of Lightweight Metallic Structures.
- Deployable Structures.
- Advanced Fabrication and Manufacturing of Polymer Matrix Composite (PMC) Structures.
- Hot Structures.

Metallic additive manufacturing (AM) technology builds near-net shape components one layer at a time using metal powder bed or wire fed processes and data from 3-D CAD models. This technology enables the direct fabrication of net or near-net shape components without the need for tooling and with minimal or no machining thereby reducing component lead-time, manufacturing cost, and material waste. The purpose of the Additive Manufacturing of Lightweight Metallic Structures subtopic is to invest in mid- and long-term research to establish rigorous, systematic, scalable, and repeatable verification and validation methods for additive manufacturing (AM) using the EBF3 system. Nearly all spacecraft flown to date are powered by deployable solar arrays, having up to 100 m^2 of solar cell area and 25 kW of electrical power. NASA has a vital interest in developing much larger arrays over the next 20 years. The Deployable Structures subtopic seeks innovative structures and materials technologies and capabilities for the next generation of lightweight solar arrays beyond 50 kW. The subtopic area for Polymer Matrix Composite (PMC) Materials and Manufacturing concentrates on developing lightweight structures, using advanced materials technologies and new manufacturing processes. The objective of the subtopic is to advance technology readiness levels of PMC materials and manufacturing for launch vehicles and in-space applications resulting in structures having affordable, reliable and predictable performance. The subtopic will address two areas, manufacturing of structures and highly damage-tolerant materials for use in cryogenic environments. NASA has developed hot structure technology for several hypersonic vehicles. Significant reductions in vehicle weight can be achieved with the application of hot structures, which do not require parasitic thermal protection systems (TPS). The most significant technical issue that must be addressed in hot structure design is the development of cost effective, environmentally durable and manufacturable material systems capable of operating at temperatures from 1500 °C to 3000 °C, while maintaining structural integrity. The Hot Structures subtopic seeks to develop innovative low cost, mass and structurally efficient high temperature materials for hot structures applications. The metrics and specific needs of each of these focus areas of technology development are described in the subtopic descriptions. 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.

H5.01 Additive Manufacturing of Lightweight Metallic Structures
Lead Center: LaRC
Participating Center(s): GRC, JSC, MSFC

The objective of this subtopic is to advance technology readiness levels of lightweight metals and manufacturing techniques for launch vehicles and in-space applications resulting in structures having affordable, reliable, predictable performance with reduced costs. Technologies developed under this subtopic are of interest to NASA programs such as Space Launch System (SLS), Multi-Purpose Crew Vehicle (MPCV), Orion, and commercial launch providers.

Metallic additive manufacturing (AM) technology builds near-net shape components one layer at a time using metal powder bed or wire fed processes and data from 3-D CAD models. Metallic AM technologies like Selective Laser Melting (SLM), Direct Metal Laser Sintering (DMLS), Electron Beam Freeform Fabrication (EBF3), and Laser Engineered Net Shaping (LENS) are of interest to NASA for fabrication of advanced metallic aerospace components and in-space fabrication and repair. These technologies enable the direct fabrication of net or near-net shape components without the need for tooling and with minimal or no machining thereby reducing component lead time, manufacturing cost, and material waste. Metallic AM also has the potential to enable novel product designs that could not be fabricated using conventional subtractive machining processes and extends the life of in-service parts through innovative repair methodologies. Currently, some metallic AM systems use sensors for process control but not for in-situ quality assurance (QA) or flaw detection.

The purpose of this subtopic is to invest in mid- and long-term research to establish rigorous, systematic, and scalable verification and validation methods for metallic AM. Beam tracking errors, part distortion, feedstock nozzle stand-off distance variability, excessive heat build-up in the deposit, stuck or unmelted feedstock, etc. can contribute to build deposit geometric anomalies and discontinuities. The objective would be to achieve a capability to have in-situ assessment during the deposition process to provide immediate feedback to the operator or a closed loop control system to enable real-time process correction or remedial actions to correct for defects. Although the technologies developed may be specific to one metallic AM system, it is desired that they have cross cutting capabilities to other metallic AM technologies. Proposals are invited that:

- Explore new and improved sensors and sensor systems for monitoring of the metallic AM build deposit.
- Offer technologies to use the signals generated by the energy beam (either electron beam or laser) or beam / substrate emissions for in-situ process monitoring and quality assurance.
- Propose additional devices to support real-time geometric part inspection and identification of flaws (voids, cracks, lack of fusion defects or other discontinuities).

Technologies should enable determination of the boundaries of the molten pool within 0.001" (in order to define the size and shape), measurement of temperature over the range from 700 °F to 3000 °F (representative of the molten pool and surrounding regions) to within 25 °F, measurement of geometric features to within +0.005", detect flaws in the range of 0.010 - 0.001", and determine chemical composition within 1 weight percent. Technologies should be compatible with standard high speed computer communication protocols and sensors should be able to update at frequencies on the order of 10 Hz. Highly desirable attributes are that technologies enable non-contact sensing and measurement, are vacuum compatible, and are relatively insensitive to contamination. Desirable attributes include that technologies are non-hazardous, do not require the use of additional consumables, and do not introduce contaminants into the process.

Research should be conducted to demonstrate technical feasibility in Phase I and show a path toward demonstration in Phase II of in-situ process monitoring and quality assurance. Phase II proposals should include delivery of a prototype system for test and evaluation in environments representative of NASA's metallic AM systems. Expected Technology Readiness Levels (TRL) at the completion of Phase I projects are 2-3 and 4-5 at the end of Phase II projects.

Links to information about NASA's additive manufacturing development projects can be found at:

- Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS).
    - (http://www.nasa.gov/exploration/systems/sls/3dprinting.html).
- Electron Beam Freeform Fabrication (EBF3)
    - (http://www.sciencedaily.com/releases/2009/11/091110071535.htm).
    - (http://www.nmc.ctc.com/useruploads/file/events/PA_Karen_Taminger.pdf).
- Laser Engineered Net Shaping (LENS).
    - (http://www.sandia.gov/mst/pdf/LENS.pdf).

H5.02 Deployable Structures
Lead Center: LaRC

Participating Center(s): GRC, JPL

Nearly all spacecraft flown to date are powered by deployable solar arrays, having up to 100 m^2 of solar cell area and 25 kW of electrical power. NASA has a vital interest in developing much larger arrays over the next 20 years with up to 4000 m^2 of deployed area (1 MW) for exploration missions using solar electric propulsion (SEP). Scaling up solar array deployed surface area by more than an order-of-magnitude will require game changing innovations. In particular, novel flexible-substrate designs are needed that minimize structural mass and packaging volume while maximizing deployment reliability, deployed stiffness, deployed strength, and longevity. Most of the mass savings in these very large future arrays will probably come from improvements to solar array supporting structures, not from improvements in the solar cells mounted on the arrays.

NASA is currently developing solar array systems for SEP in the 30-50 kW power range. This SBIR subtopic seeks innovative structures and materials technologies and capabilities for the next generation of lightweight solar arrays beyond 50 kW. Technologies are needed for the design and verification of large deployable solar arrays with:

- 200-400 m^2 of deployed area (50-100 kW) in 3-5 years.
- 400-1200 m^2 of deployed area (100-300 kW) in 5-10 years.
- 1200-4000 m^2 of deployed area (300-1000 kW) in 10-20 years.

These deployed areas are typically divided between two solar array wings, with each wing requiring half of the specified area.

This subtopic seeks innovations in the following areas for future large solar array structures:

- Novel design, packaging, deployment, and in-space manufacturing and assembly concepts.
- Lightweight, compact components including booms, ribs, substrates, and mechanisms.
- Validated modeling, analysis, and simulation techniques.
- Ground and in-space test methods.
- Load alleviation, damping, and stiffening techniques.
- High-fidelity, functioning laboratory models.

Nominal solar array requirements for large-scale SEP applications are:

- Mass specific power > 120 W/kg at beginning of life (BOL).
- Stowed volume specific power > 40 kW/m^3 BOL.
- Deployment reliability > 0.999.
- Deployed stiffness > 0.1 Hz.
- Deployed strength > 0.2 g (all directions).
- Lifetime > 5 years.

Variations of NASA's in-house large solar array concept referred to as the Government Reference Array (GRA) could be used for design, analysis, and hardware studies. Improved packaging, joints, deployment methods, etc. to enable GRA-type solar arrays up to 4000 m^2 in size (1 MW) with up to 250 W/kg and 60 kW/m3 BOL are of special interest. The GRA is described in Reference 2.

In Phase I, contractors should prove the feasibility of proposed innovations using suitable analyses and tests. In Phase II, significant hardware or software capabilities should be developed and demonstrated to advance their Technology Readiness Level (TRL). TRLs at the end of Phase II of 3-4 or higher are desired.

References:

- "Concept Design of High Power Solar Electric Propulsion Vehicles for Human Exploration" (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120000068_2011025608.pdf).
- Pappa, R. S. et al., "Solar Array Structures for 300 kW-Class Spacecraft," Presented at the Space Power Workshop, April 24, 2013.

H5.03 Advanced Fabrication and Manufacturing of Polymer Matrix Composite (PMC) Structures
Lead Center: MSFC
Participating Center(s): LaRC

The subtopic area for Polymer Matrix Composite (PMC) Materials and Manufacturing concentrates on developing lightweight structures, using advanced materials technologies and new manufacturing processes. The objective of the subtopic is to advance technology readiness levels of PMC materials and manufacturing for launch vehicles and in-space applications resulting in structures having affordable, reliable and predictable performance. The subtopic will address two areas, manufacturing of structures and highly damage-tolerant materials for use in cryogenic environments. Proposals to each area will be considered separately. Areas of interest include: advances in PMC materials for large-scale structures and for in-space applications; innovative automated manufacturing processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant/repairable structures; low-cost, durable tooling; high temperature PMC materials for high performance composite structures (high temperature applications); and materials with high resistance to micro cracking at cryogenic temperatures. Reliable, affordable, and practical joining techniques for large segmented composite structures are desired.

Lightweight structures and PMC materials have been identified as a critical need for launch vehicles since the reduction of structural mass translates directly to vehicle additional performance, reduced cost, and increased payload mass capacity. Reliable large-scale (approximately 8 meters or greater in diameter) PMC structures will be critical to the "heavy lift" of America's next-generation space fleet. The capability to transfer and store for long-term propellant, particularly cryogenic propellants in orbit, can significantly increase the nation's ability to conduct complex and extended exploration missions beyond Earth's orbit. The use of PMC materials for cryotanks offers the potential of significant weight savings. Applications include storage of cryogenic propellants on an Earth Departure Stage, a lunar or asteroid descent vehicle, long-term cryogen storage on the Moon, and propellant tanks for a heavy lift launch vehicle. Consideration shall be made for manufacturability in the sense of either using out of autoclave cure or autoclave cure and, in made in sections, novel and reliable approaches to join sections of composite structures to take advantage of the high strength to weight properties so that the joining methods do not significantly increase the complexity or weight of the overall structure. Novel approaches from cradle to grave will be considered in the sense that these very large structures required robust and lightweight tooling and transportation methods for minimal modifications to existing facilities and use of existing transportation or minimal modifications to such infrastructures.

Performance metrics for manufacturing structures 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; low-cost, durable tooling; and quantitative risk reduction capability. Research should be conducted to demonstrate novel approaches, technical feasibility, and basic performance characterization for polymer matrix composite structures or low-cost, durable tooling during Phase I, and show a path toward a Phase II design allowables and prototype demonstration. Emphasis should be on demonstrable manufacturing technology that can be scaled up for very large structures.

Performance metrics for materials developed for cryotanks are: temperature-dependent material properties including strength, modulus, CTE, and fracture toughness; and demonstrated improved resistance over present SOA of multi-directional laminates to microcracking under cryogenic temperature cycling. Initial property characterization would be done at the coupon level in Phase I. Generation of design allowables, characterization of long-term material durability, and fabrication of larger panels would be part of follow-on efforts.

High temperature polymer matrices for high performance composite structures (high temperature applications) with ease of manufacturing using the current composite manufacturing techniques.

H5.04 Hot Structures
Lead Center: LaRC

This subtopic seeks to develop innovative low cost, mass and structurally efficient high temperature materials for hot structures applications.

The National Aeronautics and Space Administration (NASA) has developed hot structure technology for several hypersonic vehicles. Significant reductions in vehicle weight can be achieved with the application of hot structures, which do not require parasitic thermal protection systems (TPS). The most significant technical issue that must be addressed in hot structure design is the development of cost effective, environmentally durable and manufacturable material systems capable of operating at temperatures from 1500 °C to 3000 °C, while maintaining structural integrity. The development of these durable and affordable material systems is critical to technology advances and to enabling future economical hypersonic vehicles. Atmospheric re-entry from cis-lunar space will push the boundaries of thermal structures system technical capabilities. Advanced hot structures are required to enable these future missions.

This subtopic seeks innovative technologies in the following areas:

- Light-weight, low-cost, composite material systems that include continuous fibers.
- Significant improvements of in-plane and thru the thickness mechanical properties, compared to current high temperature laminated composites.
- Decreased processing time and increased consistency for high temperature materials.
- Low conductivity, low thermal expansion, high impact resistance.
- High temperature performance improved with oxidation resistant coatings.

Overall looking for 20% or greater reduction in mass and an order of magnitude reduction in cost.

For all above technologies, research, testing, and analysis should be conducted to demonstrate technical feasibility during Phase I and show a path towards Phase II hardware demonstration with delivery of a manufacturing demonstration unit for NASA testing at the completion of the Phase II contract.

Phase I Deliverables – Test coupons and characterization samples for demonstrating the proposed approach to develop the hot structure material product (TRL 2-3). Matrix of verification/characterization testing to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables – Test coupons and manufacturing demonstration unit for proposed material product. A full report of the material development process will be provided along with the results of the conducted verification matrix from Phase I (TRL 3-4). Opportunities and plans should also be identified and summarized for potential commercialization.

TOPIC: H6 Autonomous & Robotic Systems

NASA invests in the development of autonomous systems, advanced avionics, and robotics technology capabilities for the purpose of enabling complex missions and technology demonstrations supporting the Human Exploration and Operations Mission Directorate (HEOMD). The software, avionics, and robotics elements requested within this topic are critical to enhancing human spaceflight system functionality. These elements increase autonomy and system reliability; reduce system vulnerability to extreme radiation and thermal environments; and support human exploration missions with robotic assistants, precursors and caretaker robots. As key and enabling technology areas, autonomous systems, avionics and robotics are applicable to broad areas of technology use, including heavy lift launch vehicle technologies, robotic precursor platforms, utilization of the International Space Station, and spacecraft technology demonstrations performed to enable complex or long duration space missions. All of these flight applications will require unique advances in autonomy, software, robotic technologies and avionics. The exploration of space requires the best of the nation's technical community to provide the technologies, engineering, and systems to enable human exploration beyond LEO, to visit Asteroids and the Moon, and to extend our reach to Mars.

H6.01 Spacecraft Autonomy and Space Mission Automation
Lead Center: ARC
Participating Center(s): JSC, JPL

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.

Spacecraft Systems Automation:

- Mutli-agent autonomous systems for mapping.
- Safe proximity operations (including astronauts).
- Uncertainty management for proximity ops, movement, etc.

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 use of open source software.

Proposals will mature technology from TRL 4 to TRL 5 or 6 by the end of Phase II work. Phase I proposals must demonstrate the viability of the maturation.

Proposal deliverables must include:

- Software (source code, build instructions, and dependencies are ideal, but binaries may be acceptable under some circumstances).
- Software interface description documents, software architecture descriptions, and other documentation.
- Demonstrations of software systems on relevant applications.
- Quantification of software performance on relevant problems, documented in a report.

TOPIC: H7 Entry, Descent, and Landing Technologies

In order to explore other planets or return to Earth, NASA requires various technologies to facilitate entry, descent and landing. This topic, at this time, is supported by a single subtopic that calls for the development, modeling, testing, monitoring, and inspection of ablative thermal protection materials and/or systems that will support planetary entry. There is interest in ablative materials that can support aerocapture, requiring them to protect the spacecraft during two heating pulses. There is interest in developing flexible and/or deployable ablative materials. There is also interest in mid to high density composites that are capable replacements to chop-molded or tape-wrapped carbon phenolic composites that were used on Venus entry vehicles in the past. Work is needed on improved reinforcement materials for composites, as well as new formulations of polymers in composites. As new materials are developed, improved analytical tools are required to more accurately predict material response in entry conditions. Instrumentation for measuring the actual surface heating, in-depth temperatures, surface recession rates during testing and/or flight is required to verify the response of the materials and to monitor the health of flight hardware. Inspection of thermal protection material/aeroshell interfaces is critical to assure quality and is extremely difficult for porous, low density composites.

H7.01 Advanced Thermal Protection Systems Technologies
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 higher performance 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 capable of enduring severe combined convective and radiative heating. In addition, in order to adequately test and design with these materials, advancements in instrumentation, inspection, and modeling of ablative TPS materials is also sought.

- Areas of interest include improvements in the reinforcement materials or integration techniques such as joining or attachment for such materials as follows:
    - Advancements in carbon felts including thickness (>1.0-in), density (>0.10 g/cm^3), uniformity to use as reinforcement for high strain-to-failure ablative TPS materials.
    - Advancements in thin (~0.1-in) three dimensional woven carbon materials to act as stress bearing structure for deployable aeroshells. If advances in integration techniques are proposed, NASA may provide materials GFE to use in the development effort.
    - Advances in ceramic felts including thickness (>1.0-in) and uniformity to use as reinforcement for flexible TPS in heating up to ~150 W/cm^2.
    - Advancements in thick (>1.0-in) three dimensional woven carbon materials to use as reinforcement for high heat flux mid-to-high density ablative TPS materials. If advances in integration techniques are proposed, NASA may provide materials GFE to use in the development effort.
- TPS Materials advancements sought in felts or woven materials impregnated with polymers and/or additives to improve ablation and insulative performance. Areas of interest include:

    - One class of materials, for planetary 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 250 ºC
    - The second class of materials, for planetary aerocapture and entry for a deployable aerodynamic decelerator, will need to survive a single or dual heating exposure, with the first (or single pulse) at heat fluxes of 50-150 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 higher velocity (>11.5km/s) Earth 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 2000 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 250 ºC.
- Development of in-situ heat flux sensors, surface recession diagnostics, and in-depth or interface thermal response measurement devices for use on rigid and/or flexible ablative materials. 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 for evaluation of bondline and in-depth integrity for light weight rigid and/or flexible ablative materials. 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 for low and mid-density fiber based (woven or felt) ablative materials. 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.

Starting Technology Readiness Levels (TRL) of 2-3 or higher are sought.

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 (TRL 3). Small samples and initial test data may be provided to demonstrate feasibility. Development of the 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 4-5). Opportunities and plans should also be identified and summarized for potential commercialization.

TOPIC: H8 High Efficiency Space Power Systems

This topic solicits technology for power systems to be used for the human exploration of space. Power system needs consistent with human spaceflight include:

- Fuel cells compatible with methane-fueled landers, and electrolyzers and fuel cells compatible with materials extracted from lunar regolith and/or the Martian soil or atmosphere.
- Nuclear fission systems to power electric spacecraft and/or surface space power systems.

Solid oxide technology is of interest for fuel cells and electrolyzers to enable:

- The operation of fuel cells using hydrocarbon reactants, including methane and fuels generated on-site at the Moon or Mars.
- Electrolysis systems capable of generating oxygen by electrolyzing CO_2 (from the Mars atmosphere, trash processing, life support, or volatiles released from soils), and/or water from either extraterrestrial soils or from life support systems.

Both component and system level technologies are of interest. Technologies to enable space-based nuclear fission systems are sought for three power classes:

- Kilowatt-class to support robotic missions as precursors to human exploration.
- 10 kWe-class power conversion devices and 400-500K radiators to support large surface power and 100 kWe-class electric propulsion vehicles.
- 100 kWe-class power conversion devices, >500K radiators, and high temperature fuels, materials, and heat transport to support MW-class electric vehicles.

H8.01 Solid Oxide Fuel Cells and Electrolyzers
Lead Center: GRC
Participating Center(s): JSC

Solid oxide technology for fuel cells and electrolyzers to enable:

- The operation of fuel cells using hydrocarbon reactants, including methane and ISRU-generated fuels.
- Electrolysis systems capable of electrolyzing CO_2 from the Mars atmosphere, and/or water from the Mars surface to generate oxygen, or to recover oxygen from CO_2 and water from crew respiration for life support.

Both component and system level technologies are of interest.

Technologies are sought that improve the durability, efficiency, and reliability of solid oxide fuel systems capable of internal reforming of hydrocarbon fuels. Hydrocarbon fuels of interest include methane and fuels generated by processing lunar and Mars soils. Primary solid oxide components and systems of interest are:

- Solid oxide cell, stack, materials and system development for operation on unreformed methane in designs scalable to 1 to 3 kW at maturity. There is a strong preference for high power density configurations, e.g., planar.
- Solid oxide cells and stacks must startup with a minimal amount of water and then be capable of sustained operation on pure methane.
- Development of hermetic sealing materials for ceramic to ceramic interconnect or ceramic to metal interconnect stacks capable of thermal cycling. Data for the proposed seals materials and sealing scheme/design should be included in the proposal.
- Development of catalysts for direct internal reforming of methane. Provide single cell performance data on dry methane for the one or more of the proposed anode compositions.

Proposed technologies should demonstrate the following characteristics:

- Systems are expected to operate as specified after at least 20 thermal cycles during Phase I and the heat up rate must be stated in the proposal.
- The developed systems are expected to operate as specified after at least 500 hours of steady state operation on propellant-grade methane and oxygen with 2500 hours expected of a mature system. System should startup “dry” or with a minimal amount of water, but after reaching operating conditions an amount of water/H_2 consistent with what can be obtained from anode recycle can be used. Amounts must be justified in the proposal.
- Minimal cooling required for power applications. Cooling in the final application will be provided by means of conduction through the stack to a radiator exposed to space and/or by anode exhaust flow.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration. Emphasis should be on demonstrating technical feasibility, prototype hardware (2-4 cell stacks preferred), conceptual designs and implementation approaches.

H8.02 Space Nuclear Power Systems
Lead Center: GRC
Participating Center(s): JPL, JSC, MSFC

NASA is developing fission power system technology for future space exploration applications using a stepwise approach. Initial small fission systems are envisioned in the 1 to 10 kWe range that utilize cast uranium metal fuel and heat pipe cooling coupled to static or dynamic power conversion. Follow-on systems could produce 10s or 100s of kilowatts utilizing a pin-type uranium fueled reactor with pumped liquid metal cooling, dynamic power conversion, and high temperature radiators. The anticipated design life for these systems is 8 to 15 years with no maintenance. Candidate mission applications include power sources for robotic precursors, human outposts on the moon or Mars, and nuclear electric propulsion (NEP) vehicles. NASA is planning a variety of nuclear and non-nuclear system ground tests 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 testing. Specific areas for development include:

- 800-1000 K heat transport technology for reactor cooling (liquid metal heat pipes, liquid metal pumps).
- 1-10 kWe-class power conversion technology (thermoelectric, Stirling, Brayton).
- 400-500 K heat rejection technology for waste heat removal (water heat pipes, composite radiators, water pumps).

The early systems are 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. Specific areas for development include:

- 100 kWe-class power conversion technologies.
- Waste heat rejection technologies for 500 K and above.
- High temperature reactor fuels, structural materials and heat transport technologies.

Expected deliverables include monthly and final reports, analytical models, and experimental hardware. Phase I activities should focus on analytical validation of technical feasibility including conceptual designs and trade studies with supporting coupon/component level testing. Phase II activities should emphasize experimental testing using prototype hardware in a subsystem context under relevant operating conditions to demonstrate technology readiness.

TOPIC: H9 Space Communications and Navigation (SCaN)

The Space Communication and Navigation Technology Area supports all NASA space missions with the development of new capabilities and services that make our missions possible. Communication links are the lifelines to our spacecraft that provide the command, telemetry, and science data transfers as well as navigation support. Advancement in communication and navigation technology will allow future missions to implement new and more capable science instruments, greatly enhance human missions beyond Earth orbit, and enable entirely new mission concepts. NASA's communication and navigation capability is based on the premise that communications shall enable and not constrain missions. Today our communication and navigation capabilities, using Radio Frequency technology, can support our spacecraft to the fringes of the solar system and beyond. As we move into the future, we are challenged to increase current data rates - 300 Mbps in LEO to about 6 Mbps at Mars - to support the anticipated 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 are very important to the future of exploration and science activities of the Agency. Additionally, innovative, relevant research in the areas of positioning, navigation, and timing (PNT) are desirable. NASA's Space Communication and Navigation (SCaN) 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, minimize the impact of latency on overall system performance.

This year, the following technology areas are being solicited to meet increasing data throughput and accuracy needs: Optical communications, RF communications, reprogrammable communications systems and flight dynamics. Emphasis is placed on size, weight and power improvements. 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 SCaN Office. For more details, see: (https://www.spacecomm.nasa.gov/spacecomm/).

H9.01 SCaN Testbed (CoNNeCT) Experiments
Lead Center: GRC
Participating Center(s): JPL

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 Space Communications and Navigation (SCaN) Testbed Project provides SBIR recipients 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 applications and experiments to run aboard the SCaN Testbed 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 NASA Space Network, White Sands Complex. Unique experimenter ground hardware equipment may also be used. For the flight system on-orbit, experiments will consist of software/firmware provided to NASA by the SBIR recipient. This call will not provide a means to develop nor fly any new hardware in space.

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:

- Cognitive applications.
- Spectrum efficient technologies.
- Multi-access communication.
- Space internetworking.
    - Disruption Tolerant Networking.
- Position, navigation and timing (PNT) technology.
- Aspects of reconfiguration.
    - Unique/efficient use of processor, FPGA, DSP resources.
    - Inter-process communications.
- Technologies/waveforms for formation flying.
- High data rate communications.
- Uplink antenna arraying technologies.
- Demonstration of mission applicability of SDR.
- RF sensing applications (science emulation).

Experimenters using ground or flight systems will be required to meet certain pre-conditions for flight including:

- Provide software/firmware deliverables (software/firmware source, executables, and models) suitable for flight.
- 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 delivery process.
- Software/firmware deliverables compliant to the Space Telecommunications Radio System (STRS) Architecture, Release 1.02.1 and submitted to waveform repository for reuse by other users.
- 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 SCaN Testbed 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 SCaN Testbed 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 control 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, due to the timeframe of the on-orbit Testbed. 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 SCaN Testbed 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:

- Waveform/application architecture and detailed design document, including plan/approach for STRS compliance.
- Experiment Reference Design Mission Concept of Operations.

- Experiment Plan (according to provided template).
- Demonstrate simulation or model of key waveform/application functions.
- Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product. Early software/firmware application source and binary code and documentation. Source/binary code will be run on engineering models and/or SDR breadboards (at TRL-3-4).
- Plan and approach for Commercialization of the technology (part of final report).

Phase II Deliverables:

- Applicable Experiment Documents (e.g., requirements, design, management plans)
- Simulation or model of waveform application.
- Demonstration of waveform/application in the laboratory on SCaN Testbed breadboards and engineering models.
- Software/firmware application source and binary code (including test software) and documentation (waveform contribution to STRS Repository for reuse by others). Source/binary code will be run on engineering models and/or demonstrated on-orbit in flight system (at TRL-5-7) SDRs. Documentation of development tool chain and procedure to build files.
- Results of implementing the Commercialization Plan outlined in Phase I.

H9.02 Long Range Optical Telecommunications
Lead Center: JPL
Participating Center(s): GRC, GSFC

This subtopic seeks innovative technologies for long range Interplanetary Optical Telecommunications supporting the needs of space missions where robotic explorers will visit distant bodies within the solar system and beyond. Our goals are increased data-rate capability in both directions, in conjunction with significant reductions of mass, power-consumption, and volume at the spacecraft. 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 and spacecraft micro-vibration environment (TRL3 Phase I, and TRL4 Phase II).

- *Vibration Isolation and Rejection Platforms and Related Technologies* - Compact, lightweight, space qualifiable vibration isolation and rejection platforms for payloads with a mass between 3 and 20 kg that require less than 5 W of power and have a mass less than 3 kg that will attenuate an integrated spacecraft micro-vibration angular disturbance of 150 micro-radians to less than 0.5 micro-radians (1-sigma), from < 0.1 Hz to ~500 Hz (TRL3 Phase I, and TRL4 Phase II).Also, innovative low-noise, low mass, low power, DC-kHz inertial, angular, position, or rate sensors. Compact, ultra-low-power, low-mass, kHz bandwidth, tip-tilt mechanisms with sub-micro-radian pointing accuracies, angular ranges of ±5 mrad and supporting up to 50 gram payloads.
- *Laser Transmitters* - Space-qualifiable, >25% DC-to-optical (wall-plug) efficiency, 0.2 to 16ns pulse width 1550-nm laser transmitter for pulse-position modulated (PPM) data with random pulses at duty cycles of 0.3% to 6.25%, <35ps pulse rise and fall times and jitter, <25% pulse-to pulse energy variation (at a given pulse width) near transform limited spectral width, single polarization output with at least 20 dB polarization extinction ratio, amplitude extinction ratio greater than 45dB, average power of 5 to 20W, massing less than 500 g/W. Laser transmitter to feature slot-serial PPM data input at CML or AC-coupled PCEL levels and an RS-422 or USB control port. All power consumed by control electronics will be considered as part of DC-to-optical efficiency. Also of interest for the laser transmitter is robust and compact packaging with >100krad radiation tolerant electronics inherent in the design. Detailed description of approaches to achieve the stated efficiency is a must (TRL3 Phase I, TRL4 Phase II).
- *Photon Counting Near-infrared Detectors Arrays for Ground Receivers* - Readout electronics and close packed (not lens-coupled) kilo-pixel arrays sensitive to 1520 to 1650 nm wavelength range with single photon detection efficiencies greater than 90%. Single photon detection jitters less than 40 picoseconds 1-sigma, active diameter greater than 500 microns, 1 dB saturation rates of at least 10 mega-photons (detected) per pixel, false count rates of less than 1 MHz/square-mm, all at an operational temperature > 1.2K.

- *Photon Counting Near-infrared Detectors Arrays for Flight Receivers* - 64x64 or larger array with integrated read-out integrated circuit for the 1030 to 1080 nm or 1520 to 1650 nm wavelength range with single photon detection efficiencies greater than 40% and 1dB saturation loss rates of at least 2 mega-photons/pixel and operational temperatures above 220K and dark count rates of <10 MHz/mm. Radiation doses of at least 5 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* - Ground station telescope/photon-bucket technologies for developing effective aperture diameter of e10 meter at modest cost. Operations wavelength is monochromatic at a wavelength in the range of 1000-1600nm. Key requirements: a maximum image spot size of <20 micro-radian; capable of operation while pointing to within 5° of the Sun; and field-of-view of >50 micro-radian. Telescope shall be positioned with a two-axis gimbal capable of <50 micro-radian pointing accuracy, with dynamic error <10 micro-radian RMS while tracking after tip-tilt correction.

Research should be conducted to convincingly prove technical feasibility (proof-of-concept) during Phase I ideally through hardware development, with clear pathways to demonstrating and delivering functional hardware, meeting all objectives and specifications, in Phase II.

References:

- (http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/42091/1/11-1338.pdf)
- (http://ipnpr.jpl.nasa.gov/progress_report/42-183/183A.pdf)
- (http://ipnpr.jpl.nasa.gov/progress_report/42-185/185D.pdf)
- (http://ipnpr.jpl.nasa.gov/progress_report/42-182/182C.pdf)

H9.03 Long Range Space RF Telecommunications
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC

This subtopic is focused on development of innovative deep space long-range and near-Earth RF telecommunications technologies supporting the needs of space missions.

In the future, robotic and human exploration spacecraft with increasingly capable instruments producing large quantities of data will be visiting the moon and the planets. These spacecraft will also support long duration missions, such as to the outer planets, or extended missions with new objectives. They will possess reconfigurable avionics and communication subsystems and will be designed to require less intervention from Earth during periods of low activity. Concurrently, the downlink data rate demands from Earth science spacecraft will be increasing. The communication needs of these missions motivate higher data rate capabilities on the uplink and downlink, as well as more reliable RF and timing subsystems. Innovative long-range telecommunications technologies that maximize power efficiency, reliability, receiver capability, 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 deep 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%. Due to the applicability of communication components and subsystems with science instruments such as radar, technologies that can benefit both RF communication and advanced instruments are within the scope of this subtopic.

Technologies of interest:

- Ultra-small, light-weight, low-cost, low-power, modular deep space and near-Earth transceivers, transponders, amplifiers, 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 CW medium output power (10-15 W) and CW high-output power (15-35 W), 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).

- Solid-state multi-function modules that can be commanded to toggle between amplifying conventional digital modulation format signals for communications to pulsed operation for synthetic aperture radar (SAR) with resolution on the order of few meters.
- Ultra low-noise amplifiers (MMICs or hybrid, uncooled) for RF front-ends (< 50 K noise temperature).
- High dynamic range (> 65 dB), data rate receivers (> 20 Mbps) supporting BPSK/QPSK modulations.
- 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.
- Novel approaches to mitigate RF component susceptibility to radiation and EMI effects.
- Innovative packaging techniques that can lead to small size, light weight compact SSPAs with integrated heat extraction for thermal stability and reliability.

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 (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.

H9.04 Flight Dynamics GNC Technologies and Software
Lead Center: GSFC
Participating Center(s): GRC, JPL

NASA is investing in re-engineering its suite of tools and facilities that provide guidance, navigation, and control (GNC) services for the design, development, and operation of near-Earth and interplanetary missions. This solicitation seeks proposals that will develop ground system algorithms and software for flight dynamics GNC technologies to support engineering activities from concept development through operations and disposal. This subtopic does not target on-board algorithms or software.

This solicitation is primarily focused on NASA's needs in the following focused areas:

- Addition of advanced guidance, navigation, and control improvements to existing NASA software.
- Replacement of heritage GNC software systems that are nearing obsolescence or improvement of their maintainability.
- Interface improvements, tool modularization, APIs, workflow improvements, and cross platform interfaces to existing NASA software.
- Applications of optimal control theory to high and low thrust space flight guidance and control systems.
- Numerical methods and solvers for robust targeting, and non-linear, constrained optimization.
- Applications of cutting-edge estimation techniques to spaceflight navigation problems.
- Applications of cutting-edge guidance and control techniques to space trajectories.
- Applications of advanced dynamical theories to space mission design and analysis, in the context of unstable orbital trajectories in the vicinity of small bodies and libration points.

Proposals that could lead to the replacement of the Goddard Trajectory Determination System (GTDS), or leverage state-of-the-art capabilities already developed by NASA such as the General Mission Analysis Tool (gmatcentral.org), GPS-Inferred Positioning System and Orbit Analysis Simulation Software, (http://gipsy.jpl.nasa.gov/orms/goa/), Optimal Trajectories by Implicit Simulation (otis.grc.nasa.gov) are especially encouraged. Proposers who contemplate licensing NASA technologies are highly encouraged to coordinate with the appropriate NASA technology transfer offices prior to submission of their proposals.

Technologies and software should support a broad range of spaceflight customers. Those that are focused on a particular mission's or mission set's needs are the subject of other solicitations by the relevant sponsoring organizations and should not be submitted in response here.

Phase I efforts shall demonstrate technical and cost feasibility at the TRL 3 level and provide a plan for completion of the effort in Phase II. Preliminary software, algorithms, and documentation shall be delivered to NASA for evaluation.

With the exception listed below for heritage software modifications, Phase II new technology development efforts shall deliver components at the TRL 5-6 level with mature algorithms and software components complete and preliminary integration and testing in an operational environment. For efforts that extend or improve existing NASA software tools, the TRL of the deliverable shall be consistent with the TRL of the heritage software. Note, for some existing software systems (see list above) this requires delivery at TRL 8. Final software, test plans, test results, and documentation shall be delivered to NASA.

H9.05 Advanced Celestial Navigation Techniques and Systems for Deep-Space Applications
Lead Center: GRC
Participating Center(s): GSFC

NASA is seeking proposals to develop advanced celestial navigation techniques and system in support of deep-space missions. Advances in positioning, attitude estimation, orbit determination, time and frequency keeping and dissemination and orbit determination are sought. System and sub-system concepts should support significant advances of independence from Earth supervision including the ability to operate effectively in the absence of Earth-based transmissions or transmissions from planetary relay spacecraft while minimizing spacecraft burden by requiring low power and minimal mass and volume. While system concepts that operate in the complete absence of human intervention or Earth-based transmissions are preferred, testing and verification of proposed systems performance will, necessarily, include Earth-based systems.

Operation during all phases of mission operations, including cruise phase, orbit phase and circularization phases are of interest. An application of interest is to enable open–loop (i.e., beaconless) pointing of high rate optical communications terminals to earth terminals. Methods and systems should be sufficient accuracy to support this capability; however, concepts which are capable of supporting planetary missions of any type are of interest.

Subjects appropriate for this sub-topic include, but are not limited to:

- Advanced methods and sensors for optical/IR detection of star fields (i.e., star cameras).
- Advanced methods and sensors detecting RF and x-ray pulsars.
- Methods to process celestial observations to perform Orbit Determination (OD) and precision attitude estimation.

Proposals to develop Artificial Intelligence methods (e.g., supervisory control) should identify gaps in the knowledge base that are particular to the use of advanced celestial methods, unique to the deep space navigation problem. User spacecraft impact is of significant importance and proposed solutions include assessments of mass, power, thermal impact on targeted mission spacecraft. Current and past mission spacecraft may be used as paradigms. Proposals that include re-purposing/cross-purposing of advanced sensors contemplated for future deep-space missions such as x-ray telescopes are preferred.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and software demonstration unit or software package for NASA testing at the completion of the Phase II contract. Deliverables must include a phased testing, verification and validation plan. Plans that include graduated flight testing are preferred.

TOPIC: H10 Ground Processing & ISS Utilization

The Human Exploration and Operations Mission Directorate (HEOMD) provides mission critical space exploration services to both NASA customers and to other partners within the U.S. and throughout the world: assembling and operating the International Space Station (ISS); 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 astronauts. Activities include ground-based and in-flight processing and operations tasks, along with support that ensures these tasks are accomplished efficiently and accurately, and enable 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 the utilization of the ISS for both in-situ research and as a test bed for development of improved space exploration technologies. A typical flight focused approach would include:

- Phase I - Research to identify and evaluated 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 test in at the completion of the Phase II contract and, if possible, demonstrate earth based uses or benefits.

H10.01 Recycling/Reclamation of 3-D Printer Plastic for Reuse
Lead Center: MSFC
Participating Center(s): ARC, JSC, KSC

The subtopic seeks to develop innovative concepts to support the development of recycling/reclaiming technologies for Acrylonitrile Butadiene Styrene (ABS) plastic parts in space, thus providing viable solutions for self-sustained additive manufacturing capability with plastic materials.

As the National Aeronautics and Space Administration (NASA) destinations push farther beyond the limits of low Earth orbit, the convenience of fabricating components and equipment on the ground to quickly resupply missions will no longer be a reasonable option. Resupply is difficult during deep space missions; it requires a paradigm shift in the way the Agency currently relies on an Earth-based supply chain for spares, maintenance, repair, and hardware design models, including those currently on the International Space Station (ISS). With the ISS program extension, there is a high likelihood of necessary replacement parts. This is a unique opportunity to begin changing the current model for resupply and repair to prepare and mature technology for deep space exploration missions.

3-D printing, formally known as “Additive Manufacturing”, is the method of building parts layer-by-layer from data files such as Computer Aided Design models. Data files with tool and part schematics can be pre-loaded onto the device before a launch, or up-linked to the device while on-orbit. 3-D printers currently scheduled for on-board ISS use will employ extrusion-based additive manufacturing, which involves building an object out of plastic deposited by the melting of feedstock by an extruder head. The plastic extrusion additive manufacturing process is a low-energy, low-mass solution to many common needs on board the ISS.

The 3-D Printing in Zero-G “3-D Print” Technology Demonstration and the Additive Manufacturing Facility (AMF) plan to utilize the commercial 3-D printing standard 1.75mm ABS filament as feedstock on ISS. To truly develop a self-sustaining, closed-loop on-orbit manufacturing process that will result in less mass to launch and increased on-demand capability in space, a means of recycling and reclaiming the feedstock is required. This SBIR seeks technologies that can take ABS parts analogous to those which could be printed on ISS (maximum size of 6cm x 12 cm x 6 cm) and demonstrate recycling/reclamation capability of the part back into 1.75mm filament feedstock.

This subtopic seeks innovative technologies in the following areas:

- ABS part reclamation - decomposing a plastic part (maximum size of 6 cm x 12 cm x 6 cm) and reconstitution into 1.75mm (±0.1mm) diameter wire spools, pellets, or other forms that can be fed into an extrusion device.

- Production of recycled plastic filament while maintaining repeatable, consistent filament diameter of 1.75mm with ±0.1mm tolerance.
- Methods to avoid bulging of feedstock as the filament is created.
- Gravity-independent filament spooling capability: drawing the filament onto a feedstock spool as it is being created without relying on gravity to guide the filament. Goal for spool dimension should be 156mm OD, 48mm ID, 43mm wide.
- Environmental containment for Foreign Object Debris (FOD) and material off-gassing.

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 for NASA testing at the completion of the Phase II contract. Demonstration of the Engineering Unit at the end of Phase II may lead to an opportunity for a Phase III contract for a Flight Unit.

Phase I Deliverables - Feasibility study with proposed path forward to develop Engineering Unit in Phase II; study should address how the design will meet flight certification, safety requirements, and operational constraints for spaceflight; and bench top proof-of-concept, including samples and test data, proving the proposed approach to develop a given product (TRL 3-5).

Phase II Deliverables - Functioning Engineering Unit of proposed product, along with full report of development and test data (TRL 5-6).

H10.02 International Space Station (ISS) Utilization
Lead Center: JSC
Participating Center(s): ARC, GRC, JPL, KSC, MSFC

NASA continues to invest in the near- and mid-term development of highly-desirable systems and technologies that provide innovative ways to leverage existing ISS facilities for new scientific payloads and to provide on orbit analysis to enhance capabilities. Utilization of the ISS is limited by available up-mass, down-mass, and crew time as well as by the capabilities of the interfaces and hardware already developed and in use. Innovative interfaces between existing hardware and systems, which are common to ground research, could facilitate both increased and faster payload development and subsequent utilization. Technologies that are portable and that can be matured rapidly for flight demonstration on the International Space Station are of particular interest.

Desired capabilities that will continue to enhance improvements to existing ISS research hardware include, but are not limited to, the below examples:

- Providing additional on-orbit analytical tools. Development of instruments for on-orbit analysis of plants, cells, small mammals and model organisms including Drosophila, C. elegans, and yeast. Instruments to support studies of bone and muscle loss, multi-generational species studies and cell and plant tissue are desired. 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.
- Technologies that determine 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. Required technology characteristics include: 2 year shelf-life; functionality in microgravity and low pressure environments (~8 psi). Technologies that show improvements in miniaturization, reliability, life-time, self-calibration, and reduction of expendables are also of interest.
- Providing a Magnet Processing Module (MPM) for installation and operations in the Materials Science Research Rack (MSRR) would enable new and improved types of materials science investigations aboard the ISS. Essential components of the MPM include an electromagnet, which can provide field strength up to 0.2 Tesla and a high temperature insert, which can provide directional solidification processing capability at temperatures up to 1500 °C.
- Increased use of the Light Microscopy Module (LMM). Several additions to the module continue to be solicited, such as: laser tweezers, dynamic light scattering, stage stabilization (or sample position encoding) for reconstructing better 3-D confocal images.

- Instruments that can be used as infrared inspection tools for locating and diagnosing material defects, leaks of fluids and gases, and abnormal heating or electrical circuits. The technology should be suitable for hand-held portable use. Battery powered wireless operation is desirable. Specific issues to be addressed include: pitting from micrometeoroid impacts, stress fractures, leaking of cooling gases and liquids and detection of abnormal hot spots in power electronics and circuit boards.

For the above, research should be conducted to demonstrate technical feasibility and prototype hardware development during Phase I and show a path toward Phase II hardware and software demonstration and delivering an engineering development unit or software package for NASA testing at the completion of the Phase II contract that could be turned into a proof-of-concept system which can be demonstrated in flight.

Phase I Deliverables - Written report detailing evidence of demonstrated prototype technology in the laboratory or in a relevant environment and stating the future path toward hardware and software demonstration on orbit. Bench or lab-level demonstrations are desirable. The technology concept at the end of Phase I should be at a TRL of 3-6.

Phase II Deliverables - Emphasis should be placed on developing and demonstrating hardware and/or software prototype that can be demonstrated on orbit (TRL 8), or in some cases 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 an engineering development unit for functional and environmental testing at the completion of the Phase II contract. The technology at the end of Phase II should be at a TRL of 6-7.

TOPIC: H11 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. All space radiation environments in which humans may travel in the foreseeable future are considered, including geosynchronous orbit, Moon, Mars, and the Asteroids. Advances are needed in mitigation schema for the next generation of exploration vehicles inclusive of radiation shielding systems 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 clear that the ability to mitigate the risks posed to both crews and vehicle systems by the space weather environment is also of central importance. Advances in radiation shielding systems technologies are needed to protect humans from all threats of space radiation. All particulate radiations are considered, including electrons, protons, neutrons, alpha particles, light ions, and heavy ions. This topic is particularly interested in mid-TRL (technology readiness level) technologies. Lightweight radiation shielding materials are needed to shield humans in aerospace transportation vehicles, large space structures, space stations, orbiters, landers, rovers, habitats, and spacesuits. The materials emphasis should be on non-parasitic radiation shielding materials, or multifunctional materials, where two of the functions are structural and radiation shielding. Non-materials solutions, such as utilizing food, water, and waste already on board as radiation shielding are also sought. A challenge of particular interest is to contain and use human waste as radiation shielding. Advanced computer codes are needed to model and predict the transport of radiation through materials and subsystems, as well as to predict the effects of radiation on the physiological performance, health, and well-being of humans in space radiation environments. Laboratory and spaceflight data are needed to validate the accuracy of radiation transport codes, as well as to validate the effectiveness of multifunctional radiation shielding materials and subsystems. Also of interest are comprehensive radiation shielding databases and design tools to enable designers to incorporate and optimize radiation shielding into space systems during the initial design phases. 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.

Reference: Wilson, John W.; Townsend, Lawrence W.; Schimmerling, Walter; Khandelwal, Govind S.; Khan, Ferdous; Nealy, John E.; Cucinotta, Francis A.; Simonsen, Lisa C.; Shinn, Judy L.; and Norbury, John W.: Transport Methods and Interactions for Space Radiations. NASA Reference Publication (RP) 1257, December 1991.

H11.01 Radiation Shielding Systems

Lead Center: LaRC
Participating Center(s): MSFC

Advances in radiation shielding systems technologies are needed to protect humans from the hazards of space radiation during NASA missions. All space radiation environments in which humans may travel in the foreseeable future are considered, including low Earth orbit (LEO), geosynchronous orbit, Moon, Mars, and the Asteroids. All particulate radiations are considered, including electrons, protons, neutrons, alpha particles, and light to heavy ions up to iron. Mid-TRL (3 to 5) technologies of specific interest include, but are not limited to, the following:

- Innovative lightweight radiation shielding materials are needed to shield humans in aerospace transportation vehicles, large space structures such as space stations, orbiters, landers, rovers, habitats, and spacesuits. The materials emphasis should be on non-parasitic radiation shielding materials, or multifunctional materials, where two of the functions are structural and radiation shielding. Phase I deliverables are materials coupons. Phase II deliverables are materials panels or standard materials test specimens, along with relevant materials test data.
- Non-materials solutions, such as utilizing food, water, and waste already on board as radiation shielding. A challenge of particular interest is to contain and use human waste as radiation shielding. Phase I deliverables are detailed conceptual designs. Phase II deliverables are working prototypes.
- Advanced computer codes are needed to model and predict the transport of radiation through materials and subsystems. Advanced computer codes are needed to model and predict the effects of radiation on the physiological performance, health, and well-being of humans in space radiation environments. Comprehensive radiation shielding design tools are needed to enable designers to incorporate and optimize radiation shielding into space systems during the initial design phases. Phase I deliverables are alpha-tested computer codes. Phase II deliverables are beta-tested computer codes.
- Laboratory and spaceflight data are needed to validate the accuracy of radiation transport codes. Laboratory and spaceflight data are needed to validate the effectiveness of multifunctional radiation shielding materials and subsystems. Comprehensive radiation shielding databases are needed to enable designers to incorporate and optimize radiation shielding into space systems during the initial design phases. Phase I deliverables are draft data compilations or databases. Phase II deliverables are formal, publishable, and archival data compilations or databases.

TOPIC: H12 Human Research and Health Maintenance

NASA's Human Research Program (HRP) investigates and mitigates the highest risks to astronaut health and performance in exploration missions. The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration, and to ensure safe and productive human spaceflight. The scope of these goals includes both the successful completion of exploration missions and the preservation of astronaut health over the life of the astronaut. HRP developed an Integrated Research Plan (IRP) to describe the requirements and notional approach to understanding and reducing the human health and performance risks. The IRP describes the Program's research activities that are intended to address the needs of human space exploration and serve HRP customers. The IRP illustrates the program's research plan through the timescale of early lunar missions of extended duration. The Human Research Roadmap (http://humanresearchroadmap.nasa.gov) is a web-based version of the IRP that allows users to search HRP risks, gaps, and tasks. The HRP is organized into Program Elements:

- Human Health Countermeasures.
- Behavioral Health & Performance.
- Exploration Medical Capability.
- Space Human Factors and Habitability.
- Space Radiation and ISS Medical Projects.

Each of the HRP Elements addresses a subset of the risks, with ISS Medical Projects responsible for the implementation of the research on various space and ground analog platforms. With the exception of Space Radiation, HRP subtopics are aligned with the Elements and solicit technologies identified in their respective research plans.

H12.01 Next Generation Oxygen Concentrator for Medical Scenarios
Lead Center: GRC
Participating Center(s): JSC

For exploration missions, a contingency system which concentrates the oxygen within the cabin environment and provides the required concentration of oxygen to the crewmember for various medical scenarios will be necessary. Oxygen concentration technology is being pursued to concentrate oxygen from the ambient environment so that oxygen as a consumable resource and the fire hazard of an elevated cabin oxygen atmosphere can be reduced. The goal of this project is to develop an oxygen concentration module that minimizes the hardware mass, volume, and power footprint while still performing at the required clinical capabilities.

An Oxygen Concentrator Module (OCM) with an adjustable positive pressure output 2-15 lpm of O_2 at 50% to >90% oxygen concentrations by volume has been recommended by the flight medical team. The unit must be able to operate continuously in microgravity and partial gravity exploration atmospheres that include the atmospheres of 14.7 psia/21% oxygen, 10.2 psia/26.5% oxygen, and 8.2 psia/34% oxygen by volume. The unit must run continuously on available spacecraft power, and be switchable between 28 VDC and120 VDC. It must have adequate heat rejection so as to not exceed a touch temperature of 45oC. It is also highly desirable to have a portable low output capability for use in EVA pre-breathing or patient transfer between vehicles. Usage scenarios for oxygen treatment of smoke inhalation or toxic spills also predicates the need for an inlet filter on the unit that removes (converts/absorbs/filters) toxic gases from the delivered gas stream to the patient.

The OCM system should be capable of regulating the oxygenation of the patient using a closed loop feedback system that senses the oxygenation level of the patient tissues and adjusts the oxygen flow rate and/or oxygen concentration according to treatment protocols for the illness being treated. The system shall also be able to operate open loop in the event of feedback signal failure. The control variable(s) are not specified (rate/concentration) here since the basic unit's topology may dictate how the regulation is best achieved. Because the system may be configured during times of duress, it shall be user friendly to the caretaker by adopting a "plug and play" philosophy.

This SBIR Phase I development is to determine the architecture of such a system exhibiting the characteristics (high capacity flow range, closed-loop tissue oxygen control, and operations in microgravity or partial gravity exploration atmospheres), a description of the basic unit as a sub-system component, method of optimizing power over the range of flows and oxygen levels, redundancy and sparing for a long duration missions, and the relationship of the OCM system to caretaker (what does the caretaker need to do to fulfill the medical need?).

Phase I Requirements - Phase I should concentrate on developing the scientific, technical, and commercial merit and feasibility of the proposed innovation resulting in a feasibility report and concept, complete with analyses that discuss functionality in microgravity and at the proposed exploration atmospheres, algorithms for closed-loop oxygenation protocols, and inlet filtering of smoke or toxic gases.

NASA Deliverables - A concept for a microgravity and partial gravity exploration atmospheres oxygen concentrator with a closed loop oxygenation flow rate system with inlet filtering of potential toxic ambient gases.

HRP IRP Risk - Risk of Unacceptable Health and Mission Outcomes Due to Limitations of In-flight Medical Capabilities.

H12.02 Inflight Calcium Isotope Measurement Device
Lead Center: JSC

Bone loss in crewmembers is a major concern for long duration space flight. The ability to rapidly detect changes in bone mineral balance (BMB) in crewmembers living on ISS would have great potential as a surveillance tool for future exploration missions. Calcium isotopes have been shown to detect changes in BMB on very short timescales (e.g., one week). In order to detect these important changes, a technological device could be used in-flight. Thus, we are seeking a device (portable to bench top size) with the same accuracy and precision as is currently available in the non-flyable Multiple Collector Inductively Coupled Plasma mass spectrophotometer.

Phase I Requirements - The sensitivity required to make the Calcium isotope measurements would need to be approximately 10^{12}-10^{16} (i.e., this is how sensitive the machine should be for finding the Calcium isotope; it should be able to pick up one "atom" or unit in a pool of 10^{16} other things). Systems that measure elemental composition typically have sensitivities around 10^{6}-10^{9} for some elements. The absolute concentrations of the isotopes are not required. We are looking for an instrument that can measure the variations in the ratio of any two Calcium isotopes on the order of 0.1-0.5 parts per 10,000 (44Ca/42Ca) but could vary depending on the isotopes used. A successful proposal will include the technologies being considered and detailed test plan for evaluating them during Phase I.

Phase I deliverables - Test results and plan for developing a low volume, low mass, easy-to-operate prototype. TRL of 3 desired.

Phase II deliverables - Prototype in year 1 with sample testing against industry standard in year 2.

HRP IRP Risk - Risk of Early Onset Osteoporosis Due to Spaceflight

Technology Readiness Levels (TRL) of 4 to 5 or higher are sought upon completion of the project.

H12.03 Objective Sleep Measures for Spaceflight Operations
Lead Center: JSC

Currently in spaceflight, crewmembers report their sleep duration as requested by their crew surgeon. This approach has several limitations, including the burden it places on the crew and the tendency for subjective over-reporting of sleep (Lauderdale et al., 2008; Van Den Berg et al., 2008; Silva et al., 2007). Given evidence that demonstrates the relationship between sleep and circadian phase and performance, sleep-activity data should be collected as unobtrusively possible during long duration spaceflight. Wrist-worn actigraphy has been implemented as a successful, validated research tool in spaceflight but lacks features to render it a useful tool operationally, such as real-time feedback and minimal crew time requirements. Hence, there is a need for a minimally obtrusive or unobtrusive measure that evaluates sleep-wake activity plus light exposure; is acceptable for continuous wear; minimizes crew time by allowing for automatic downloads; provides immediate feedback to the user; incorporates the constraints of spaceflight hardware, such as extended battery life; and potentially incorporates other features, including other physiological sensors. The proposed technology should build on existing technologies with a focus on enhancing the product to ensure spaceflight readiness.

Requirements - Phase I should concentrate on the enhancement of a prototype device providing minimally obtrusive data collection that objectively measures sleep duration and other relevant characteristics in the spaceflight environment. Phase II should also yield a plan for continued development (if needed) and for validation of the device prior to spaceflight implementation.

NASA Deliverables - An objective, validated measure of sleep that is feasible and acceptable in the spaceflight environment.

HRP IRP Risk - Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness and Work Overload.

A TRL Start of 3-4 with a TRL End of 7-8 (at the end of Phase II) is desired for this project.

H12.04 Advanced Food Technology
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 foods with a shelf life of five years will be required to support the crew. Concurrently, the food system requirements must efficiently balance with their use of vehicle resources such as mass, volume, water, air, waste, power, and crew time.

NASA provisions currently consist solely of shelf stable foods due to vehicle resource limitations preventing food refrigeration or freezing. Stability is achieved by thermal, irradiative processing, or drying to kill or prevent microorganism growth in the food. These methods coupled with environmental factors (such as moisture ingress and oxidation) impact the micronutrients within the food. Since the food system is the sole source of nutrition to the crew, a significant loss in nutrient availability could jeopardize the health and performance of the crew.

This subtopic requests methods or technologies that enable development of an acceptable and safe food system to deliver appropriate amounts of bioavailable nutrients to crewmembers throughout a five year mission with no resupply. Vitamin content in NASA foods, such as vitamin C, vitamin K, thiamin, and folic acid, are key nutrients degraded during processing and storage. NASA is seeking novel food ingredients, protective or stabilizing technologies (e.g., encapsulation), controlled-release systems, or novel processing technologies that allow the delivery of key nutrients at the time of consumption. Consideration must be given to food safety as well as acceptability, as under-consumption will similarly lead to nutritional deficiencies.

Deliverables - Feasibility demonstration of a novel food system approach with the potential to enable vitamin stability in an acceptable and safe food system for extended duration missions. Phase I should include a comprehensive report detailing the system feasibility, and show a clear path to Phase II development and analyses, with the expectation that Phase II will demonstrate that the food system will retain 70% of original content of vitamin C, vitamin K, thiamin, or folic acid over five years of ambient temperature storage. Phase II should deliver the innovation in a form that can be tested in NASA’s food system.

HRP IRP Risk - Risk of Inadequate Food System.

Technology Readiness Levels (TRL) of 4 to 5 or higher are sought.

TOPIC: H13 Non-Destructive Evaluation

Future manned space missions will require technologies that enable detection and monitoring of the space flight vehicles during deep space missions. Development of these systems will also benefit the safety of current missions such as the International Space Station and Aerospace as a whole. Technologies sought under this SBIR Topic can be defined as advanced sensors, sensor systems, sensor techniques or software that enhance or expand NASA’s Nondestructive Evaluation (NDE) and Structural Health Monitoring (SHM) capability beyond the current State of the Art. Sensors and Sensor systems sought under this topic can include but are not limited to techniques that include the development of quantum, meta- and nano sensor technologies for deployment. Technologies enabling the ability to perform inspections on large complex structures will be encouraged. Technologies should provide reliable assessments of the location and extent of damage. Advanced processing and displays are needed to reduce the complexity of operations for astronaut crews who need to make important assessments quickly. Examples of structural components that will require sensor and sensor systems are multi-wall pressure vessels, batteries, thermal tile, thermal blankets, micrometeoroid shielding, International Space Station (ISS) Radiators or aerospace structural components. SHM technologies and integrated vehicle health management (IVHM) systems and analysis tools can include both active and passive SHM systems. Techniques sought include modular/low mass-volume systems, low power, low maintenance systems, and systems that reduce or eliminate wiring, as well as stand-alone smart-sensor systems that provide processed data as close to the sensor as practical and systems that are flexible in their applicability. Damage detection modes include leak detection, ammonia detection, micrometeoroid impact and others. Reduction in the complexity of standard wires and connectors and enabling sensing functions in locations not normally accessible with previous technologies is also desirable. Examples of space flight hardware will include light weight structural materials including composites and thin metals. Consideration will be given to the all system ability operate and survive in on-orbit and deep space.

H13.01 Advanced NDE Techniques for Complex Built Up Structures
Lead Center: LaRC
Participating Center(s): DFRC, GRC, GSFC, JSC, MSFC

Technologies sought under this SBIR program can be defined as advanced sensors, sensor systems, sensor techniques or software that enhance or expand NASA's current senor capability. It is considered to be advantageous but not necessary to target structural components of space flight hardware. In a general sense space flight hardware will include light weight structural materials including composites and thin metals.

Technologies sought include modular smart advanced NDE sensors systems and associated capture and analysis software. It is advantageous for techniques to include the development on quantum, meta- and nano sensor technologies for deployment. Technologies enabling the ability to perform inspections on large complex structures will be encouraged. Technologies should provide reliable assessments of the location and extent of damage. Methods are desired to perform inspections in areas with difficult access in pressurized habitable compartments and external environments for flight hardware. Many applications require the ability to see through assembled conductive and/or thermal insulating materials without contacting the surface. Techniques 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. Advanced processing and displays are needed to reduce the complexity of operations for astronaut crews who need make important assessments quickly. NDE inspection sensors are needed for potential use on free-flying inspection platforms. Integration of wireless systems with NDE may be of significant utility. It is strongly encouraged to provide explanation of how proposed techniques and sensors will be applied to a complex structure. Examples of structural components include but are not limited to multi-wall pressure vessels, batteries, tile, thermal blankets, micrometeoroid shielding, International Space Station (ISS) Radiators or other aerospace structural components.

Phase I Deliverables - Lab prototype, feasibility study or software package including applicable data or observation of a measureable phenomena on which the prototype will be built. Inclusion of a proposed approach to develop a given methodology to Technology Readiness Level (TRL) of 2-4. All Phase I's will include minimum of short description for Phase II prototype. It will be highly favorable to include description of how the Phase II prototype or methodology will be applied to structures.

Phase II Deliverables - Working prototype or software of proposed product, along with full report of development and test results. Prototype or software of proposed product should be of Technology Readiness Level (TRL 5-6). Proposal should include plan of how to apply prototype or software on applicable structure or material system. Opportunities and plans should also be identified and summarized for potential commercialization.

H13.02 Advanced Structural Health Monitoring
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC, GSFC, JSC, MSFC

Future manned space missions will require spacecraft and launch vehicles that are capable of monitoring the structural health of the vehicle and diagnosing and reporting any degradation in vehicle capability. This subtopic seeks new and innovative technologies in structural health monitoring (SHM) and integrated vehicle health management (IVHM) systems and analysis tools.

Techniques sought include modular/low mass-volume systems, low power, low maintenance systems, and systems that reduce or eliminate wiring, as well as stand-alone smart-sensor systems that provide processed data as close to the sensor as practical and systems that are flexible in their applicability. Examples of possible system are: Surface Acoustic Wave (SAW)-based sensors, passive wireless sensor-tags, flexible sensors for highly curved surfaces direct-write film sensors, and others. Damage detection modes include leak detection, ammonia detection, micrometeoroid impact and others. Reduction in the complexity of standard wires and connectors and enabling sensing functions in locations not normally accessible with previous technologies is also desirable. Proposed techniques should be capable of long term service with little or no intervention. Sensor systems should be capable of identifying material state awareness and distinguish aging related phenomena and damage related conditions. It is considered advantageous that these systems perform characterization of age-related degradation in complex composite and metallic materials. Measurement techniques 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. Some consideration will be given to the IVHM /SHM ability to survive in on-orbit and deep space conditions, allow for additions or changes in instrumentation late in the design/development process and enable relocation or upgrade on orbit. System should allow NASA to gain insight into performance and safety of NASA vehicles as well as commercial launchers, vehicles and payloads supporting NASA missions. Inclusion of a plan for detailed technical operation and deployment is highly favored.

Phase I Deliverables - Lab prototype or feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 2-4). Plan for Phase II including proposed verification methods.

Phase II Deliverables - Working engineering model or software of proposed product, along with full report of development and test results, including verification methods (TRL 5-6). Opportunities and plans should also be identified and summarized for potential commercialization.

9.1.1 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/).

The following topics and subtopics seek to develop technology to enable science missions in support of these strategic objectives.

TOPIC: S1 Sensors, Detectors and Instruments

NASA's Science Mission Directorate (SMD) (http://nasascience.nasa.gov/) encompasses research in the areas of Astrophysics, Earth Science, Heliophysics and Planetary Science. The National Academy of Science has provided NASA with recently updated Decadal surveys that are useful to identify technologies that are of interest to the above science divisions. Those documents are available at the following locations:

- Astrophysics - (http://sites.nationalacademies.org/bpa/BPA_049810).
- Planetary - (http://solarsystem.nasa.gov/2013decadal/index.cfm).
- Earth Science - (http://science.nasa.gov/earth-science/decadal-surveys/).
- Heliophysics - The 2009 technology roadmap can be downloaded at (http://science.nasa.gov/heliophysics/).

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.

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 of components, subsystems and systems 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 Remote Sensing Technologies
Lead Center: LaRC
Participating Center(s): GSFC, JPL

NASA recognizes the potential of lidar technology in meeting many of its science objectives by providing new capabilities or offering enhancements over current measurements of atmospheric and topographic parameters from ground, airborne, and space-based platforms. To meet NASA's requirements, advances are needed in state-of-the-art lidar technology with an emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar subsystem and component technologies systems that directly address the measurement of atmospheric constituents and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic.

Proposals relevant to the development of lidar instruments that can be used in planned missions or current technology programs are highly encouraged. Examples of planned missions and technology programs are:

- Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS).
- Aerosols-Clouds-Ecosystems (ACE).
- Doppler Wind Lidar (3D-WINDS).
- Laser Interferometer Space Antenna (LISA).
- Ozone Lidar.
- Lidar for Surface Topography (LIST).
- Mars atmospheric sensing, atmospheric entry and descent sensors for Mars and Earth, and tracking large-scale water movement (GRACE-II).

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. Compact, high efficiency lidar instruments for deployment on unconventional platforms, such as balloon, small sat, and cube sat, are also considered and encouraged.

The proposals should target advancement of lidar technologies for eventual space utilization. Phase I research should demonstrate the technical feasibility and show a path toward a Phase II prototype unit. Phase II prototypes should be capable of laboratory demonstration and preferably suitable for operation in the field from a ground-based station, an aircraft platform, or any science platform amply defended by the proposer. For the 2014 SBIR Program, we are soliciting the component and subsystem technologies described below.

Solid state, single frequency, pulsed, laser transmitters operating in the 1.0 µm to1.7 µm range with a wall-plug efficiency of greater than 25% suitable for CO_2 measurement, and free-space laser communication applications. The laser transmitters must be capable of generating frequency transform-limited pulses with a quality beam M^2 of less than 1.5 with an approximately 20 W of average power. We are interested in two different regimes of repetition rates: from 5 kHz to 20 kHz, and from 20 Hz to 100 Hz. In addition, development of non-traditional optical amplifier architectures that yield optical efficiency of >70% are of interest.

Compact and rugged single-frequency CW laser systems operating at 1.06 mm, 1.57 mm, 1.651 mm and 2.05 mm wavelengths suitable for precision space interferometry applications such as LISA, GRACE-II, and coherent detection lidars. The lasers must be developed with space environment considerations and demonstrate a clear path to space. Proposed lasers must be able to generate at least 20 mW of power with less than 10 kHz linewidth over a tunable range of about 50 nm. Systems must be highly wavelength stable and come with full supporting electronic systems for thermal and power control.

Long wavelength solid state laser transmitter technology (e 10 µm) is needed for atmospheric lidar and possible terrain altimeter instruments for Venus. The highly dense atmosphere, volatile clouds, and thick scattering layers make this measurement a low probability event, but should be possible with significant pulse energies at long wavelengths. In combination of large, lightweight receiver, we can maximize the possibility of achieving a round trip remote sensing link from low Venus orbit. Minimum pulse energies of e 100 mJ are needed to reach the surface in the best conditions, such as with periodic holes and gaps in the clouds. Repetition rates of e 10Hz are desired for reasonable footprint spacing should a link be achieved.

Ultra-low noise photo receiver modules, operating either at 1.6 or 2.0 micron wavelengths for measuring CO_2 concentration, comprising of the detection device, complete Dewar/cooling systems, and associated amplifiers. General requirements are: large active detection diameter (>200 micron), high quantum efficiency (>85%), noise equivalent power of the order of 10-14 W/sqrt(Hz), and bandwidth greater than 20 MHz.

Lightweight scanning telescopes capable of a conical pattern with nadir angle fixed in the range of 30 to 45 degrees. The lightweight scanning telescopes are sought for both direct and heterodyne detection wind lidars and tropospheric ozone lidars. For winds, the direct detection lidar operates in 355 nm to 1064 nm wavelength region and the heterodyne detection lidar in 1550 nm to 2050 nm. For ozone, these systems should operate between 280-300 nm. The ozone systems are designed to support NASA's TOLNet network providing data for satellite validation and the study of anthropogenic pollution. High optical efficiency and near diffraction-limited performance are among major considerations. The proposer must show a clear path to space by addressing scalability to apertures greater than 1 m, materials (e.g., substrates and coatings) selection compatible with a space environment, and thermally-stable design. Phase II should result in a prototype unit capable of demonstration in a high-altitude aircraft environment, with aperture of at least 10 inches in diameter.

S1.02 Microwave Technologies for Remote Sensing
Lead Center: GSFC
Participating Center(s): JPL, LaRC

NASA employs active (radar) and passive (radiometer) microwave sensors 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, for planetary landing, upper atmospheric monitoring, and global snow coverage (SCLP). We are seeking proposals for the development of innovative technologies to support these future radar and radiometer missions and applications. The areas of interest for this call are listed below:

- W-band Solid State Power Amplifier: Freq: 94 GHz +/- 500 MHz, Peak power: > 50 W, Duty cycle: > 20 % , Gain: > 40 dB, Gain flatness within band: <+/- 1 dB, Phase linearity within band:< +/- 1 degree, On/off switching speed: < 1 µs, Noise figure: < 15 dB, Spurious: < -60 dBc, Harmonic: < -25 dBc.
- 640 GHz Polarimeter I, Q, U Channels, Polarimetric measurements to provide microphysical parameterization of ice clouds applicable to ACE.
- Broadband low noise cryogenic amplifier operating between 1 and 6 GHz.
- G-band (140-220 GHz) Components: 3-port strip line/CPW based switch (20 dB isolation, 1 dB loss, 1 kHz switching frequency), G-band (140-220 GHz) Components: Isolator with isolation > 15 dB, Insertion loss < 1.2 dB.
- High power Solid-State Ka-band Transmitter: Psat > 200W, Duty Cycle > 20%, DC to RF Efficiency > 30%, Gain > 50 dB.
- Very high-efficiency VHF Power Amplifier for CubeSats: Center frequency range: 40MHz to 100MHz, Fractional bandwidth: 20%, Psat >25W, Gain > 40 dB, Efficiency > 90%.
- Technology for low-power, rad-tolerant broad band spectrometer back ends for microwave radiometers. Includes: digitizers with 20 Gsps, 20 GHz bandwidth, 4 or more EOB and a simple interface to FPGA; ASIC implementations of polyphase spectrometer digital signal processing with ~1 watt/GHz.
- Back ends for microwave radiometers and sounders including compact low power RFI mitigation hardware for upgrading existing systems and low-power, low-mass filter back ends with >5 GHz spectral coverage, 200 MHz resolution, and less than one watt.

S1.03 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/).

- Development of un-cooled or cooled infrared detectors (hybridized or designed to be hybridized to an appropriate read-out integrated circuit) with NEΔT<20mK, QE>30% and dark currents <1.5x10-6 A/cm^2 in the 5-14 µm infrared wavelength region. Array formats may be variable, 640 x 512 typical, with a goal to meet or exceed 2k X 2k pixel arrays. Evolve new technologies such as InAs/GaSb type-II strained layer super-lattices to meet these specifications.
- New or improved technologies leading to measurement of trace atmospheric species (e.g., CO, CH_4, N_2O) or broadband energy balance in the IR and far-IR from geostationary and low-Earth orbital platforms. Of particular interest are new direct, nanowire or heterodyne detector technologies made using high temperature superconducting films (YBCO, MgB_2) or engineered semiconductor materials, especially 2-Dimensional Electron Gas (2-DEG) and Quantum Wells (QW) that operate at temperatures achieved by standard 1 or 2 stage flight qualified cryocoolers and do not require cooling to liquid helium temperatures. Candidate missions are thermal imaging, LANDSAT Thermal InfraRed Sensor (TIRS), Climate Absolute Radiance and Refractivity Observatory (CLARREO), BOReal Ecosystem Atmosphere Study (BOREAS), Methane Trace Gas Sounder or other infrared earth observing missions.
- 1k x 1k or larger format MCT detector arrays with cutoff wavelength extended to 12 microns for use in missions to NEOs, comets and the outer planets.
- Compact, low power, readout electronics for KID arrays. Enables mega pixel arrays for mm to Far IR telescopes and spectrometers for astrophysics and earth observation.
- Development of a robust wafer-level integration technology that will allow high-frequency capable interconnects and allow two dis-similar substrates (i.e., silicon and GaAs) to be aligned and mechanically 'welded' together. Specially develop ball grid and/or Through Silicon Via (TSV) technology that can support

submillimeter-wave arrays. Initially the technology can be demonstrated at the '1-inch' die level but should be do-able at the 4-inch wafer level.

S1.04 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 planetary 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:

- 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.
- Visible-blind SiC Avalanche Photodiodes (APDs) for EUV photon counting are required. The APDs must show a linear mode gain >10E6 at a breakdown reverse voltage between 80 and 100V. The APD's must demonstrate detection capability of better than 6 photons/pixel/s down to 135nm wavelength. See needs of National Research Council's Earth Science Decadal Survey (NRC, 2007): Tropospheric ozone.
- 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 focal planes for JEM-EUSO and OWL ultra-high energy cosmic ray instruments and ground Cherenkov telescope arrays such as CTA, and ring-imaging Cherenkov detectors for cosmic ray instruments such as BESS-ISO. As an example (JEM-EUSO and OWL), 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 (10E4 to 10E6), 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 (2g/cm^2 goal). Individual pixel readout is required. The entire focal plane detector can be formed from smaller, individual sub-arrays.

S1.05 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 CubeSats, ICON, GOLD, 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.
- 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 ASICs including Low-power multi-channel ADCs, DACs, and spectrum analyzer modules that determine 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).
- High efficiency (5% or greater) conversion surfaces for low-energy neutral atom conversion to ions.
- Miniature low-power, high-efficiency, thermionic cathodes, and cold 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.
- APDs in single pixel and multi-pixel. The APDs, typically used for photons, should be optimized for particles including thin dead layer, increased energy range, gain stability and radiation hardness, but with much higher energy resolution (<0.5KeV) compared to SSDs.
- Solar Blind particle detectors less sensitive to light such as silicon carbide based.
- 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.

S1.06 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 and 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 that support NASA's New Frontiers 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 dust environment measurements and particle analysis, small body resource identification, and/or quantification of potential small body resources (e.g., oxygen, water and other volatiles, hydrated minerals, carbon compounds, 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.
- 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 and 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 and 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.

S1.07 Airborne Measurement Systems
Lead Center: GSFC
Participating Center(s): ARC, JPL, KSC, LaRC, MSFC, SSC

Measurement system miniaturization and/or increased performance is needed to support for NASA's airborne science missions, particularly those utilizing the Global Hawk, SIERRA, Dragon Eye or other unmanned aircraft. The subject airborne instruments are intended as calibration/validation systems - the proposers should demonstrate an understanding of the measurement requirements and be able to link those to instrument performance. Linkages to other subtopics such as S3.04 Unmanned Aircraft and Sounding Rocket Technologies are encouraged. Complete instrument systems are desired, including features such as remote/unattended operation and data acquisition, low power consumption, and minimum size and weight. Desired sensors include:

- Precipitation- multiphase (0.1 mm to 20 mm with 5 % accuracy in three dimensions).
- Surface snow thickness (5 cm resolution).
- Aerosols and cloud particles (0.01 micron to 200 micron with 10 % accuracy).
- Volcanic ash (0.25 to 100 micron with 10 % accuracy).
- Sulfur dioxide (4 ppb resolution).
- Carbon dioxide (1 ppm accuracy).
- Methane (5 ppm accuracy, 10 ppm precision).
- Three-dimensional wind measurement (1 mps accuracy/resolution at 10 Hz sampling).

S1.08 Surface and Sub-surface Measurement Systems
Lead Center: GSFC
Participating Center(s): ARC, JPL, KSC, LaRC, MSFC, SSC

Relevance to future space missions such as Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS), Orbiting Carbon Observatory – 2 (OCO-2), Global Precipitation Measurement (GPM), Geostationary Coastal and Air Pollution Events (GEO-CAPE), Hyperspectral InfraRed Imager (HyspIRI), Aerosol, Cloud, Ecosystems (ACE, including Pre-ACE/PACE), etc., is important, yet early adoption for alternative uses by NASA, other agencies, or industry is recognized as a viable path towards full maturity. Additionally, sensor system innovations with significant near-term commercial potential that may be suitable for NASA's research after full development are of interest:

- Precipitation (e.g., motion stabilized disdrometer for shipboard deployments).
- Suspended particle concentrations and spectra of mineral and biogenic (phytoplankton and detritus) components.
- Gases - carbon dioxide, methane, etc.
- Miniaturized air-dropped sensors, suitable for Global Hawk deployment, for ocean surface and subsurface measurements such as conductivity, temperature, and depth. Miniature systems suitable for penetration of thin ice are highly desirable.
- Multi-wavelength, LIDAR-based, atmospheric ozone and aerosol profilers for continuous, simultaneous observations from multiple sites. Examples include three-band ozone measurement systems operating in the UV spectrum (e.g., 280-316 nm, possibly tunable), combined with visible or infrared systems for aerosols. Remote/untended operation, minimum eye-hazards, and portability are desired.
- Miniaturized and novel instrumentation for measuring inherent and apparent optical properties (specifically to support vicarious calibration and validation of ocean color satellites, i.e., reflectance, absorption, scattering), in situ biogeochemical measurements of marine and aquatic components and rates including but not limited to nutrients, phytoplankton and their functional groups, and floating and submerged aquatic plants.

Novel geophysical and diagnostic instruments suitable for ecosystem monitoring. Fielding for NASA's Applications and Earth Science Research activities is a primary goal. Innovations with future utility for other NASA programs (for example, Planetary Research) that can be matured in an Earth science role are also encouraged.

S1.09 Atomic Interferometry
Lead Center: JPL
Participating Center(s): GSFC

Recent developments of laser control and manipulation of atoms have led to a new type of precision inertial force and gravity sensors based on atom interferometry. Atom interferometers exploit the quantum mechanical wave nature of atomic particles and quantum gases for sensitive interferometric measurements. Ground-based laboratory experiments and instruments have already demonstrated beyond the state of the art performances of accelerometer, gyroscope, and gravity measurements. Microgravity environment in space provides opportunities for further drastic improvements in sensitivity and precision. Such inertial sensors will have great potential to provide new capabilities for NASA Earth and planetary gravity measurements, for spacecraft inertial navigation and guidance, and for gravitational wave detection and test of properties of gravity in space.

Currently the most mature development of atom interferometers as measurement instruments are those based on light pulsed atom interferometers with freefall cold atoms. There remain a number of technical challenges to infuse this technology in space applications. Some of the identified key challenges are (but not limited to):

- Compact high flux ultra-cold atom sources for free space atom interferometers ($>1x10^6$ total useful free-space atoms, <1 nK, Rb, K, Cs, Yb, Sr, and Hg are example candidates but others can be justified by the offeror).
- Ultra-high vacuum seal technologies that allow completely sealed, non-magnetic enclosures with high quality optical access (base pressure maintained $<1x10^{-9}$ torr, consideration should be given to the inclusion of cold atom sources of interest).
- Beyond the state-of-the-art photonic components at wavelengths for atomic species of interest, particularly at NIR and visible: efficient acousto-optic modulators (low rf power ~ 200 mW or less, low thermal distortion, ~80$ or greater diffraction efficiency); efficient electro-optic modulators (low bias drift, residual AM, and return loss, fiber-coupled preferred), miniature optical isolators (~30 dB isolation or greater, ~ -2 dB loss or less), robust high-speed high-extinction shutters (switching time < 1 ms, extinction > 60 dB are highly desired).

- Flight qualifiable lasers of narrow linewidth and higher power for clock and cooling transitions of atomic species of interest. Clock lasers: 1 $Hz/s^{1/2}$ at 1 s, ~ 1W output power or greater; Cooling and trapping lasers: 10 kHz linewidth and ~ 1 W or greater.
- Analysis and simulation tool of cold atom system in trapped and freefall states relevant to atom interferometer and clock measurements in space.

The subsystem technology development proposals should clearly state the relevance, define requirements, relevant atomic species and working laser wavelengths, and indicate its path to a space-borne instrument.

Recognizing the fact that the field of atom interferometry is an active research field and there are potential breakthrough approaches still being investigated in research laboratories, NASA is also interested in new ideas of atom interferometry that will lead to better and smaller inertial sensors for rotational sensors, accelerometers, and gravity measurement instruments and will benefit and enable future NASA space missions. Therefore, this subtopic call is also soliciting practical approaches to new sensor ideas that may have high risk but can have high payoffs. Some of the known examples are:

- Bose Einstein condensate based sensors.
- Sensors using large momentum transfer.
- Guided atom wave sensors.
- Non-classical atom interferometers.
- Any other cold atom-based sensor technology such as optical clocks.

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 light-weight 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 °K. 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 telescopes for Earth science.

S2.01 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

- Image plane hybrid metal/dielectric, and polarization apodization masks in linear and circular patterns.
- Transmissive holographic masks for diffraction control and PSF apodization.
- Sharp-edged, low-scatter pupil plane masks.
- Low-scatter, low-reflectivity, sharp, flexible edges for control of scatter in starshades.
- Systems to measure spatial optical density, phase inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of high-dynamic range apodizing masks.
- Pupil remapping technologies to achieve beam apodization.
- Techniques to characterize highly aspheric optics.
- Methods to distinguish the coherent and incoherent scatter in a broad band speckle field.
- Coherent fiber bundles consisting of up to 10,000 fibers with lenslets on both input and output side, such that both spatial and temporal coherence is maintained across the fiber bundle for possible wavefront/amplitude control through the fiber bundle.

Wavefront Measurement and Control Technologies

- Small stroke, high precision, deformable mirrors and associated driving electronics scalable to 10,000 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.
- Instruments to perform broad-band sensing of wavefronts and distinguish amplitude and phase in the wavefront.
- Integrated mirror/actuator programmable deformable mirror.
- Multiplexers with ultra-low power dissipation for electrical connection to deformable mirrors.
- Low-order wavefront sensors for measuring wavefront instabilities to enable real-time control and post-processing of aberrations.
- Thermally and mechanically insensitive optical benches and systems.

Optical Coating and Measurement Technologies

- Instruments capable of measuring polarization cross-talk and birefringence to parts per million.
- Highly reflecting, uniform, broadband coatings for large (> 1 m diameter) optics.
- Polarization-insensitive coatings for large optics.
- Methods to measure the spectral reflectivity and polarization uniformity across large optics.

Other

- Methods to fabricate diffractive patterns on large optics to generate astrometric reference frames.
- Artificial star and planet point sources, with 1e10 dynamic range and uniform illumination of an f/25 optical system, working in the visible and near infrared.
- Deformable, calibrated, collimating source to simulate the telescope front end of a coronagraphic system undergoing thermal deformations.
- Technologies for high contrast integral field spectroscopy, in particular for microlens arrays with or without accompanying mask arrays, working in the visible and NIR (0.4 - 1.8 microns), with lenslet separations in the 0.1 -0.4 mm range, in formats of ~140x140 lenslets.

S2.02 Precision Deployable Optical Structures and Metrology
Lead Center: JPL
Participating Center(s): GSFC, LaRC

Planned future NASA Missions in astrophysics, such as the 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) requires 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.

Before embarking on the design and fabrication of complex space-based deployable telescopes, additional risk reduction in operating an actively controlled telescope in orbit is desired. To be cost effective, deployable apertures that conform to a cubesat (up to 3-U) or ESPA format are desired. Consequently, deployment hinge and latching concepts, buildable for these missions and scaleable to larger systems are desired. Such a system should allow <25 micron deployment repeatability and sub-micron stability for both thermal and mechanical on-orbit disturbances. A successful proposal would deliver a full-scale cubesat or ESPA ring compatible deployable aperture with mock optical elements.

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).

S2.03 Advanced Optical Systems
Lead Center: MSFC
Participating Center(s): GSFC, JPL

This subtopic solicits solutions in the following areas:

- Optical Components, Coatings and Systems for potential x-ray missions.

- Optical Components, Coatings and Systems for potential UV/Optical missions.

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.

The primary emphasis of this subtopic is to mature technologies needed to manufacture, test or operate complete mirror systems or telescope assemblies. Section 3 contains a detailed discussion on specific technologies which need developing for each area.

The 2010 National Academy Astro2010 Decadal Report specifically identifies optical components and coatings as key technologies needed to enable several different future missions, including:

- Light-weight x-ray imaging mirrors for future large advanced x-ray observatories.
- Large aperture, light-weight mirrors for future UV/Optical telescopes.
- Broadband high reflectance coatings for future UV/Optical telescopes.

The 2012 National Academy report “NASA Space Technology Roadmaps and Priorities” states that one of the top technical challenges in which NASA should invest over the next five years is developing a new generation of larger effective aperture, lower-cost astronomical telescopes that enable discovery of habitable planets, facilitate advances in solar physics, and enable the study of faint structures around bright objects. To enable this capability requires low-cost, ultra-stable, large-aperture, normal and grazing incidence mirrors with low mass-to-collecting area ratios. To enable these new astronomical telescopes, the report identifies three specific optical systems technologies:

- Active align/control of grazing-incidence imaging systems to achieve < 1 arc-second angular resolution.
- Active align/control of normal-incidence imaging systems to achieve 500 nm diffraction limit (40 nm rms wavefront error, WFE) performance.
- Normal incidence 4-meter (or larger) diameter 5 nm rms WFE (300 nm system diffraction limit) mirrors.

Finally, impacting potential space telescopes, NASA is developing a heavy lift space launch system (SLS). An SLS with an 8 to 10 meter fairing and 80 to 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 < 0.5 arc-sec and surface micro-roughness < 0.5-nm rms.

Technical Challenges:

In all cases, the most important metric for an advanced optical system (after performance) is affordability or areal cost (cost per square meter of collecting aperture). Currently both x-ray and normal incidence space mirrors cost \$4 million to \$6 million per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 5 to 50 times, to less than \$1M to \$100K/m^2.

Successful proposals shall provide a scale-up roadmap (including processing and infrastructure issues) for full scale space qualifiable flight optics systems. Material behavior, process control, active and/or passive optical performance, and mounting/deploying issues should be resolved and demonstrated.

Optical Components, Coatings and Systems for Potential X-ray Missions

Potential x-ray missions require:

- X-ray imaging telescopes with <1 arc-sec angular resolution and > 1 to 5 m^2 collecting area.
- Multilayer high-reflectance coatings for hard x-ray mirrors (similar to NuSTAR).
- X-ray transmission and/or reflection gratings.

Regarding x-ray telescope, multiple technologies are needed to enable < 1 arc-sec x-ray observatories. These include, but are not limited to: new materials such as silicon carbide, porous silicon, beryllium; improved techniques to manufacture (such as direct precision machining, rapid optical fabrication, slumping or replication technologies) 0.3 to 2 meter diameter mirror shells or segments; improved metrology, performance prediction and testing techniques; active control of mirror shape; new structures for holding and actively aligning of mirrors in a telescope assembly.

For example, the Wide-Field X-Ray Telescope (WFXT) requires a 6 meter focal length x-ray mirror with 1 arc-sec resolution and 1 m^2 of collecting area. One implementation of this mirror has 71 concentric full shell hyperbola/parabola pairs whose diameters range from 0.3 to 1.0 meter and whose length is 150 to 240 mm (this length is split between the H/P pair). Total mass for the integrated mirror system (shells and structure) is < 1000 kg. For individual mirror shells, axial slope errors should be ~ 1 arc-sec rms (~100 nm rms figure error for 20 mm spatial frequencies) and surface finish should be < 0.5 nm rms.

Additionally, potential Heliophysics missions require a grazing incidence telescope with an effective collecting area of ~3 cm^2 for 0.1 to 4 nm wavelengths, 4 meter effective focal length, 0.8 degree angle of incidence and surface roughness of 0.2 nm rms.

Regarding x-ray coatings, future x-ray missions require multilayer depth gradient coatings with high broadband reflectivity for 5 to 80 keV energy photons.

Regarding improved metrology and performance prediction, technology is needed to fully characterize x-ray mirrors (and mandrels) and predict their angular resolution performance. Potential solutions include (but are not limited to): both sub-aperture stitching (in the lateral direction) to acquire data over the entire optical surface, and merging/interpolating data with different spatial frequency domains. This can be done using different surface measuring instruments with different fields of view and resolutions.

Successful proposals will demonstrate an ability to manufacture, test and control a prototype 0.25 to 0.5 meter diameter x-ray mirror assembly; or, to coat a 0.25 to 0.5 meter class representative optical component; or, to characterize and performance predict a 0.5 to 1.0 meter class x-ray mirror or mandrel. An ideal Phase I project would deliver a sub-scale component such as a 0.25 meter x-ray precision mirror; or demonstrate a prototype metrology system capable of characterizing the optical surface morphology of an x-ray component and predicting its angular performance. An ideal Phase II project would further advance the technology to produce a space-qualifiable 0.5 meter mirror, with a TRL in the 4 to 5 range; or deliver a metrology system capable of characterizing 0.5 to 1.0 meter class x-ray mirrors (or mandrels) and predicting their angular resolution performance. Both Phase I and Phase II 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.

Optical Components, Coatings and Systems for Potential UV/Optical Missions

Potential UV/Optical missions require:

- Large aperture, light-weight mirrors.
- Broadband high reflectance coatings.

Regarding large aperture mirrors, future UVOIR missions require 4 to 8 or 16 meter monolithic 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).

Regarding broadband reflectance coating, future UVOIR missions require coatings with broadband reflectivity > 60% and uniform polarization from 90 nm to 2500 nm which can be deposited onto a 2 to 4 to 8 meter mirror substrate. Additionally, the coatings need to have > 90% reflectivity from 450 nm to 2500 nm. Future EUV missions require coatings with reflectivity > 90% from 6 nm to 200 nm which can be deposited onto mirror substrates as large as 2.4 meters in diameter.

Successful proposals will demonstrate an ability to manufacture, test and control ultra-low-cost precision 0.25 to 0.5 meter optical systems; or to coat a 0.25 to 0.5 meter representative optical component. Potential solutions include, but are not limited to, new mirror materials such as silicon carbide, nanolaminates or carbon-fiber reinforced polymer; 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 mirrors or lens segments. 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.

Potential solutions to improve UV reflective coatings include, but are not limited to, investigations of new coating materials with promising UV performance; new deposition processes; and examination of handling processes, contamination control, and safety procedures related to depositing coatings, storing coated optics, and integrating coated optics into flight hardware. An ability to demonstrate optical performance on 2 to 3 meter class optical surfaces is important.

An ideal Phase I deliverable would be a precision mirror of at least 0.25 meters; or a coated mirror of at least 0.25 meters. An ideal Phase II project would further advance the technology to produce a space-qualifiable mirror greater than 0.5 meters, with a TRL in the 4 to 5 range. Both Phase I and Phase II 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.

S2.04 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:

- WFIRST concepts (http://wfirst.gsfc.nasa.gov/).
- NGXO (http://ixo.gsfc.nasa.gov/).
- SGO (http://lisa.gsfc.nasa.gov/).

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. Also, novel metrological solutions that can measure figure errors over a large fraction of the PSD range are desired, especially techniques and instrumentation that can perform measurements while the optic is mounted to the figuring/polishing machine. Large lightweight monolithic metallic aspheres manufactured using innovative mirror substrate materials that can be assembled and welded together from smaller segments are sought. Also of interest is analytical software to process, fit, and model large optics surface metrology data with the goals to characterize surface morphology over spatial frequency bandwidths determined by the desired angular resolution performance; to provide stitched metrology capabilities obtained with different surface measuring instruments with different fields of view and resolution; to provide a data analysis tool for defining the optical surface fabrication tolerances based on the desired x-ray optics angular resolution performance; to allow forecasting of the surface morphological properties of optics.

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 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.
- Innovative method of bonding extremely lightweight (less than 1 kg/m^2 areal density) and thin (less than 1 mm) mirrors to a housing structure, preserving both alignment and figure.
- Innovative method of improving the figure of extremely lightweight and thin mirrors without polishing, such as using the coating stress.
- Manufacturing technology and wavefront sensing and control as applied to coronagraph applications for exoplanet detection.

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 2014 are sought in the areas of:

- Command and Data Handling, and Instrument Electronics.
- Power Generation and Conversion.
- Propulsion Systems for Robotic Science Missions.
- Power Electronics and Management, and Energy Storage.
- Unmanned Aircraft and Sounding Rocket Technologies.
- Thermal Control Systems.
- Guidance, Navigation and Control.
- Terrestrial and Planetary Balloons.

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 115 °C or higher, non-functioning); penetrating radiation (requirements not yet established); or vapor-phase hydrogen peroxide (specification pending). 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).

S3.01 Power Generation and Conversion
Lead Center: GRC
Participating Center(s): ARC, JPL, JSC

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.

Thermoelectric Power Conversion: advances in, but not limited to, the following:

- Advanced bulk materials enabling demonstration of high efficiency thermoelectric energy conversion (>15%) when using high grade space-qualified heat sources (> 1000 K).
- Advanced thermoelectric couple and module component technologies that will facilitate integration of new high performance materials into high reliability, high temperature long life systems, such as: thermally stable, low resistance and mechanically compliant interface structures, advanced lightweight thermal insulation materials and stable thermoelectric material encapsulation coatings.
- Advanced concepts capable of taking advantage of miniature space-qualified heat sources (~ 1Wth class) and compatible with very high g loadings at the system level (> 10,000 g) as well as operation in extreme environments (temperature, radiation).

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. Photovoltaic technologies that provide enhancing and/or enabling capabilities for a wide range of aerospace mission applications will be considered. Technologies that address specific NASA Science mission needs include:

- 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.

S3.02 Propulsion Systems for Robotic Science Missions
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://solarsystem.nasa.gov/multimedia/download-detail.cfm?DL_ID=742). 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 and low-power, nuclear electric propulsion (NEP) missions. Roadmaps for propulsion technologies can be found from the National Research Council (http://www.nap.edu/openbook.php?record_id=13354&page=168) and NASA’s Office of the Chief Technologist (http://www.nasa.gov/pdf/501329main_TA02-InSpaceProp-DRAFT-Nov2010-A.pdf).

The focus of this solicitation is for next generation propulsion systems and components, including micropropulsion rocket technologies, and low cost/low mass electric propulsion technologies. Propulsion technologies related specifically to Power Processing Units will be sought under S3.03 Power Electronics and Management, and Energy Storage and should not be submitted to this subtopic.

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 fully develop a technology and infuse it into a NASA program.

Electric Propulsion Systems

This subtopic also seeks proposals that explore uses of technologies that will provide superior performance in high specific impulse/low mass electric propulsion systems at low cost. These technologies include:

- Long-life thrusters and related system components with efficiencies > 55% and up to 1 kW of input power that operate with a specific impulse between 1600 to 3500 seconds to enable radioisotope electric propulsion.

- Any long-life, electric propulsion technology between 1 to 10 kW/thruster that would enable a low-power nuclear electric propulsion system based on a kilopower nuclear reactor.

Mini-satellite Propulsion Systems

This subtopic also seeks proposals that address the propulsion for spacecraft 180-1000 kg. It is desired that the capability of plane-changing or de-orbiting in a timely manner be achieved. These system or component technologies would likely be:

- Low mass and low volume fractions.
- Wide range of delta-V capability to provide 100-1000s of m/s.
- Wide range of specific impulses up to 1000s of seconds.
- Precise thrust vectoring and low vibration for precision maneuvering.
- Efficient use of onboard resources (i.e., high power efficiency and simplified thermal and propellant management).
- Affordability.
- Safety for users and primary payloads.

Small Satellite/CubeSat Propulsion

The small satellite (<180kg) market shows significant promise to enable low cost science missions. Launch vehicle providers, like SLS, are considering a large number of secondary payload opportunities. The majority of small satellite missions flown are often selected for concept or component demonstration activities as the primary objectives. Opportunities are anticipated to select future small satellite missions based on application goals (i.e., science return). However, several technology limitations prevent high value science from low-cost small spacecraft, such as post deployment propulsion capabilities. Additionally, propulsion systems often place constraints on handling, storage, operations, etc., that may limit secondary payload consideration.

Specifically, proposals are sought for propulsion systems capable of full scale flight demonstration on 12U CubeSats or smaller; to enable science through secondary payloads carried by SLS or other launch vehicles. Mission applications can be extended up to ESPA based or up to 180kg spacecraft.

Proposals are sought that can deliver hardware products and proof-of-concept demonstrations in Phase I. Proposals are sought that can deliver hardware at or greater than TRL 6 suitable for flight demonstration within the Phase II resources provided. Propulsion systems requiring Phase II-E or II-X funding will be considered if justified through enabling mission capabilities.

Specific propulsion technologies of interest to interplanetary small satellites include:

- Moderate to high specific impulse propulsion systems.
- High specific impulse - density solutions.
- Systems that require no pressurization prior to operations.
- Systems that place no demanding storage requirements prior to launch.
- Systems than can remain quiescent under ambient conditions for extended durations (>6 months) prior to launch.

In addressing technology requirements, proposers should identify potential mission applications and quantify the expected advancement over state-of-the-art alternatives.

Note to Proposer: Topic H2 under the Human Exploration and Operations Directorate also addresses advanced propulsion. Proposals more aligned with exploration mission requirements should be proposed in H2.

S3.03 Power Electronics and Management, and Energy Storage
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC

Future NASA science objectives will include missions such as Earth Orbiting, Venus, Europa, Titan/Enceladus Flagship, Lunar Quest and Space Weather. 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 which could potentially benefit from these technology developments include S4.04 Extreme Environments Technology, and S4.01 Planetary Entry, Descent and Landing Technology. This subtopic is also directly tied to S3.02 Power Electronics and Management, and Energy Storage 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://www8.nationalacademies.org/ssbsurvey/publicview.aspx), 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 which 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 °C to over 450 °C) with a number of thermal cycles. Novel approaches to minimizing the weight of advanced PPUs are also of interest. Advancements are sought for power electronic devices, components, packaging and cabling 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 two programs each year.

Overall technologies of interest include:

- High voltage, radiation hardened, high temperature components.
- High power density/high efficiency power electronics and associated drivers for switching elements.
- Lightweight, highly conductive power cables and/or cables integrated with vehicle structures.
- Intelligent management and fault-tolerant electrical components and PMAD systems.
- Advanced electronic packaging for thermal control and electromagnetic shielding; integrated packaging technology for modularity.

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 mechanical or magnetic energy storage devices, 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.

Patent 6,461,944, Methods for growth of relatively large step-free SiC crystal surfaces Neudeck, et al., October 8, 2002.

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.

S3.04 Unmanned Aircraft and Sounding Rocket Technologies
Lead Center: GSFC
Participating Center(s): ARC, DFRC, GRC, JPL, KSC, LaRC

Unmanned Aircraft Systems

Breakthrough technologies that will enhance performance and utility of NASA’s Airborne Science fleet with expanded use of unmanned aircraft systems (UAS) are sought. Desired performance envelope expansion over existing capabilities includes lower and higher altitudes, longer range and endurance, and flight in hazardous conditions (hurricanes, tornadoes, and volcano plumes, for example). Novel airborne platforms incorporating tailored sensors and instrumentation suitable for supporting NASA’s Earth science research goals are encouraged. Additionally, innovative subsystem elements that will support existing or future UAS are desired. Potential concepts include:

- Coordinated (Matrixed) Platforms: Systems that enable multiple measurements from several vantage points to increase spatial and temporal coverage.
- Optical or radio frequency system networks that will enable multiple unmanned aircraft systems to communicate with a global communication systems.
- Sense and avoid systems that enable flights in the National Airspace System.
- Attitude and navigation control for highly turbulent conditions.
- Low cost, high precision inertial navigation systems (< 0.10 degree accuracy, resolution).
- Small, easily transportable systems requiring a crew of one or two.
- Novel propulsion approaches targeting increased range and endurance, flight in adverse conditions, reduced operating costs, and/or minimum sampling contamination (NASA’s SIERRA requires 25 to 40 hp, for example).
- Guided Dropsondes.

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:

- High data rate telemetry and on board recording (greater than 20Mb/s).
- High-accuracy, small, and affordable attitude, acceleration, and rate sensors for guidance, navigation and control systems.
- High capacity, small, light-weight, operationally safe, and affordable batteries for on-board power systems.
- 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.

S3.05 Guidance, Navigation and Control
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC

NASA seeks innovative, ground breaking, and high impact developments in spacecraft guidance, navigation, and control technologies in support of future science and exploration mission requirements. This subtopic covers the technologies enabling significant performance improvements over the state of the art in the areas of positioning, navigation, timing, attitude determination, and attitude control. Component technology developments are sought for the range of flight sensors, actuators, and associated algorithms and software required to provide these improved capabilities. Technologies that apply to a range of spacecraft platform sizes, from large, to mid-size, to emerging smallsat-cubesat class spacecraft are desired.

Advances in the following areas are sought:

- Navigation systems: Autonomous onboard flight navigation sensors and algorithms incorporating a range of measurements from GNSS measurements, ground-based optical and RF tracking, and celestial navigation. Also relative navigation sensors enabling precision formation flying and astrometric alignment of a formation of vehicles relative to a background starfield.
- Attitude Determination and Control Systems: Sensors and actuators that enable milli-arcsecond class pointing capabilities for large space telescopes, with improvements in size, weight, and power requirements. Also lightweight, compact sensors and actuators that will enable pointing performance comparable to large platforms on lower cost, small spacecraft.

Proposals should address the following specific technology needs:

- Precision attitude reference sensors, incorporating optical, inertial, and x-ray measurements, leading to significant increase in accuracy and performance over the current state of the art.
- Autononomous navigation sensors and algorithms applicable to missions in HEO orbits, cis-lunar orbits, and beyond earth orbit. Techniques using above the constellation GNSS measurements, as well as measurements from celestial objects.
- Compact, low power attitude determination and control systems for small satellite platforms, including ESPA (EELV Secondary Payload Adapter) class spacecraft and smaller, university standard cubesat form factors.
- Relative navigation sensors for spacecraft formation flying and autonomous rendezvous with asteroids. Technologies applicable to laser beam steering and pulsed lasers for LIDAR.

Proposals should show an understanding of one or more relevant science or exploration needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.06 Terrestrial and Planetary Balloons
Lead Center: GSFC
Participating Center(s): JPL

Terrestrial Balloons

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 two key areas:

- *Power Storage* - Improved devices to store electrical energy onboard balloon payloads are needed. Long duration balloon flights can experience 12 hours or more of darkness, and excess electrical power generated during the day from solar panels needs to be stored and used. Improvements are needed over the current state of the art in power density, energy density, overall size, overall mass and/or cost. Typical parameters for balloon are 28 VDC and 100 to 1000 watts power consumption. Rechargeable batteries are presently used for balloon payload applications. Lithium Ion rechargeable batteries with energy densities of 60 watt-hours per kilogram are the current state of the art.
- *Satellite Communications* - Improved downlink bitrates using satellite relay communications from balloon payloads are needed. Long duration balloon flights currently utilize satellite communication systems to relay science and operations data from the balloon to ground based control centers. The current maximum downlink bit rate is 150 kilobits per second operating continuously during the balloon flight. Future requirements are for bit rates of 1 megabit per second or more. Improvements in bit rate performance, reduction in size and mass of existing systems, or reductions in cost of high bit rate systems are needed. TDRSS and Iridium satellite communications are currently used for balloon payload applications. A commercial S-band TDRSS transceiver and mechanically steered 18 dBi gain antenna provide 150 kbps continuous downlink. TDRSS K-band transceivers are available but are currently cost prohibitive. Open port Iridium service is under development, but the operational cost is prohibitive.

Planetary Balloons

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 mechanically or electronically 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: dish antenna diameter of 0.8 m (or equivalent non-dish gain), total mass of antenna and pointing system of ≤ 10 kg, power consumption for the steering system ≤ 5 W (avg.), pointing accuracy ≤ 0.5 deg (continuous), hemispheric pointing coverage (2 pi steradians), azimuthal and rotational slew rates ≥ 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.
- *Altitude-Cycling Balloons for Venus* - NASA is interested in Venus balloons that continuously cycle across a wide altitude range without the use of ballast drops. Such balloons not only enable scientific measurements at different altitudes, they also enable the periodic cooling of the payload during the time spent at the highest altitude. Innovative concepts and system-level solutions are sought for such an altitude cycling Venus balloon with the following characteristics: a minimum cycling altitude of 45 km or lower, a maximum cycling altitude

of 58 km or higher, a balloon large enough to carry a 100 kg payload, and a flight duration of at least 14 (Earth) days comprising both day and night conditions. It is expected that a Phase I effort will consist of a complete system-level design and a proof-of-concept experiment on one or more key components.

S3.07 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 cross-cutting thermal control discipline are sought in the following areas:

- Future highly integrated electronics for CubeSat/SmallSat will drastically increase the performance per unit volume, mass and power of electronics systems. High flux heat acquisition and transport devices are required. In addition, high conductivity, vacuum-compatible interface materials are needed in order to reduce interface temperature gradients and facilitate efficient heat removal.
- Components of advanced small spacecraft such as CubeSat/SmallSat will have very small masses (i.e., small thermal capacitance), and their temperatures are highly sensitive to variations in the component power output and spacecraft environmental temperature. Advanced thermal devices capable of maintaining components within their specified temperature ranges are needed. Some examples are:
    - Phase change systems with high thermal capacity, low volume and low mass for endothermic/exothermal thermal management and conditioning.
    - Durable thermal coatings with low absorptance, variable emmittance, and good electrical conductivity.
    - High performance, low cost insulation systems for diverse environments.
    - Passive radiator turn-down devices to enable variation of heat rejection rates.
- Advanced thermal control systems with easily adaptable/reconfigurable thermal management architectures are needed in order to accommodate multiple heat sources and multiple heat sinks, particularly a thermal system that can facilitate heat sharing among on and off components and heat dissipation among multiple radiators placed on various locations on the spacecraft surface. Also needed are improved design and analysis tools for rapid design, integration and testing, and flight operations.
- Thermal control systems for long duration operation are needed, including long life pumps, single-phase and two-phase mechanically pumped fluid systems, components adaptable to distributed heat acquisition and rejection in diverse environments such as high radiation doses (Europa, etc.), and novel heat lift capabilities that enable operation in warm environments.
- Advanced detectors and optical systems at infrared wavelengths require efficient cooling methods to low temperatures. Advanced cryogenic thermal devices for precision temperature measurement and control over much larger sensor areas than currently possible are needed.

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 H3.01 Thermal Control for Future Human Exploration Vehicles, under the Human Exploration and Operations Mission Directorate, also addresses thermal control technologies. Proposals more aligned with exploration mission requirements should be proposed in H3.01.

TOPIC: S4 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://mars.nasa.gov/msl/mission/technology/) 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 115 °C or higher, non-functioning); penetrating radiation (requirements not yet established); or vapor-phase hydrogen peroxide (specification pending).

S4.01 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 subtopic 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 of 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 situational awareness during landing by identifying hazards (rocks, craters, slopes) and/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.
- For a sample-return mission, monitoring local environmental (weather) conditions on the surface prior to landing of a "fetch" rover or launch of a planetary ascent vehicle, 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.

S4.02 Robotic Mobility, Manipulation and Sampling
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC

Technologies for robotic mobility, manipulation, and sampling are needed to enable access to sites of interest and acquisition and handling of samples for in-situ analysis or return to Earth from planetary and solar system small bodies including Mars, Venus, comets, asteroids, and planetary moons.

Mobility technologies are needed to enable access to crater walls, canyons, gullies, sand dunes, and high rock density regions for planetary bodies where gravity dominates, such as the Moon and Mars. Trafficability challenges include steep terrain, obstacle size, and low soil cohesion. Tethered systems, non-wheeled systems, and marsupial systems are examples of mobility technologies that are of interest. Technologies to enable mobility on small bodies in micro-gravity environments are also of interest.

Manipulation technologies are needed to enable deployment of sampling tools and handling of samples. Mars mission sample-handling technologies are needed to enable transfer and storage of a range of rock and regolith cores approximately 1cm long and up to about 10cm long. Small-body mission manipulation technologies are needed to deploy sampling tools to the surface and transfer samples to in-situ instruments and sample storage containers.

Sample acquisition tools are needed to acquire samples on planetary and small bodies. For Mars, a coring tool is needed to acquire rock and regolith cores approximately 1cm diameter and up to 10cm long which also supports transfer of the samples to a sample handling system. Abrading bits for the tool are needed to provide rock-surface abrasion capability to better than 0.2mm scale roughness. A deep drill is needed to enable sample acquisition from the subsurface including rock cores to 3m depth and icy samples from deeper locations. Tools for sampling from asteroids and comets are needed which support transfer of the sample for in-situ analysis or sample return. Tools for acquisition and transfer of icy samples on Europa are also of interest. Minimization of mass and ability to work reliably in the harsh mission environment are important characteristics for the tools. Example environmental conditions include microgravity for small-body missions, high temperature and pressure (460 °C, 93bar) on Venus, and at Europa the radiation environment is estimated at 2.9 Mrad total ionizing dose (TID) behind 100 mil thick aluminum.

Contamination control and planetary protection are important considerations for sample acquisition and handling technologies. Contamination may include Earth-source contaminants produced by the sampling tool, handling system, or deposited on the sampling location from another source on the rover. "Cleaning to sterility" technologies are needed that will be compatible with spacecraft materials and processes. Surface cleaning validation methods are needed that can be used routinely to quantify trace amounts (~ng/cm^2) of organic contamination and submicron particle (~100nm size) contamination. Priority will be given to cleaning and sterilization methods that have potential for in-situ applications.

Component technologies for low-mass and low-power systems tolerant to the in-situ environment are of particular interest. Technical feasibility should be demonstrated during Phase I and a full capability unit of at least TRL 4 should be delivered in Phase II. 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. Specific areas of interest include the following:

- Six-axis force-torque sensors for 100g and 35kg payloads.
- Steep terrain adherence.
- Tether play-out and retrieval systems including tension and length sensing.
- Low-mass tether cables with power and communication.
- Sampling system deployment mechanisms.
- Low mass/power vision systems and processing capabilities that enable faster surface traverse.
- Modular actuators and actuators for harsh environments.
- Abrading bit providing smooth surface preparation.
- Small body sampling tool.
- Cleaning to sterility technologies that will be compatible with spacecraft materials and processes.

- Surface cleaning validation technology to quantify trace amount (~ng/cm^2) of organic contamination and submicron particle (~100nm size) contamination.
- Sample handling technologies that minimize cross contamination and preserve mechanical integrity of samples.

S4.03 Spacecraft Technology for Sample Return Missions
Lead Center: JPL
Participating Center(s): GRC

NASA plans to perform sample return missions from a variety of scientifically important targets including Mars, small bodies such as asteroids and comets, and outer planet moons. These types of targets present a variety of spacecraft technology challenges.

Some targets, such as Mars and some moons, have relatively large gravity wells and will require ascent propulsion. Includes propellants that are transported along with the mission or propellants that can be generated using local resources.

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 (-270 °C), dust, and ice particles.

Technology innovations should either enhance vehicle capabilities (e.g., increase performance, decrease risk, and improve environmental operational margins) or ease sample return mission implementation (e.g., reduce size, mass, power, cost, increase reliability, or increase autonomy).

S4.04 Extreme Environments Technology
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC, MSFC

NASA is interested in expanding its ability to explore the deep atmosphere and surface of giant planets, asteroids, and comets 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 planets. Proposals are sought for technologies that are suitable for remote sensing applications at cryogenic temperatures, and in-situ atmospheric and surface explorations in the high-temperature high-pressure environment at the Venusians surface (485 ^{0}C, 93 atmospheres), or in low-temperature environments such as Titan (-180 ^{0}C), Europa (-220 ^{0}C), Ganymede (-200 ^{0}C), Mars, the Moon, asteroids, comets and other small bodies. Also Europa-Jupiter missions may have a mission life of 10 years and the radiation environment is estimated at 2.9 Mega-rad total ionizing dose (TID) behind 0.1 inch thick aluminum. Proposals are sought for technologies that enable NASA's long duration missions to extreme wide-temperature and cosmic radiation environments. High reliability, ease of maintenance, low volume, low mass, and low out-gassing characteristics are highly desirable. Special interest lies in development of following technologies that are suitable for the environments discussed above.

- Wide temperature range precision mechanisms i.e., beam steering, scanner, linear and tilting multi-axis mechanisms.
- Radiation-tolerant/radiation hardened low-power low-noise mixed-signal mechanism control electronics for precision actuators and sensors.
- Wide temperature range feedback sensors with sub-arc-second/nanometer precision.
- Long life, long stroke, low power, and high torque/force actuators with sub-arc-second/nanometer precision.
- Long life Bearings/tribological surfaces/lubricants.
- High temperature energy storage systems.
- High-temperature actuators and gear boxes for robotic arms and other mechanisms.
- Low-power and wide-operating-temperature radiation-tolerant /radiation hardened RF electronics.

- Radiation-tolerant/radiation-hardened low-power/ultra-low-powerwide-operating-temperature low-noise mixed-signal electronics for space-borne system such as guidance and navigation avionics and instruments.
- Radiation-tolerant/radiation-hardened power electronics.
- Radiation-tolerant/ radiation-hardened electronic packaging (including, shielding, passives, connectors, wiring harness and materials used in advanced electronics assembly).

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.

TOPIC: S5 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 and information to create knowledge. For example, 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, provide visualizations of datasets that are extremely large and complicated, and aid in the design of systems and missions. 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 data and science information are 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.

S5.01 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.
- 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.
- 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.
    - Cloud supercomputing with high performance interconnects (e.g., InfiniBand).
    - Enhanced visualization technologies.
    - Improved algorithms for key codes.
    - Power-aware "Green" computing technologies and techniques.
    - 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 and porting codes (e.g., debugging and performance analysis), running computations, managing files and data, analyzing and visualizing results, transmitting data, collaborating, etc.
- Ultra-Scale Computing - Over the next decade, the HEC community faces great challenges in enabling its users to effectively exploit next-generation supercomputers featuring massive concurrency to the tune of millions of cores. To overcome these challenges, this subtopic element seeks ultra-scale computing technologies that enable resiliency/fault-tolerance in extreme-scale (unreliable) systems both at job startup and during execution. Also of interest are system and software co-design methodologies, to achieve performance and efficiency synergies. Finally, tools are sought that facilitate verification and validation of ultra-scale applications and systems.

S5.02 Earth Science Applied Research and Decision Support
Lead Center: SSC
Participating Center(s): ARC, DFRC, GSFC, 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.

Currently, creating decision support tools (DST) that effectively utilize remote sensing data requires significant efforts by experts in multiple domains. This creates a barrier to the widespread use of Earth observations by state and local governments, businesses, and the public. This subtopic aims to democratize the creation of Earth science driven decision support tools and to unleash a creative explosion of DST development that significantly increases the return on investment for Earth science missions.

Specifically, this subtopic develops core capabilities that can be integrated to build multiple remote sensing driven DSTs customized to the requirements of different users in varied fields. Proven development and commercialization strategies will be used to meet these objectives. Similar to Eclipse, this subtopic will create an open-source DST development framework that enables components from multiple providers to be seamlessly integrated. This subtopic will also create software components that plug into the framework and open source tools that help users create new components. The components will provide functionality ranging from basic operations, such as retrieval of data meeting user-specified criteria from online repositories and visualization, to sophisticated data processing and analysis algorithms, such as atmospheric correction, data fusion, computational model interfaces, and machine learning based quality control.

To expedite DST development and deployment by knowledgeable users, this subtopic seeks an open source graphical workflow tool, similar to Labview or Simulink, which enables well informed users to quickly create a functional DST from a catalog of software components. Ultimately, a more sophisticated graphical workflow development tool, similar to MIT's Scratch would enforce functionally, but not necessarily logically, "correct by construction" rules that would enable a broad population of people to successfully create DSTs. Open source and commercial components, as well as services, will be available through an online "store" similar to iTunes or Google Play.

The framework, components and resulting DSTs should be able to run in a commercial cloud such as Amazon EC2 or Google Compute Engine. Cloud enabled components and DSTs, those that can intelligently take advantage of flexible computing resources for processing, analysis, visualization, optimization, etc. are highly desired.

Ideally, users should be able to create, configure deploy DSTs, and view outputs such as status, reports, alerts, plots, maps, etc. via desktop computers (Windows 7 and OS X) as well as tablet and smart phones running recent versions of Android (4.0 and later) and iOS (5.0 and later). An HTML5 web application in a standards compliant browser, such as Chrome, can provide the required level of interoperability and capability. Due to serious security issues, Java and Flash based approaches will not be considered.

S5.03 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, KSC, LaRC, MSFC, SSC

The size of NASA's observational data sets is growing dramatically as new missions come on line. In addition, NASA scientists continue to generate new models that regularly produce data sets of hundreds of terabytes or more. It is growing ever increasingly difficult to manage all of the data through its full lifecycle, as well as provide effective data analytical methods to analyze the large amount of data. For example, the HyspIRI mission is expected to produce an average science data rate of 800 million bits per second (Mbps), JPSS-1 will be 300 Mbps and NPP is already producing 300 Mbps, compared to 150 Mbps for the EOS-Terra, Aqua and Aura missions. Other examples are SDO with a rate of 150 Mbps and 16.4 Gigabits for a single image from the HiRise camera on the Mars Reconnaissance Orbiter (MRO).

This subtopic area seeks innovation and unique approaches to solve issues associated around the use of "Big Data" within NASA. The emphasis of this subtopic is on tools that leverage existing systems, interfaces, and infrastructure, where it exists and where appropriate. Reuse of existing NASA assets is strongly encouraged.

Specifically, innovations are being sought in the following areas:

- *Parallel Processing for Data Analytics* - Open source tools like the Hadoop Distributed File Systems (HDFS) have shown promise for use in simple MapReduce operations to analyze model and observation data. In addition to HDFS, there is a rapid emergence and adoption of cloud software packages integrated with object stores, such as OpenStack and Swift. The goal is to accelerate these types of open source tools for use with binary structured data from observations and model output using MapReduce or a similar paradigm.
- *High Performance File System Abstractions* - NASA scientists currently use a large number of existing applications for data analysis, such as GrADS, python scripts, and more, that are not compatible with an object storage environment. If data were stored within an object storage environment, these applications would not be able to access the data. Many of these applications would require a substantial amount of investment to enable them to use object storage file systems. Therefore, a file system abstraction, such as FUSE (file system in user space) is needed to facilitate the use of existing data analysis applications with an object storage environment. The goal is to make a FUSE-like file system abstraction robust, reliable, and highly performing for use with large NASA data sets.
- *Data Management of Large-Scale Scientific Repositories* - With increasing size of scientific repositories comes an increasing demand for using the data in ways that may never have been imagined when the repository was conceived. The goal is to provide capabilities for the flexible repurposing of scientific data, including large-scale data integration, aggregation, representation, and distribution to emerging user communities and applications.
- *Server Side Data Processing* - Large data repositories make it necessary for analytical codes to migrate to where the data are stored. Hadoop does that at the level of a single HDFS. In a densely networked world of geographically distributed repositories, tiered intermediation is needed. The goal is to provide support for migratable codes and analytical outputs as first class objects within a provenance-oriented data management cyberinfrastructure.
- *Techniques for Data Analysis and Visualization* - New methods for data analytics that scale to extremely large data sets are necessary for data mining, searching, fusion, subsetting, discovery, visualization, and more. In addition, new algorithms and methods are needed to look for unknown correlations across large, distributed scientific data sets. The goal is to increase the scientific value of model and observation data by making analysis easier and higher performing. Among others, some of the topics of interest are:
    - Techniques for automated derivation of analysis products such as machine learning for extraction of features in large image datasets (e.g., volcanic thermal measurement, plume measurement, automated flood mapping, disturbance mapping, change detection, etc.).
    - Workflows for automated data processing, interpretation, and distribution.
- *Accelerated Large Scale Data Movement* - There are a multitude of large distributed data stores across NASA that includes both observation and model data. The movement of data across the network must be optimized to take full advantage of large-scale data analytics, especially when comparing model to observation data. The goal is to optimize data movement in the following ways:
    - Accelerate and make it easier to move data over the wide area to facilitate large-scale data management and analysis.
    - Optimize the movement of data within more local environments, such as the usage of Remote Direct Memory Access (RDMA) within HDFS.
    - Virtualization of high-speed network interfaces for use within cloud environments.

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.

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.

S5.04 Integrated Science Mission Modeling
Lead Center: GSFC
Participating Center(s): ARC, JPL

NASA seeks innovative systems modeling methods 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.
- Enable disciplined system analysis for the ongoing management and decision support of the space science technology portfolio, particularly with regard to understanding technology alternatives, relationships, priorities, timing, availability, down-selection, maturation, investment needs, system engineering considerations, and cost-to-benefit ratios; to examine "what-if" scenarios; and to facilitate multidisciplinary assessment, coordination, and integration of the technology roadmaps as a whole.

Use of System Modeling Language (SysML) is encouraged but not required. SysML is a general purpose graphical modeling language for analyzing, designing and verifying complex systems that may include hardware, software, information, personnel, procedures and facilities. As a language, SysML represents requirements, structure, behavior, and equations in nine different diagram types, and can represent both hardware and software models. The language can be extended to provide metamodels for different disciplines, and is supported by multiple commercial tools. SysML is finding increased use throughout the agency to support systems engineering and analysis.

Specific areas of interest include the following:

- Integration of system and mission modeling tools with high-fidelity multidisciplinary design and modeling tools, supporting efficient analysis methods that accommodate uncertainty, multiple objectives, and large-scale systems - This requires the development of robust interfaces between SysML and other tools, including CAD/CAE/PDM/PLM applications, used to support NASA science mission development, implementation and operations. The objective is to produce a unified environment supporting mixed systems-level and detailed analysis during any lifecycle phase, and rapid analysis of widely varying concepts/configurations using mixed-fidelity models, including geometry/mesh-based models when required. The human interface for such a system could be a "dashboard" (web-based is highly desirable) which initially allows for monitoring of the dataflow across a heterogeneous set of tools and finally allows for control of the data flow between the variety of applications.
- Modeling and rapid integration of programmatic, operational, and risk elements - Fully integrated system model representations must include non-physics based constructs such as cost, schedule, risk, operations, and organizational model elements. Novel methods and tools to model these system attributes are critical. In addition, approaches to integrate these in a meaningful way with other system model elements are needed. Methods that consider the development of these models as by-products of a collaborative and/or concurrent design process are particularly valuable.
- Library of SysML models of NASA related systems - Using a library of SysML models, engineers will be able to design their systems by reusing a set of existing models. Too often, these engineers have to begin from scratch the design of the systems. A library of verified and validated models would provide a way for the engineers to design a new spacecraft by assembling existing models that are domain specific, and therefore easy to adapt to the target system. In order to provide for seamless integration between SysML models each model must identify its level of abstraction both in terms of the modeling of time (progression: no ordering of events, qualitative ordering of events, metric time ordering of events) and the modeling of space (progression: lumped parameters models, distributed parameter models). Such levels of abstraction "certificates" for SysML will help determine integration interface requirements between any two models.
- Profiles for spacecraft, space robotics, and scientific instruments - Profiles provide a means of tailoring SysML for particular purposes. Extensions of the language can be inserted. This allows an organization to create domain specific constructs which extend existing SysML modeling elements. By developing profiles

for NASA domains such as Spacecraft, Space Robotics and Scientific Instruments, powerful mechanisms will be available to NASA systems engineers for designing future space systems.

- Requirements Modeling - SysML offers requirements modeling capabilities, thus providing ways to visualize important requirements relationships. There is a need to combine traditional requirements management, supported by tools including but not limited to DOORS and CRADLE, and SysML requirements modeling in a standardized and sustainable way.
- Functional Modeling - The intermediate data products between requirements and specification are detailed functional models that identify all of the functions required to achieve the mission profile(s). There is a critical need to model this layer as it is a key data product to provide traceability between requirements and implementation.
- Model and Modeling Process Synthesis - As model-based design broadens and integrates larger and more complex models, methods for how to sequence and operate the design synthesis, evaluation (e.g., V&V) and elaboration process will become more important, as will considerations of how model-based processes are made compatible with existing review and development cycles.

S5.05 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 and 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 the 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 TECHNOLOGY

The Space Technology Mission Directorate (STMD) enables a new class of missions by drawing on talent from the NASA workforce, academia, small businesses, and the broader space enterprise to deliver innovative solutions that dramatically improve technological capabilities for NASA and the Nation. The rapid development and infusion of new technologies and capabilities are critical components to advancing the Nation's future in space. These activities fuel an emerging aerospace economy and build upon the space technology needs of other government agencies, as well as the overall aerospace enterprise. NASA supports these objectives and contributes to the demands of larger national technology goals by investing in Space Technology.

Using a broad investment strategy, NASA's Space Technology investments address the identified range of technology areas found in NASA's Space Technology Roadmaps as prioritized by the National Academies. Under the direction of STMD, NASA funds the development of pioneering technologies that will increase the Nation's capability to perform space science, operate in space, and enable deep space exploration. Significant progress in technology areas such as in-space power systems, solar electric propulsion, radiation protection, next generation life-support, human robotic systems, cryogenic fluid handling, and entry, descent and landing capabilities, are essential for future science and human exploration missions. Developing these solutions will stimulate the growth of the Nation’s innovation economy by enabling new technology sectors in areas such as robotics, advanced manufacturing, and synthetic biology.

SBIR and STTR continue to support early-stage research and mid-TRL development performed by small businesses through competitively awarded contracts. These programs produce innovations for both Government and commercial applications. SBIR and STTR provide the high-technology small business sector with opportunities to develop technology for NASA, as well as commercialize those technologies to provide goods and services that address other national needs based on the products of NASA innovation.

(http://www.nasa.gov/directorates/spacetech/home/index.html)

TOPIC: Z1 Space Technology for Cross-Cutting Applications

The Advanced Space Power Systems topic area will focus on technologies that generate power and/or store energy within the space environment. Functional areas, subtopics, of interest include:

- *High Energy Density Batteries* - Components and chemistries for rechargeable battery cells that can enable performance that approaches 500 Wh/kg and 700 Wh/l on a cell level when integrated into a full cell with other advanced components and that can sustain stable performance over > 500 cycles are sought. Advanced next generation chemistries and components must have the potential to meet performance goals while simultaneously delivering a high level of safety.
- *Advanced Photovoltaics* - System and component technologies are sought that can deliver cost, reliability, mass, volume, and efficiency improvements under typical space operating conditions. Future NASA missions may well depend on PV technologies that provide 100's kW of prime power. Technologies considered under this subtopic must enable or enhance the ability to provide this power at considerably lower cost and specific power than present technologies.
- *Nuclear Power Systems* - Innovative solutions for integrating radioisotope and small fission power systems with electric propulsion devices for space science missions. The goal is to develop architectures that optimize the power delivery and overall propulsive capabilities.
- *Modeling and Simulation* - Innovative M&S tools that will provide insight into design decisions and trade-offs are sought. The focus is on the reduction of overall development time for advanced future systems needed for space exploration.

Z1.01 Advanced Photovoltaic Systems
Lead Center: GRC
Participating Center(s): 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 cost, reliability, mass, volume, and efficiency improvements under various operating conditions, in extreme environments, and over wide temperature ranges.

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.

Areas of particular emphasis for FY 2014 include:

- Automated/ modular fabrication methods for PV panels/ modules on flexible blankets (includes cell laydown, interconnects, shielding and high voltage operation mitigation techniques).
- Improvements to solar cell efficiency that is consistent with low cost, high volume fabrication techniques.
- PV module/ component technologies that emphasize low mass and cost reduction (in materials, fabrication and testing).
- Advanced PV blanket and component technology/ designs that support very high power and high voltage (> 200 V) applications.
- Integrated PV system including cells, blanket, array, inverters, interconnect technologies, storage, structures, etc. with a balance-of-components while matching specifications of various systems.
- Simulated PV capability that optimizes system components, ensures compatibility of modules/inverters, and takes temperature extremes and unique aspects of the space environment into account including radiation tolerance.

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.

Z1.02 Advanced Space Battery Technology
Lead Center: GRC
Participating Center(s): JPL, JSC

NASA seeks innovative, advanced technologies for next generation battery chemistries. Breakthrough battery cell technologies that far exceed the specific energy and energy density of current state-of-the-art lithium-ion cell technologies are required to achieve NASAs far-term energy storage goals for human and robotic missions. Future NASA missions will require rechargeable battery technologies that can provide 500 Wh/kg and 700 Wh/liter and can deliver > 1000 cycles at full depth of discharge. Components and chemistries for rechargeable battery cells that can enable performance that approaches 500 Wh/kg and 700 Wh/l on a cell level when integrated into a full cell with other advanced components and that can sustain stable performance over > 500 cycles are sought. Advanced next generation chemistries and components must have the potential to meet performance goals while simultaneously delivering a high level of safety. Proposed components may include, but are not limited to:

- Methods to enable safe, stable cycling of lithium metal.
- Innovative lithium-ion conducting electrolytes that offer ionic conductivities of 10E-3 Siemens per centimeter at room temperature and that can enable safe, stable cycling of lithium metal. These may include, but are not limited to, solid state electrolytes and ionic liquids.
- Other innovative cell component technologies that can enable the desired cell- level performance when integrated into a cell with other advanced components.

Offerors may propose to develop a single component or full cells. Phase I proposals shall include quantitative analysis, data, and technical rationale that clearly demonstrates how the proposed component, components, or cells will meet or contribute to the stated (as proposed) cell performance goals by the end of a Phase II effort. If a single component is proposed, the Offeror shall also include in their justification of the proposed technology the performance that other advanced cell components must achieve in order to meet the claimed cell-level goals in an integrated system. During the Phase I effort, the proposed component(s) shall be incorporated into an appropriate test vehicle, such as half or full cell laboratory cells, to demonstrate feasibility. Phase I proposals shall describe the technical path that will be followed to achieve the claimed (as proposed) goals. Where possible, laboratory scale prototype hardware should be proposed as deliverables to NASA in Phase I.

Z1.03 Integrated Nuclear Power & Propulsion
Lead Center: GRC
Participating Center(s): MSFC

This subtopic seeks innovative solutions for integrating radioisotope and small fission power systems with electric propulsion devices for space science missions. The goal is to develop architectures that optimize the power delivery and overall propulsive capabilities. Separate subtopics are developing innovative power generation (S3.01), power management (S3.03), and electric thruster technologies (S3.02). Here, the objective is to take existing components and assemble them into testbeds to demonstrate functionality, robustness, and performance. Emphasis is on novel integration schemes that maximize efficiency and reliability while minimizing mass. Phase I activities would develop the power architecture and identify the key design elements. Phase II activities would assemble testbeds and perform experimental testing to validate design methods. The assumed building blocks are described below with additional information available from literature searches. However, the system should be evolvable to incorporate advanced components developed under S3.01, Power Generation & Conversion; S3.02, Propulsion Systems for Robotic Science Missions; and S3.03, Power Electronics and Management, and Energy Storage.

Power sources:

- Advanced Stirling Radioisotope Generator, 140 watts at 28 Vdc.
- Multi-Mission Radioisotope Thermoelectric Generator, 110 watts at 28 Vdc.
- Small Thermoelectric Fission Power System, 0.5 to 3 kW at 28 to 100 Vdc.
- Small Stirling Fission Power Systems, 1 to 10 kW at 15 to 300 Vac, 100 hz single-phase.

Representative Electric Propulsion Devices (Isp = specific impulse):

- 200 – 600 W Hall thrusters, at 200-250 Vdc and 1300-1600 sec Isp.
- 1.4 kW – 5 kW Hall thrusters, at 300-600 Vdc and 1600-2700 sec Isp.
- 10 kW Hall thrusters, at 300 Vdc and 2200 sec Isp.
- 100-600 W Ion thrusters, at 800-1500 Vdc and 2000-3800 sec Isp.
- 2.3-5 kW Ion thrusters, at 1200-1500 Vdc and 3300-3800 sec Isp.
- 7-10 kW Ion thrusters, at 1800-2000 Vdc, and 4100-5000 sec Isp.

Z1.04 Modeling and Measurements for Propulsion and Power
Lead Center: GRC
Participating Center(s): ARC, MSFC

To reduce the development time of advanced future systems needed for space exploration, physics-based modeling tools are sought for:

- Electrochemical systems such as battery chemistries with “beyond Lithium ion” expected specific energies, proton exchange membrane and solid oxide fuel cells and electrolyzers, and chemical sensors for safety and operational monitoring.
- Electric propulsion systems such as Hall thrusters, nested Hall thrusters, ion engines, electrospray propulsion, and micro-propulsion.
- Nuclear power and propulsion systems such as 1kW-class, 10kW-class, and 100kW-class fission reactors, and nuclear thermal propulsion systems.

In each case, the emphasis is on determining performance-limiting features and determining potential means to overcome limitations. Either Dcomponents or full systems can be targeted.

Model validation is also required; improved measurement techniques needed for validation are also of interest provided they are coupled with a modeling activity outlined above.

Finally, tools that exclusively model proprietary systems will not be considered for award.

Below are listed examples of the types of models of interest for each area, and subtopics that contain additional information about systems of interest:

- Modeling the kinetics and thermodynamics of batteries, fuel cells and electrolyzers; and modeling the dielectrophoresis in the alignment of nanostructures within chemical and physical sensors for aerospace propulsion systems.
    - Z1.02 Advanced Space Battery Technology.
    - H8.01 Solid Oxide Fuel Cells and Electrolyzers.
    - T12.02 High Temperature Materials and Sensors for Propulsion Systems.
- Modeling electric propulsion (EP) life and failure mechanisms to predict the performance, plasma properties and lifetime of EP devices of interest and to help assess the interaction between the EP device plume and spacecraft surfaces.
    - H2.02 In-Space Propulsion Systems.
- Creating interfaces between reactor models and engine system models, including radiation effects; modeling NTP ground test engine exhaust filtering and containment.
    - H8.02 Space Nuclear Power Systems.
    - H2.04 Nuclear Thermal Propulsion (NTP) Ground Test Technologies.

TOPIC: Z2 Cross Cutting Advanced Manufacturing Processes for Large Scale Bulk Metallic Glass Systems for Aerospace Applications

Amorphous metals (also known as bulk metallic glasses) are a unique class of non-crystalline metals that possess the ability to be cast into high-tolerance hardware using similar processing techniques as plastics and yet retain mechanical properties similar (and in most cases superior to) titanium alloys Amorphous metals are a relatively new class of metal alloys that have mechanical properties and processing characteristics which set them apart from similar crystalline alloys (e.g., titanium, aluminum, or steel). Glassy metals are first designed by finding deep eutectic melting points in multi-element alloys such that when cooled at a high rate (usually >1000 K/s) crystal nucleation and growth does not occur and the amorphous liquid structure is frozen into the solid. Further work on amorphous metals has led to the development of composites consisting of an amorphous matrix phase reinforced with soft, crystalline dendrites which improve the composite's toughness and ductility. The properties of the amorphous metal can thus be tuned by the second phase. Strength, hardness, ductility, fatigue life, toughness, density, thermal expansion, thermal diffusivity, among others, can all be adjusted in these amorphous metal composites. Special emphasis is placed on new processes for fabricating large sheets (width >150 mm, uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous) of bulk metallic glass alloys and advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes at widths greater than 75 mm.

Z2.01 Cross Cutting Advanced Manufacturing Process for Large Scale Bulk Metallic Glass Systems for Aerospace Applications
Lead Center: JPL
Participating Center(s): LaRC, MSFC

Amorphous metals (also known as bulk metallic glasses) are a unique class of non-crystalline metals that possess the ability to be cast into high-tolerance hardware using similar processing techniques as plastics and yet retain mechanical properties similar (and in most cases superior to) titanium alloys Amorphous metals have mechanical properties and processing characteristics which set them apart from similar crystalline alloys (e.g., titanium, aluminum, or steel). They are metastable, resulting in manufacturing challenges as well as post processing and machining challenges, especially when scaling these materials. If BMGs can be scaled up to usable sheets (sizes greater than 150 mm wide), these materials see a greater infusion threshold in aerospace and defense applications. Specific applications for BMG sheets include MMOD shielding and multifunctional structures; casings and structural components on launch vehicles and habitats.

BMG alloys (to include but not limited to Al-based, Zr-, Mg-, Fe-, etc.) are desired in sheet form at a width >150 mm, a uniform thickness nominally between 0.1 and 1 mm, a length > 2 x width to continuous. In addition to BMG alloy sheets, the development of BMG composite sheets consisting of an amorphous matrix phase reinforced with soft, crystalline dendrites which improve the composite's toughness and ductility are also desired. BMG composite sheets at a width >150 mm, a uniform thickness nominally between 0.1 and 1 mm, a length > 2 x width to continuous. The properties of the amorphous metal can thus be tuned by the second phase. Strength, hardness, ductility, fatigue life, toughness, density, thermal expansion, thermal diffusivity, among others, can all be adjusted in these amorphous metal composites.

Special emphasis is placed on new processes for fabricating large BMG alloy and BMG composite sheets (width >150 mm, uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous) of bulk metallic glass alloys and advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes at widths greater than 75 mm.

A phase I effort should demonstrate one or more manufacturing/processing approach(s) that yield a sheet with the following dimensions: width >150 mm and uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous) of bulk metallic glass alloys and/or advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes approaching widths greater than 75 mm as proof of concept. Material should be delivered to the sponsor for evaluation. Plans for meeting dimensional goals, measuring manufacturing characteristics including but not limited to thickness, width, fraction or percent crystallinity, porosity or other defects, and evaluating manufacturing capability including but not limited to capacity/lead time, yield, cost reduction and process improvement opportunities to be reported at the conclusion of phase I.

A Phase II effort should demonstrate the manufacturing capability from Phase I that produces a BMG alloy and/or BMG composite sheet with a width >150 mm, uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous). The sheet should then be post processed and formed into a complex structural component from either/or of the large sheets of bulk metallic glass alloys and/or advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes at widths greater than 75 mm. Manufacturing variability of critical characteristics, including but not limited to thickness, width, fraction or percent crystallinity, porosity or other defects, should be measured. Manufacturing capability including but not limited to capacity/lead time, yield, cost reduction and process improvement opportunities (future work) should be reported. Material should be delivered to the sponsor for evaluation.

9.2 STTR

The STTR Program Solicitation topics correspond to strategic technology research areas of interest to NASA. The subtopics reflect NASA's current highest priority technology thrusts being worked through each of its ten Centers.

TOPIC: T1 Launch Propulsion Systems

Includes all propulsion technologies required to deliver space missions from the surface of the Earth to Earth orbit or Earth escape, including solid rocket propulsion systems, liquid rocket propulsion systems, air breathing propulsion systems, ancillary propulsion systems, and unconventional/other propulsion systems. The Earth to orbit launch industry is currently reliant on very mature technologies, to which only small incremental improvements are possible. Breakthrough technologies are not on the near horizon, therefore research and development efforts will require both significant time and financial investments.

T1.01 Affordable Nano-Launcher Upper Stage Propulsion
Lead Center: MSFC
Participating Center(s): GRC, KSC, LaRC

Small satellites are becoming ever more capable of performing valuable missions for both government and commercial customers. However, currently these satellites can only be launched affordably as secondary payloads. This makes it difficult for the sll satellite mission to launch when needed, to the desired orbit, and with acceptable risk. A dedicated launch vehicle is needed that will affordably meet the small sat launch needs. This subtopic solicits technology proposals for the upper stage propulsion system of such a launcher. Specifically, the subtopic requests proposals for propulsion design tools, systems, and stages for application as upper stages or orbit insertion stages with the following goals and constraints:

- A recurring stage cost not to exceed $100K (for 8/year).
- The stage shall be capable of providing at least 13,000 fps delta-v to a 150 lbm mass from in vacuum conditions.
- The stage shall be designed to a diameter of 3.0 ft or less.
- The stage shall be capable of compressively supporting 700 lbf on its forward end (in addition to its own loaded mass).
- Total stage wet mass shall not exceed 1800 lbm.
- Other desired functionality include TVC, basic health and status monitoring, and throttling.
- Design analysis techniques that provide rapid, high fidelity insight into the operation of these systems are also needed.

Technologies meeting these goals will support development of an affordable launcher capable of delivering 55 lbm to 100 lbm to low-earth orbit. Phase I activities will develop the data necessary to assert with confidence that the proposed technology solution will meet the goals of the subtopic. Phase II activities will provide functionality verification and substantiation of recurring cost.

Mission Traceability - STMD, HEOMD, and SMD all have missions that would benefit from this technology. In particular, STMD’s SST and GCD Programs have expressed a strong need.

T1.02 Small Launch Vehicle Propulsion Technology
Lead Center: MSFC
Participating Center(s): GRC, KSC

Small satellites are becoming ever more capable of performing valuable missions for both government and commercial customers. However, currently these satellites can only be launched affordably as secondary payloads on large launch vehicles. This makes it difficult for the small satellite mission to launch when needed, to the optimal orbit, and with acceptable risk to the mission. There is no affordable, dedicated launcher available that will meet the small satellite launch needs. This subtopic solicits technology proposals for the boost propulsion system(s) of such a launcher. Specifically, the subtopic requests proposals for propulsion systems for application as first stages or strap-on boosters with the following functional and cost goals and within the following geometric constraints:

- Cost goal - Assuming a production rate of 8 boost systems per year, a recurring stage cost of $400K
- Total Impulse goal - The stage shall be capable of providing 2.5M lbf-sec total impulse

- Delta-V goal - The stage shall be capable of providing 6800 fps delta-v to a 8,000 lbm mass from ground launch.
- Size goal - The stage shall be designed to fit within the size envelope of height of 25 ft and a diameter of 3.5 ft for individual elements. If a cluster of elements is proposed, the central element should stay within this envelope.
- Strength goal - It shall be capable of structurally supporting (compressively) 8,000 lbflbm for use as a core booster stage.

Though not explicit goals, other desired functionality in the first stage include thrust vector control (TVC), basic health and status monitoring, and throttling.

Technologies meeting these goals will support development of a 25 kg to 50 kg payload launcher to low-earth orbit. Phase I activities will be used to develop the data necessary to assert with confidence that the proposed technology solution will meet the goals of the subtopic. Phase II activities will include verification of functionality, as much as possible through testing, and substantiation of recurring cost projections. At the end of Phase II there will be sufficient validation of the technology to warrant purchase of one or more stages for initial flight testing under potential follow-on activities.

TOPIC: T2 In-Space Propulsion Technologies

Reserved for future Solicitations.

TOPIC: T3 Space Power and Energy Storage

Space Power and Energy Storage is divided into four technology areas: power generation, energy storage, power management and distribution, and cross cutting technologies. NASA has many unique needs for space power and energy storage technologies that require special technology solutions due to extreme environmental conditions. These missions would all benefit from advanced technologies that provide more robust power systems with lower mass.

T3.01 Innovative Energy Harvesting Technology Development
Lead Center: SSC
Participating Center(s): GRC, JSC, KSC, LaRC, MSFC

The NRC has identified a NASA Top Technical Challenge as the need to "Increase Available Power". Additionally, a NASA Grand Challenge is "Affordable and Abundant Power" for NASA mission activities. As such, novel energy harvesting technologies are critical toward supporting future power generation systems to begin to meet these challenges. This subtopic addresses the potential for deriving power from waste engine heat, warm soil, liquids, kinetic motion, piezoelectric materials or other naturally occurring energy sources, etc. Development of energy harvesting (both capture and conversion) technologies would also address the national need for novel new energy systems and alternatives to reduce energy consumption.

Areas of special focus for this subtopic include consideration of:

- Innovative technologies for the efficient capture and/or conversion of acoustic, kinetic, and thermal energy types.
- Technologies which can work either under typical ambient environments for the above energy types and/or under high intensity energy environments for the above energy types as might be found in propulsion testing and launch facilities.
- Innovations in miniaturization and suitability for manufacturing of energy capture and conversion systems so as to be used towards eventual powering of assorted sensors and IT systems on vehicles and infrastructures.
- High efficiency and reliability for use in environments that may be remote and/or hazardous and having low maintenance requirements.
- Employ green technology considerations to minimize impact on the environment and other resource usage.

Rocket propulsion test facilities within NASA provide excellent test beds for testing and using the innovative technologies discussed above because they offer a wide spectrum of energy types and energy intensities to capture and convert. Additional Federal mandates require the optimization of current energy use and development of alternative energy sources to conserve on energy and to enhance the sustainability of these and other facilities.

TOPIC: T4 Robotics, Tele-Robotics and Autonomous Systems

The topic for Robotics, Tele-Robotics and Autonomous Systems, consists of seven technology subareas: Sensing and Perception; Mobility; Manipulation; Human-Systems Integration; Autonomy; Autonomous Rendezvous and Docking (AR&D); and Robotics, Tele-Robotics and Autonomous Systems Engineering. Robotics, Tele-Robotics and Autonomous Systems supports NASA space missions with the development of new capabilities, and can extend the reach of human and robotic exploration through a combination of dexterous robotics, better human/robotic interfaces, improved mobility systems, and greater sensing and perception. The Robotics, Tele-Robotics and Autonomous Systems topics focuses on several key issues for the future of robotics and autonomy: enhancing or exceeding human performance in sensing, piloting, driving, manipulating, and rendezvous and docking; development of cooperative and safe human interfaces to form human-robot teams; and improvements in autonomy to make human crews independent from Earth and make robotic missions more capable.

T4.01 Dynamic Servoelastic (DSE) Network Control, Modeling, and Optimization
Lead Center: DFRC
Participating Center(s): ARC, JPL, LaRC

This subtopic addresses advanced control-oriented techniques for dynamic servoelastic (DSE) terrestrial, planetary, and space environment flight systems using distributed network sensor and control systems. Methods include modeling, simulation, optimization and stabilization of DSE systems to actively and/or adaptively control structural dynamic geometry/topology, vibration, atmospheric and intraspace disturbances, static/dynamic loads, and other structural dynamic objectives for enhanced dynamic servoelastic performance and stability characteristics.

- DSE control for performance enhancements while minimizing dynamic interaction.
- Flexible aircraft and spacecraft stabilization and performance optimization.
- Modeling and system identification of distributed DSE dynamics.
- Sensor/actuator developments and modeling for distributed DSE control.
- Uncertainty modeling of complex DSE system behavior and interactions.
- Distributed networked sensing and control for vehicle shape, vibration, and load control.

This subtopic also addresses capabilities enabling design solutions for performance and environmental challenges of future air and space vehicles. Research in revolutionary aerospace configurations include lighter and more flexible materials, improved propulsion systems, and advanced concepts for high lift/performance and drag/energy reduction. This subtopic targets efficiency and environmental compatibilities requiring performance challenges and novel control-oriented techniques for aero-servoelastic considerations which are gaining prevalence in advanced aerospace flight vehicles, atmospheric and extra-terrestrial.

Technical elements for the Phase I proposals may also include:

- Mission/maneuver adaptivity with dissipative optimal energy-force distribution.
- Data-driven multi-objective DSE control with physics-based sensing.
- Robust sensing-control-communication networks for sensor-based distributed control.
- Compressive information-based sensing and information structures.
- Evolving systems as applied to self-assembling and robotic maneuvering.
- Scalable and evolvable information networks with layering architectures.
- Modular architectures for distributed autonomous aerospace systems.
- Multi-objective, multi-level control and estimation architectures.
- Distributed multi-vehicle dynamics analysis and visualization with complex simulations.

- Reduced order modeling capable of substructure coupling of nonlinear materials

Development of distributed sensory-driven control-oriented DSE systems is solicited to enable future flight vehicle concepts and designs that manage structural dynamic uncertainty on a vehicle's overall performance. Proposals should assist in revolutionizing improvements in performance to empower a new generation of air and space vehicles to meet the challenges of terrestrial and commercial space concerns with novel 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 information network decompositions that have different characteristics in efficiency, robustness, and asymmetry of information and control with tradeoff between computation and communication.

Advanced mission applicability in Phase II should show the ability of aerospace GN&C systems to achieve mission objectives as a function of GN&C sensor performance, vehicle actuation/power/energy, and the ability to jointly design them as onboard-capable, real-time computing platforms with applicable environmental effects and robust guidance algorithms. Goals are to:

- Provide capabilities that would enable new projects/missions that are not currently feasible.
- Impact multiple missions in NASA space operations and science, earth science, and aeronautics.
- Be influential across aerospace and non-aerospace disciplines with dynamic interactions.

New technologies proposed should have the potential to impact the following NASA missions:

- Data availability for science missions.
- Mission planning.
- Autonomous rendezvous/docking technology.
- Environmental monitoring for human habitation.

Apart from NASA missions, the aeronautics technology could be adapted for development and use in autonomous operation of wind/ocean energy and smart space power grid systems in dynamic environments.

There are number of advantages to exploring this subtopic technology:

- Increase in autonomy and fuel efficiency of coordinated robotic vehicles and sub-components.
- Improved science, atmospheric, and reconnaissance data.
- Cost, risk and reliability of flight vehicles for a terrestrial, planetary, or space mission.
- Inter-networks with improved dynamic behavior.

Potential technical impacts are:

- Vehicle energy efficiency with passive/active dissipativity for control and dynamic stability with extreme power constraints.
- Weight minimization through dynamic servoelastic control.
- Mission adaptivity and robustness with real-time, consensus-coordinated control dealing with computation, communication, and dynamics.

T4.02 Regolith Resources Robotics - R3
Lead Center: KSC
Participating Center(s): ARC, LaRC

The use of robotics for In-Situ Resource Utilization (ISRU) in outer space on various planetary bodies is essential since it uses large quantities of regolith that must be acquired and processed. In some cases this will happen while the crew is not there yet, or it will take place at a remote destination where the crew cannot spend much time due to radiation exposure limits (Asteroids, Mar's Moons and NEO's). Communications latencies of greater than 40 minutes at Asteroids mandate autonomous robotics applications. Proposals are sought which provide solutions for the following space resource related technology area:

Asteroid Resource Prospecting and Characterization - The first step towards using resources derived from small bodies in space, such as water, volatiles, metals and organic compounds is to visit the Near Earth Object (NEO) target body and prospect it with sample acquisition devices and subsequently do characterization of these samples. Proposals are sought for innovative resource prospecting mission concepts and associated technology demonstrations such as autonomous small marsupial free flyer prospector spacecraft that can sample an asteroid, comet or Mars moon and transport the sample back to a locally orbiting spacecraft with an associated suite of characterization instruments for analysis.

TOPIC: T5 Communication and Navigation

Communications and Navigation Systems, consists of six technology subareas: optical communication and navigation; radio frequency communication; internetworking; position, navigation and timing; integrated technologies; and revolutionary concepts. Communication links are the lifelines to spacecraft, providing commanding, telemetry, and science data transfers as well as navigation support. Therefore, the Communications and Navigation Systems Technology Area supports all NASA space missions. Advancement in communication and navigation technology will allow future missions to implement new and more capable science instruments, greatly enhance human missions beyond Earth orbit, and enable entirely new mission concepts.

T5.01 Autonomous Communications Systems
Lead Center: GRC
Participating Center(s): GSFC, JPL

Future missions will require end to end communications systems that can support greater levels of autonomy and possess greater awareness of the environment and knowledge of assets that can be used for enhanced reach back and data delivery. Autonomous Communications Systems (ACS) have the potential to improve overall system performance and reduce the user burden associated with configuring and managing communications systems through the use of automated systems-level analysis and configuration control.

An ACS nominally includes the Radio/Optical subsystems and the storage and networking subsystems capable of supporting autonomous network operations. ACS capabilities would also support on-board learning to extract, catalog, and utilize information from both positive and negative experiences to enhance nominal and anomalous situations. Other desired enabling functions would include:

- Ability to increase the capabilities of on-board communications services to make network connections self-configurable and autonomous. Further advances would lead to the ability to determine how a learning system would be implemented in an on-board system, such as Artificial Intelligence.
- Ability to determine the type and how on-board information, including settings, would be exchanged between the communications components.
- Smart environment sensing capable of mitigating outages, interference and performance degradation. This could include Spectrum resource allocation and/or Dynamic frequency assignment capability to enhance throughput and connectivity.
- Low power, low cost, flexible receiver front ends that allows for efficient spectrum utilization (i.e., frequency reconfigurable) and are compatible with SDR/cognitive radio platforms allowing the use of multiple waveforms and autonomous operation to increase capacity and to enable more efficient high-data data handling and delivery, are of interest. In particular, the following enabling technologies should be addressed:
    - Frequency, pattern, polarization (FPP) agile reconfigurable antennas.
    - Dynamic impedance matching networks.
    - Digital beam forming antennas.
    - Testbeds addressing one or more of the above.

State of the Art - Current NASA flight transceivers are capable of performing communication and radiometrics. With the recent launch of the SCaNTestbed on the ISS, advances in software defined radios (SDRs) that are reconfigurable are now being assessed to support communications, navigation and networking experiments and applications.

However, today's flight transceivers and SDRs are not aware of their environment and do not react to it; hence lack ability to support autonomous network operations.

Background/Rationale - NASA HEOMD and SMD conduct scientific exploration that is enabled by access to space and innovative technologies to expand mankind's understanding of planet earth and the universe. Communications and navigation technologies are integral in projecting humankind’s vantage point into space with observatories in Earth orbit and deep space, spacecraft visiting the Moon and other planetary bodies, and robotic landers, rovers, and sample return missions. As the needs to gather more data and extend mankind's presence beyond low earth orbit, even more advanced communications and navigation technologies will be essential to deliver orders of magnitude more data and enable greater participation by the public through high-data rate telepresence networks.

TOPIC: T6 Human Health, Life Support and Habitation Systems

Human Health, Life Support and Habitation Systems, includes technologies necessary for supporting human health and survival during space exploration missions and consists of five technology subareas: environmental control and life support systems and habitation systems; extravehicular activity systems; human health and performance; environmental monitoring, safety, and emergency response; and radiation. These missions can be short suborbital missions, extended microgravity missions, or missions to various destinations, and they experience what can generally be referred to as “extreme environments” including reduced gravity, high radiation and UV exposure, reduced pressures, and micrometeoroids and/or orbital debris.

T6.01 Synthetic/Engineering Biology for NASA Applications
Lead Center: ARC
Participating Center(s): JSC, KSC, MSFC

Synthetic Biology (SB) provides a unique opportunity to engineer organisms that reliably perform necessary functions for future exploration activities. NASA is interested in harnessing this emerging field to create technological advances that will benefit both spaceflight and future surface missions in a variety of enabling areas. Proposals must use a biologically-based approach, such as synthetic biology, to engineer novel biologically-based (or inspired) functions that do not exist in nature. Proposed projects may include creating new capability by designing microorganisms, plants, and/or cell-free systems for air revitalization, water recovery, in situ resource utilization, and/or the production of novel chemicals and biomolecules of benefit to space exploration. Applications may include (but are not limited to) more reliable and efficient life support systems; the acquisition and utilization of in situ resources; and the production of consumables such as feedstock for advanced manufacturing or food. Proposals should address how systems and technologies will reduce the required up-mass and dependence on consumables, resupply, and energy.

Of additional interest is the miniaturization and automation of critical technologies required to monitor and implement synthetic biology beyond low Earth orbit.

All proposals should consider the novel environment in which these systems will eventually be deployed – this includes altered gravity, temperature extremes, high radiation, etc.

T6.02 Metal Organic Framework Sorbents for Spacecraft Medical Applications
Lead Center: JSC
Participating Center(s): GRC

Metal Organic Frameworks (MOFs) are a new class of porous materials in which metal-to-organic ligand interactions yield structured three dimensional porosity. MOFs have several important attributes:

- They have ultrahigh porosity.
- MOFs have demonstrated thermal and chemical stability.
- They can be synthesized into a wide variety of structures with a wide range of pore sizes.
- They can be synthesized to be superhydrophobic.

Because of these attributes, MOFs show promise to improve the efficiency and effectiveness of practical gas separation systems.

To ensure human health for space exploration, NASA seeks the capability to administer therapeutic oxygen in a medical emergency. In a traditional hospital setting, medical oxygen can be delivered, and the excess oxygen is diluted and ventilated. In a confined spacecraft, administering medical oxygen by conventional means can cause ambient oxygen levels to exceed flammability limits. If oxygen could be efficiently concentrated from spacecraft cabin air, medical oxygen could be administered without increasing oxygen levels in the cabin. State of the art oxygen concentrators are too large and use too much energy to effectively operate in a spacecraft environment, in part because the oxygen separation sorbents are adversely affected by the presence of water vapor.

Much attention is being paid on using MOFs to store fuels such as hydrogen under practical conditions. This solicitation, however, is focused on exploiting the properties of MOFs to separate oxygen from cabin air. Thermal and chemical stability, selectivity in the presence of water, and selectivity under dynamic gas separation conditions are especially important. In addition to water selectivity, some operational scenarios require oxygen separation from air that contains elevated levels of CO, CO_2, HCN, and HF.

TOPIC: T7 Human Exploration Destination Systems

Reserved for future Solicitations.

TOPIC: T8 Science Instruments, Observatories and Sensor Systems

Science Instruments, Observatories, and Sensor Systems addresses technologies that are primarily of interest for missions sponsored by NASA’s Science Mission Directorate and are primarily relevant to space research in Earth science, heliophysics, planetary science, and astrophysics. This topic consists of three Level 2 technology subareas:

- Remote sensing instruments/sensors.
- Observatories.
- In situ instruments/sensors.

T8.01 Technologies for Planetary Compositional Analysis and Mapping
Lead Center: JPL
Participating Center(s): LaRC

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 and 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.

Phase I contracts will be expected to demonstrate feasibility, and Phase II contracts will be expected to fabricate and complete laboratory testing on an actual instrument/test article.

T8.02 Next Generation Total Lightning Detection Sensor
Lead Center: KSC
Participating Center(s): GSFC, LaRC, MSFC, SSC

NASA is concerned with the uncertainty of the current lightning detection sensors NASA is concerned with the uncertainty of current lightning detection sensors. The location accuracy and detection efficiency are both lacking, currently at less than 90% and 250m respectively. Total lightning detection with location accuracy in the meters should be the requirement of the next generation launch vehicle and ground operations. NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-cloud and cloud-to ground lightning detection. The current total lightning detection technology has been fairly stagnant for the last decade, with the only improvements being small tweaks to location accuracy and classification algorithms and requiring both a suite of cloud-to-ground sensors and inter-cloud sensors. The combination is cost prohibitive to most locations and requires a large array of sensors spanning tens of meters to create solutions. Through current collaborations with other government agencies, the NASA team has come across several universities and at least two small businesses that have conceptual designs that could potentially deliver a brand new sensor with the detection capability to meet the important technology gap. Based on an early assessment of these small business and university concepts, it is likely that systems could be developed within the next 2-3 years, at great cost efficiencies for NASA while providing the needed detection and location accuracy.

Under this subtopic, proposals are invited that explore novel sensors and sensor systems for the detection of both inter-cloud and cloud-to-ground lightning. With regard to detection efficiency and location accuracy, the emphasis is developing systems that have a near total detection and are accurate within 10s of meters. Approaches that use multiple sensors in combination to improve detection and location are also of interest. Technologies may take the form of prototypes and/or devices.

TOPIC: T9 Entry, Descent and Landing Systems

Reserved for future Solicitations.

TOPIC: T10 Nanotechnology

Nanotechnology, addresses four subareas: engineered materials and structures, energy generation and storage, propulsion, and sensors, electronics, and devices. Nanotechnology describes the manipulation of matter and forces at the atomic and molecular levels and includes materials or devices that possess at least one dimension within a size range of 1-100nm. At this scale, quantum mechanical forces become important in that the properties of nano-sized materials or devices can be substantially different than the properties of the same material at the macro scale. Nanotechnology can provide great enhancement in properties, and materials engineered at the nano-scale will shift the paradigm in space exploration, sensors, propulsion, and overall systems design.

T10.01 Lightweight Structural Nanomaterial Concepts
Lead Center: LaRC

Carbon fiber reinforced polymeric (CFRP) composites are considered state of the art (SOA) for lightweight aerospace structural materials. However, a systems study suggests that having specific mechanical properties that exceed CFRPs by 2-4x will yield significant savings in launch vehicles. Currently, SOA nanomaterials with potential to supplant CFRPs as the lightweight structural material of choice are available in formats possessing mechanical properties far below those measured at the nanoscale. These excellent nanoscale properties have to be demonstrated at scales that permit the evaluation of these materials in structural components with properties that offer mass advantage over CFRPs. Proposals are sought in the following areas:

- Innovative approaches to chemically and/or physically enhance load carrying capability of nanomaterials and influence their macroscale mechanical properties as demonstrated by structural properties on the coupon scale that are at least double the specific strength and stiffness of epoxy CFRPs.
- Manufacturing methods that permit the control of nanostructures at the molecular level to induce structural perfection of such structures as to produce articles at the coupon scale which possess mechanical properties that are at least double those measured for epoxy CFRPs.

T10.02 Smart Structural Composites for Space
Lead Center: JSC
Participating Center(s): GRC, LaRC

Advanced structural composites with the potential for enhanced damage detection are highly desired for spacecraft. Smart aspects, for example structural health monitoring or self-healing, should be introduced through utilization of advanced materials and nano-additives. Such composites could allow for the realization of the mass reduction that composite materials have promised for spacecraft but have not yet achieved.

NASA is currently evaluating composite materials for structures due to their relatively high strength, light weight, and potential low cost. There are a multitude of potential applications to primary and secondary structures, including vehicle, habitat module, and pressure vessel structures. Lighter materials with high specific strength can have drastic reduction in uptake mass, resulting in more cost effective space exploration. Smart materials such as piezoelectric, shape memory, and self-healing materials, will take structural composites to the next level.

One integral and limiting design concern for structural composites is that of damage tolerance. Upon impact, nearly imperceptible cracks may form upon impact, which, while tiny, may have drastic effects on structural integrity. To compensate, structural composites are designed to be thicker and heavier than would otherwise be required, thus negating the weight savings that these materials promise. One way to surmount this challenge and to realize the anticipated weight savings is to design smart materials. For instance, advanced materials and technologies should be developed to detect damage incidents, from tool drops during manufacturing to micrometeoroid and orbital debris impacts on orbit. Monitoring of extent of damage and the initiation of self-healing could reduce the complexity of composite maintenance and increase materials performance lifetime and reliability. Thermal/electrical/mechanical properties may be introduced or enhanced for multi-functionality such as thermal management or electrostatic discharge prevention and resultant weight savings. Overall, smart structures focused on space applications will have a significant impact on NASA's Space Exploration program.

While the subtopic description is broad, the offerer will narrowly define the composite system and intended applications. This subtopic is not intended for materials coupon-level work only; proposed systems should have a targeted demonstrator structure identified as a deliverable. Solutions may employ nanotechnology but are not required to do so. The smart structural composite should be proposed as an alternate material in this identified structure, with additional or enhanced functionality. In Phase I, composite samples will be fabricated and tested to demonstrate basic functionality. The targeted demonstrator structure will be identified, and critical test environments and associated performance predictions will be defined relative to the final operating environment. Deliverables include composite samples and the associated test data, predictions, and definitions. During Phase II, while full-scale parts are not required, scaled-up composite samples will be built in application-appropriate geometries. Samples will be tested in a simulated operational environment for demonstrate of performance in critical areas. Further scale-up requirements will be defined, and performance predictions will made for subsequent development phases. Deliverables will include composite samples and the associated test data, definitions, and predictions.

TOPIC: T11 Modeling, Simulation, Information Technology and Processing

Modeling, Simulation, Information Technology and Processing consists of four technology subareas, including computing, modeling, simulation, and information processing. NASA’s ability to make engineering breakthroughs and scientific discoveries is limited not only by human, robotic, and remotely sensed observation, but also by the ability to transport data and transform the data into scientific and engineering knowledge through sophisticated needs. With data volumes exponentially increasing into the petabyte and exabyte ranges, modeling, simulation, and information technology and processing requirements demand advanced supercomputing capabilities.

T11.01 Information Technologies for Intelligent and Adaptive Space Robotics
Lead Center: ARC
Participating Center(s): JPL, JSC

The objective of this subtopic is to develop information technologies that enable robots to better support space exploration. Robots are already at work in all of NASA's Mission Directorates and will be critical to the success of future exploration missions. The NASA “Robotics, Tele-Robotics, and Autonomous Systems” roadmap (TA04) indicates that extensive and pervasive use of robots can significantly enhance exploration, particularly for missions that are progressively longer, complex, and operate with fewer ground control resources.

Intelligent 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 robotic tasks include: scouting, site surveys, sampling, payload deployment and unskilled labor (site clean-up, close-out tasks, etc).

The performance of intelligent robots is directly linked to the quality and capability of the information technologies used to build and operate them. Thus, proposals are sought that address the following technology needs:

- Advanced user interfaces for shared-autonomy and remotely operated robots, which facilitate distributed collaboration, geospatial data visualization, summarization and notification, and robot tasking. This does NOT include user interfaces for direct teleoperation / purely manual control (e.g., joystick-based rate control), telepresence, or immersive virtual reality. The primary objective is to enable more effective and efficient interaction with semi-autonomous telerobots.
- Mobile robot navigation (localization, hazard avoidance, etc.) for operations in man-made (inside human spacecraft) and unstructured environments (planetary surfaces). Emphasis on multi-sensor data fusion,

obstacle detection, and proximity ops. The primary objective is to radically and significantly increase the performance of mobile robot navigation through advanced on-board sensors, perception algorithms and software.
- Robot software architecture that radically reduces operator workload for remotely operating mobile robots. This includes frameworks for adjustable autonomy, on-board health management and prognostics, automated data triage, and high-performance robot middleware. The primary objective is to facilitate the creation, extensibility and maintenance of complex robot systems.

Deliverables to NASA:

- Identify scenarios and use cases.
- Define specifications based on design trades.
- Develop concepts to address use cases.
- Demonstrate prototype systems and technology demonstrations.

T11.02 Computational Simulation and Engineering
Lead Center: JPL

Virtual Worlds - We solicit proposals for development of computational tools that enable rapid demonstration of mission concepts. The intent of such a tool is to enable non-experts in animation to rapidly build mission scenarios and visually express their concepts in a virtual world. These tools should enable full 3D visualization by importing of CAD parts of electromechanical systems (e.g., rovers, landers, orbiters), environment models (height field maps with textures for terrain, star maps and planetary bodies), animation functionality to show temporal progression and movement of appropriate objects in the scene. The tool should support animation of flexible bodies (e.g., solar panel vibrations) along with articulation of components. The tool should feature a ray-tracing engine for good quality visualization with shadowing, ambient lighting, etc. The tool should also be able to demonstrate terrain artifacts such as rocks, dust and ejecta as both static and dynamic objects. An example of a static artifact may be a rock pile that does not move during the animation while a dynamic artifact may be dust rising from a lander thruster interaction with terrain. Note that the emphasis is on visualization and not necessarily on the physics of the problem. However, the tool should have a standard API for integration with physics engines (e.g., ODE, Bullet, Proprietary Code) so that physics simulations can be used to control temporal progression of a scene. While it is preferred to have a representative physics engine coupled to the tool, it is not required. There should also be a functionality to write simple scripts for animating the virtual entities. There should be an avenue for developing a library of animation objects (e.g., rovers, terrains and locations) for re-use in later concept developments. The tools should be cross platform and enable development of animations or movies. The tool should take advantage of graphics processors or enable use of cluster computers for fast rendering of complex scenes. Alternately, the tool could feature a server-based functionality where the front-end user-interactions are through a webpage (using Java, HTML or other alternatives) and the computations are remotely conducted. Support for multiple concurrent users for content creating is desired. Ease of user interaction is key to the success of the tools. It is expected that at the end of Phase I, the performer will deliver an architecture document that captures the full intent of the tool. Similarly, performer will deliver software prototype of the implementation of the tool. It is expected that the software at the end of Phase I will be a prototype and may not have all features implemented or debugged. Performer will identify options for desired licensing options for the software to be developed for Phase II. At the end of Phase II, the performer will deliver all source code associated with the tool and verification test cases demonstrating all the proposed features within the software. The performer will also deliver a document summarizing the installation and usage of the tool and appropriate licensing options. In case of use of any third party software (e.g., open-source code) in this effort, the performer will deliver an acknowledgement that they have complied with appropriate licensing agreements. The anticipated TRL level at the end of Phase II is 5-6.

Computational Optimization - We solicit proposals for developing numerical tools that enable robust continuous and discrete optimization as well as sensitivity analysis for physics based computational models. There are a number of open-source and proprietary tools that are capable of meeting this objective at various levels of success. We are interested in proposals that develop a standard API for using the various open-source tools for different kinds of numerical problems. This would be in the form of a cross-platform abstraction API that enables users to have a standard API set for interacting with different optimization engines. We are also interested in software for autonomous optimization (genetic algorithms, simulated annealing, etc.), mixed (discrete and continuous) optimization problems and human-in-the-loop optimization / minimization. Methods for classifying problems (potentially in a catalogue) and associating them with solution methods are also of interest. Methods for measuring the similarity between a new problem with those solved in the past (e.g., those in a catalogue) and hence identifying associated solution method(s) are of high interest. Phase I deliverables should include:

- A document summarizing the different numerical methods that would be implemented in Phase II and representative numerical examples of these methods developed in Matlab or similar program.
- Pseudo-code of the abstraction API.
- Architecture for classification (or cataloguing) problems with their solution methods and measuring similarity between problems.

Performer will identify options for desired licensing options for the software to be developed for Phase II. At the end of Phase II, the performer will deliver all source code associated with the abstraction API and as well as the software tool for interfacing with different numerical engines for solving optimization or sensitivity analysis problems, mechanisms for cataloguing problems and measuring similarity between problems. Performer will deliver verification test cases demonstrating the proposed features within the software. The performer will also deliver a document summarizing the installation and usage of the software and appropriate licensing options. In case of use of any third party software (e.g., open-source code) in this effort, the performer will deliver an acknowledgement that they have complied with appropriate licensing agreements. The anticipated TRL level at the end of Phase II is 4-6.

TOPIC: T12 Materials, Structures, Mechanical Systems and Manufacturing

Materials, Structures, Mechanical Systems, and Manufacturing This topic is extremely broad, covering five technology areas: materials, structures, mechanical systems, manufacturing, and cross-cutting technologies. The topic consists of enabling core disciplines and encompasses fundamental new capabilities that directly impact the increasingly stringent demands of NASA science and exploration missions.

T12.01 High Fidelity Predictions for Spacecraft and Launch Vehicle Vibroacoustic Environments and Coupling
Lead Center: LaRC
Participating Center(s): MSFC, SSC

Fully verified and validated physics-based methods are desired to predict aero-acoustic and buffet loads experienced by launch vehicles and the resulting structural response. Prediction improvements in both the external environments and transmitted internal vibration are needed to better design lighter and cheaper spacecraft and launch vehicle structure as well as lower costs associated with ruggedizing and qualifying spacecraft and launch vehicle secondary structures. New methods are needed to improve environment predictions in terms of absolute levels, spatial definition including cross-spectra, and associated dispersions. Innovations in the following specific areas are solicited:

- Fundamental physics based CFD predictions of the flow over compression and expansions corners and protuberances and the resulting fluctuating pressure loads.
- Wind tunnel and/or flight tests to provide validation data of the cross spectra dynamic loads for the above problem areas and for the influence of protuberance disturbed pressure fields on vibration.
- Innovative approaches to measure full spectrum surface loads over broad areas to 8kHz full scale.
- New techniques to measure and predict rocket plume-induced fluctuating pressure loads.
- Concepts to accurately and efficiently couple these loads to realistic launch vehicle structures.
- Improved deterministic and statistical modeling of the loads and resulting vibration and transmission.
- Improved integration of vibro-acoustic design criteria into early structural design to provide more effective trade-off studies.

T12.02 High Temperature Materials and Sensors for Propulsion Systems
Lead Center: GRC
Participating Center(s): ARC, DFRC, LaRC, MSFC, SSC

Advanced high temperature materials, structures and sensors are crosscutting technologies which are essential in the design, development and health maintenance/detection needs of components and subsystems that will be needed in future generations of aeronautical and space propulsion systems. The extreme temperature and environmental stability requirements posed by aerospace propulsion systems requires material improvements to meet the challenges of systems of the future. Increased temperature capability can be achieved through the development of new and improved materials as well as through innovative designs, with both materials and designs dependent on advanced processing techniques. The combined effect of environment plus mechanical/thermal loading is expected to have a greater degree of influence on the durability of aerospace high temperature materials. Nanotechnology offers a means to develop higher-temperature/environmentally-resistant structural materials with engineered microstructures that can optimize material properties for propulsion hot section components. Multifunctional materials and structures offer a means to reduce component weight in aerospace flight vehicles, enabling efficiency, performance improvements and reduced fuel burn for aircraft and greater payload mass and launch cost reduction for spacecraft. The small volume and high force-to-weight ratio of shape memory alloys are an attractive actuator replacement for current ones based on electric motors, hydraulic or pneumatic systems. Sensing methods and measurement techniques that are cost-effective and reliably assess the health of aerospace engines and vehicle components in harsh high-temperature environments (to 3000 °F) allow for a proactive approach to maintain capability and safety. Proposals are sought to:

- Develop innovative approaches to enhance the processability, performance and reliability of advanced high temperature materials, including metals, ceramics, polymers, high-strength fibers, composites, hybrids and coatings to improve environmental durability for engine components.
- Develop innovative methods, evaluate and model the impact on the mechanical properties of representative aerospace materials tested while resident in the extreme application environment, to compare to mechanical property testing in air or in vacuum.
- Demonstrate novel processing approaches (simpler, more cost effective) for advanced aerospace materials for propulsion systems.
- Develop physics-based modeling tools to predict durability and life based on damage mechanisms of advanced materials.

T12.03 Additive Manufacturing of metal Plus Insulator Structures with sub-mm Features
Lead Center: GSFC

NASA is interested in investigating additive manufactured structures combining metals and insulators demonstrating multiple layers of 10-500 um lines and spaces, 200 um thick insulator layers, and 200 um diameter blind vias on 400 um centers capable of withstanding ~800 V between layers.

Expected Deliverables: Fabrication of a small area, few cm^2, micro-well detector with 200 um diameter holes, 200 um deep, on 400 um centers that operates up to ~800 V. Demonstration of scalability to large, ~1 m^2, area.

Mission Traceability: The Advanced Energetic Pair Telescope (AdEPT), a medium energy gamma-ray polarimeter.

Beyond the initial medium-energy gamma-ray instrument application, NASA foresees a wide range of further scientific space instruments enabled by additive manufacturing (3-D printing) that combines metals and insulators with sub-mm feature sizes. Possibilities include fabrication of electro-mechanical structures for ionization detectors, mass spectrometers, charged particle detectors et cetera for both small and large scale space missions.

In addition, this is a generic technology which would also be suitable for fabrication of commercial grade, micro-scale electronics.

State of the Art: Additive manufacturing with metals or insulators (plastics) is advancing rapidly. SOA is limited in feature size, inability to combine metals and insulators, and surface smoothness needed for high voltage applications. 3-D additive manufacturing that combines insulators and conductors is being pursued by several entities. Combining metals and insulators with sub-mm features would provide significant improvements in performance and size of the micro-well detectors for AdEPT. Current micro-well fabrication using laser micro-machining requires RIE post processing to eliminate residue from laser ablation that leads to high voltage breakdown in the micro-wells.

T12.04 Experimental and Analytical Technologies for Additive Manufacturing
Lead Center: MSFC
Participating Center(s): ARC, GRC, JSC, LaRC

Additive manufacturing is becoming a leading method for reducing costs, increasing quality, and shortening schedules for production of innovative parts and component that were previously not possible using more traditional methods of manufacturing. In the past decade, methods such as selective laser melting (SLM) have emerged as the leading paradigm for additive manufacturing (AM) of metallic components, promising very rapid, cost-effective, and on-demand production of monolithic, lightweight, and arbitrarily intricate parts directly from a CAD file. In the push to commercialize the SLM technology, however, the modeling of the AM process and physical properties of the resulting artifact were paid little attention. As a result, commercially available systems are based largely on hand-tuned parameters determined by trial and error for a limited set of metal powders. The system operation is far from optimal or efficient, and the uncertainty in the performance of the produced component is too large. This, in turn, necessitates a long and costly certification process, especially in a highly risk-aware community such as aerospace.

This topic seeks technologies that close top technology gaps in both experimental and analytical areas in materials design, process modeling and material behavior prediction to reduce time and cost for materials development and process qualification for SLM:

- Additive Manufacturing Technologies: Develop real-time additive manufacturing process monitoring for real-time material quality assurance prediction; Finish inspection and qualification of parts for implementation, replacement, and repair; Develop standards for accepting additively manufactured parts for use in space systems.
- Research-grade test beds: Experimental test beds that will allow for detailed study of individual phases of the SLM and other methods of additive manufacturing by NASA scientists, academic groups, etc. (Affordability of test bed will be crucial for fostering a large community of developers for next-generation SLM/AM systems.)
- Physics-based models: Reduced-order physics models for individual phases of additive manufacturing techniques, mainly to enable rapid processing of process data and to facilitate model-based optimal process control. (Note that most, if not all, phases of the SLM cycle requires coupled multi-physics modeling.)
- Analytical Tools: Develop analytical tools to understand effects of process variables on materials evolution to insure expected material microstructure and apply to certification of manufacturing process.
- Digital models: Standardize the use of structured light scanning or equivalent within manufacturing processes; model-based design environment where manufacturing does not rely on both models and drawings for data; standard paperless manufacturing execution system; digital fabrication machines that combine additive, subtractive, and other multi-axial material transformation processes.
- Numerical simulation codes: Software for high-fidelity simulation of various SLM phases for guiding the development, and enabling the subsequent verification, of new analytical physics models.

Mission Traceability - STMD continues to seek manufacturing techniques and capabilities that will allow missions of increased capability and reduced costs. Manufacturing technologies have high value and make a significant contribution to the interests of others outside of NASA, specifically those that address broader national needs as well as the needs of the commercial space industry.

State of the Art - Advanced Manufacturing is rapidly evolving, and newer technologies are emerging. The first in-space 3-D print experiment will fly in 2014, and related technologies will follow exponentially.

TOPIC: T13 Ground and Launch Systems Processing

Reserved for future Solicitations.

TOPIC: T14 Thermal Management Systems

Reserved for future Solicitations.

TOPIC: T15 Aeronautics

Reserved for future Solicitations.

Appendices

Appendix A: 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/experi-mental 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 breadboard 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	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.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements.

		made for subsequent development phases.	Prototype implementations developed.	
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 B: 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 C: SBIR/STTR and the Space Technology Roadmaps

Research and technology topics/subtopics for the SBIR Program are 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 the OCT Technology Area level one (first column) and level 2 (third column), with the related SBIR Select subtopic description (fourth column) and subtopics ID (fifth column) listed as well. The Aeronautics area is included for completeness, though this is beyond the scope of the STR.

TA	STR Technology Area (TA) Level 1 Description	STR Technology Area (TA) Level 2 Description	Subtopic Description	Subtopic
TA01	1.0.0 Launch Propulsion Systems,	1.3.0 Air Breathing Propulsion Systems	Low Emissions/Clean Power	A3.03
		1.5.0 Unconventional/Other Propulsion Systems	Small Launch Vehicle Propulsion Technology	T1.02
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA02	2.0.0 In-Space Propulsion Technologies	2.1.0 Chemical Propulsion	In-Space Chemical Propulsion	H2.02
			Spacecraft Technology for Sample Return Missions	S4.03
		2.2.0 Non-Chemical Propulsion	High Power Electric Propulsion	H2.01
			Nuclear Thermal Propulsion (NTP)	H2.03
			Propulsion Systems for Robotic Science Missions	S3.02
			Integrated Nuclear Power & Propulsion	Z1.03
		2.3.0 Advanced (TRL < 3) Propulsion Technologies	Affordable Nano-Launcher Upper Stage Propulsion	T1.01
		2.4.0 Supporting Technologies	Nuclear Thermal Propulsion (NTP) Ground Test Technologies	H2.04

TA	STR Technology Area (TA) Level 1 Description	STR Technology Area (TA) Level 2 Description	Subtopic Description	Subtopic
TA03	3.0.0 Space Power and Energy Storage	3.1.0 Power Generation	Space Nuclear Power Systems	H8.02
			Advanced Photovoltaic Systems	Z1.01
			Innovative Energy Harvesting Technology Development	T3.01
		3.2.0 Energy Storage	Advanced Space Battery Technology	Z1.02
		3.3.0 Power Management and Distribution	Power Electronics and Management, and Energy Storage	S3.03
		3.4.0 Cross Cutting Technology	Solid Oxide Fuel Cells and Electrolyzers	H8.01
			Power Generation and Conversion	S3.01
			Terrestrial and Planetary Balloons	S3.06
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA04	4.0.0 Robotics, Telerobotics and Autonomous Systems	4.3.0 Manipulation	Robotic Mobility, Manipulation and Sampling	S4.02
			Regolith Resources Robotics - R3	T4.02
		4.4.0 Human-Systems Integration	Information Technologies for Intelligent and Adaptive Space Robotics	T11.01
		4.5.0 Autonomy	Real-Time Safety Assurance under Unanticipated and Hazardous Conditions	A1.03
			Spacecraft Autonomy and Space Mission Automation	H6.01
			Dynamic Servoelastic (DSE) Network Control, Modeling, and Optimization	T4.01

TA	STR Technology Area (TA) Level 1 Description	STR Technology Area (TA) Level 2 Description	Subtopic Description	Subtopic
TA05	5.0.0 Communication and Navigation	5.1.0 Optical Comm. And Navigation	Long Range Optical Telecommunications	H9.02
			Advanced Celestial Navigation Techniques and Systems for Deep-Space Applications	H9.05
		5.2.0 Radio Frequency Communications	SCaN Testbed (CoNNeCT) Experiments	H9.01
			Long Range Space RF Telecommunications	H9.03
		5.4.0 Position, Navigation, and Timing	Flight Dynamics GNC Technologies and Software	H9.04
			Guidance, Navigation and Control	S3.05
		5.5.0 Integrated Technologies	Autonomous Communications Systems	T5.01
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA06	6.0.0 Human Health, Life Support and Habitation Systems	6.1.0 Environmental Control Life Support & Habitation Systems	Human Accommodations and Habitation Systems for Future Exploration Missions	H3.03
			Development of Treatment Technologies and Process Monitoring for Water Recovery	H3.04
			Synthetic/Engineering Biology for NASA Applications	T6.01
		6.2.0 Extravehicular Activity Systems	Space Suit Pressure Garment and Airlock Technologies	H4.01
		6.3.0 Human Health and Performance	Next Generation Oxygen Concentrator for Medical Scenarios	H12.01
			Inflight Calcium Isotope Measurement Device	H12.02
			Objective Sleep Measures for	H12.03

TA	STR Technology Area (TA) Level 1 Description	STR Technology Area (TA) Level 2 Description	Subtopic Description	Subtopic
			Spaceflight Operations	
			Advanced Food Technology	H12.04
			Metal Organic Framework Sorbents for Spacecraft Medical Applications	T6.02
		6.5.0 Radiation	Radiation Shielding Systems	H11.01
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA07	7.0.0 Human Exploration Destination Systems	7.1.0 In-Situ Resource Utilization	In-Situ Resource Utilization - Mars Atmosphere/Gas Chemical Processing	H1.01
			International Space Station (ISS) Utilization	H10.02
		7.4.0 Advanced Habitat Systems	Atmosphere Revitalization and Fire Recovery for Future Exploration Missions	H3.02
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA08	8.0.0 Science Instruments, Observatories & Sensor Systems	8.1.0 Science Instruments	In Situ Sensors and Sensor Systems for Lunar and Planetary Science	S1.06
			Airborne Measurement Systems	S1.07
			Surface & Sub-surface Measurement Systems	S1.08
			Proximity Glare Suppression for Astronomical Coronagraphy	S2.01
			Precision Deployable Optical Structures and Metrology	S2.02
			Advanced Optical Systems	S2.03
			Extreme Environments Technology	S4.04
			Technologies for Planetary Compositional	T8.01

			Analysis and Mapping	
		8.2.0 Observations	Next Generation Total Lightning Detection Sensor	T8.02
		8.3.0 Sensor Systems	Aviation External Hazard Sensor Technologies	A1.01
			Lidar Remote Sensing Technologies	S1.01
			Microwave Technologies for Remote Sensing	S1.02
			Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter	S1.03
			Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments	S1.04
			Particles and Field Sensors and Instrument Enabling Technologies	S1.05
			Atomic Interferometry	S1.09
			Unmanned Aircraft and Sounding Rocket Technologies	S3.04
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA09	9.0.0 Entry, Descent and Landing Systems	9.1.0 Aeroassist & Entry	Advanced Thermal Protection Systems Technologies	H7.01
		9.4.0 Vehicle Systems Technology	Planetary Entry, Descent and Landing Technology	S4.01
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA10	10.0.0 Nanotechnology	10.1.0 Engineered Materials and Structures	Lightweight Structural Nanomaterial Concepts	T10.01
			Smart Structural Composites for Space	T10.02

TA	STR Technology Area (TA) Level 1 Description	STR Technology Area (TA) Level 2 Description	Subtopic Description	Subtopic
TA11	11.0.0 Modeling, Simulation, Information Technology and Processing	11.1.0 Computing	Technologies for Large-Scale Numerical Simulation	S5.01
			Computational Simulation and Engineering	T11.02
		11.2.0 Modeling	Quiet Performance	A3.02
			Physics-Based Conceptual Design Tools	A3.05
			Integrated Science Mission Modeling	S5.04
			Fault Management Technologies	S5.05
			Modeling and Measurements for Propulsion and Power	Z1.04
		11.3.0 Simulation	High Fidelity Predictions for Spacecraft and Launch Vehicle Vibroacoustic Environments and Coupling	T12.01
		11.4.0 Information Processing	Prognostics and Decision Making	A1.04
			Identification of Sequences of Atypical Occurrences in Massive Heterogeneous Datasets Representing the Operation of a System of Systems	A1.05
			Earth Science Applied Research and Decision Support	S5.02
			Algorithms and Tools for Science Data Processing, Discovery and Analysis, in State-of-the-Art Data Environments	S5.03

TA	STR Technology Area (TA) Level 1 Description	STR Technology Area (TA) Level 2 Description	Subtopic Description	Subtopic
TA12	12.0.0 Materials, Structures, Mechanical Systems and Manufacturing	12.1.0 Materials	Hot Structures	H5.04
			Cross Cutting advanced manufacturing process for large scale bulk metallic glass systems for aerospace applications	Z2.01
		12.2.0 Structures	Structural Efficiency-Aeroservoelasticity	A3.01
			Deployable Structures	H5.02
			Advanced Structural Health Monitoring	H13.02
			Additive Manufacturing of metal Plus Insulator Structures with sub-mm Features	T12.03
		12.3.0 Mechanical Systems	Aerodynamic Efficiency	A3.04
			Rotorcraft	A3.06
		12.4.0 Manufacturing	Additive Manufacturing of Lightweight Metallic Structures	H5.01
			Recycling/Reclamation of 3D Printer Plastic for Reuse	H10.01
			Experimental and Analytical Technologies for Additive Manufacturing	T12.04
		12.5.0 Cross-Cutting	Propulsion Efficiency-Propulsion Materials and Structures	A3.07
			Advanced Fabrication and Manufacturing of Polymer Matrix Composite (PMC) Structures	H5.03
			Advanced NDE Techniques for Complex Built Up Structures	H13.01
			Optics Manufacturing and	S2.04

			Metrology for Telescope Optical Surfaces	
			High Temperature Materials and Sensors for Propulsion Systems	T12.02
TA	**STR Technology Area (TA) Level 1 Description**	**STR Technology Area (TA) Level 2 Description**	**Subtopic Description**	**Subtopic**
TA14	14.0.0 Thermal Management Systems	14.2.0 Thermal Control Systems	Thermal Control for Future Human Exploration Vehicles	H3.01
			Thermal Control Systems	S3.07
		Topic Title	**Subtopic Title**	**Subtopic**
Aviation Research (ARMD)		Aviation Safety	Aviation External Hazard Sensor Technologies	A1.01
			Inflight Icing Hazard Mitigation Technology	A1.02
			Real-Time Safety Assurance under Unanticipated and Hazardous Conditions	A1.03
			Prognostics and Decision Making	A1.04
			Identification of Sequences of Atypical Occurrences in Massive Heterogeneous Datasets Representing the Operation of a System of Systems	A1.05
		Unmanned Aircraft Systems	Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Research	A2.01
		Air Vehicle Technology	Structural Efficiency-Aeroservoelasticity	A3.01
			Quiet Performance	A3.02
			Low Emissions/Clean Power	A3.03
			Aerodynamic Efficiency	A3.04

		Physics-Based Conceptual Design Tools	A3.05
		Rotorcraft	A3.06
		Propulsion Efficiency-Propulsion Materials and Structures	A3.07
	Ground and Flight Test Techniques and Measurement	Ground Test Techniques and Measurement Technologies	A4.01

Research Topics Index

AERONAUTICS RESEARCH

HUMAN EXPLORATION AND OPERATIONS

SCIENCE

SPACE TECHNOLOGY

STTR