SBIR/STTR 2010-1

National Aeronautics and Space Administration

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

Program Solicitations

Opening Date: July 19, 2010
Closing Date: September 2, 2010

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

2010 SBIR/STTR Solicitation Noteworthy Changes

1.2 Program Authority and Executive Order

Public Law 111-162, extending authorization of the SBIR/STTR Programs.

Executive Order 13329 (69 FR 9181) for “Encouraging Innovation in Manufacturing.”

Security Act of 2007, section 1203 for Energy Independence.

1.3 Program Management

This Management function of the NASA SBIR/STTR programs is being transitioned to the newly established Office of the Chief Technologist.

1.4.2 Phase II

The maximum value for a Phase II contract increased.

Phase II Enhancement:

The total cumulative award for the Phase II contract plus the Phase II-E increased.

3.3.3 Forms

Part 9: Subcontracts and Consultants

Change in the documentation of subcontract/consultant costs in Form C.

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2010 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, the three program phases, and information for submitting responsive proposals is contained herein. The 2010 Solicitation period for Phase I proposals begins July 19, 2010, and ends September 2, 2010.

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

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

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

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

Subject to the availability of funds, approximately 300 SBIR and 30 STTR Phase I proposals will be selected for negotiation of fixed-price contracts in November 2010. Historically, the ratio of Phase I proposals to awards is approximately 6:1 for SBIR and STTR, and approximately 45% of the selected Phase I contracts are selected for Phase II follow-on efforts.

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

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

1.2 Program Authority and Executive Order

SBIR and STTR opportunities are solicited annually pursuant to the Small Business Innovation Development Act of 1982 (Public Law 97-219), Small Business Innovation Research Program Reauthorization Act of 2000 (Public Law 106-554), the Small Business Research and Development Act of 1992 (Public Law 102-564), the Small Business Technology Transfer Program Reauthorization Act of 2001 (Public Law 107-50) as most recently amended by Public Law 111-162 extending authorization of both programs to July 31, 2010. A new authorization or extension (continuing resolution) is anticipated prior to this end date.

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

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

1.3 Program Management

The Innovative Partnerships Program Office under the Office of the NASA Associate Administrator currently provides overall policy direction for implementation of the NASA SBIR/STTR programs. This management function is being transitioned to the newly established Office of the Chief Technologist. The transition will be completed in fiscal year 2011. 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 provides the overall procurement management for the programs. All of the NASA Centers actively participate in the SBIR/STTR program; and to reinforce NASA's objective of infusion of SBIR/STTR developed technologies into its programs and projects, each Center has personnel focused on that activity.

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

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

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

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

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

1.4 Three-Phase Program

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

1.4.1 Phase I

The purpose of Phase I is to determine the scientific, technical, and 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.

Proposals must conform to the format described in Section 3.2. Evaluation and selection criteria are described in Section 4.1. NASA is solely responsible for determining the relative merit of proposals, their selection for award, and judging the value of Phase I results.

Maximum value and period of performance for Phase I contracts:

Phase I Contracts	SBIR	STTR
Maximum Contract Value	$ 100,000	$ 100,000
Period of Performance	6 months	12 months

1.4.2 Phase II

The purpose of Phase II is the development, demonstration and delivery of the innovation. Only SBCs awarded Phase I contracts are eligible for Phase II funding agreements. Phase II projects are chosen as a result of competitive evaluations based on selection criteria provided in Section 4.2.

Maximum value and period of performance for Phase II contracts:

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

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

Phase II Enhancement: The objective of the Phase II-E Option is an incentive to Phase III awards through providing cost share extension of the R&D efforts to the current Phase II contract, to meet the product/process/software requirements of a NASA program/project or third party investor to accelerate and/or enhance the infusion/commercial potential of the Phase II project. Under this option, NASA will match with SBIR/STTR funds up to $150,000 of non-SBIR/non-STTR investment from a NASA project, NASA contractor, or third party commercial investor to extend an existing Phase II project for up to 4 months to perform additional research. The total cumulative award for the Phase II contract plus the Phase II-E match is not expected to exceed $900,000.00 of SBIR/STTR funding. The non-SBIR or non-STTR contribution is not limited since it is regulated under the guidelines for Phase III award.

Regarding active Phase II awards only, NASA may enter into negotiations with awardees to create an option for "Phase II Enhancement" (Phase II-E) that will encourage transition of SBIR/STTR projects into NASA programs and projects. Additional details, including how to apply for the Phase II enhancement, will be provided no later than the 12th month of the performance of the Phase II contract. Application packages will not be accepted before the 15th month of the Phase II contract from selected awardees for a potential Phase II award but no later than the end of the 22nd month of the award.

1.4.3 Phase III

NASA may award Phase III contracts for products or services with non-SBIR/STTR funds. The competition for SBIR/STTR Phase I and Phase II awards satisfies any competition requirement of the Armed Services Procurement Act, the Federal Property and Administrative Services Act, and the Competition in Contracting Act. Therefore, an agency that wishes to fund a Phase III project is not required to conduct another competition in order to satisfy those statutory provisions. Phase III work may be for products, production, services, R/R&D, or any combination thereof that is derived from, extends, or logically concludes efforts performed under prior SBIR 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 2.18, are eligible to participate in these programs. Socially and economically disadvantaged and women-owned SBCs are particularly encouraged to propose.

STTR: SBCs shall submit a cooperative research agreement with a Research Institution (RI).

1.5.2 Place of Performance

For both Phase I and Phase II, the R/R&D must be performed in the United States (Section 2.23). However, based on a rare and unique circumstance (for example, if a supply or material or other item or project requirement is not available in the United States), NASA may allow a particular portion of the research or R&D work to be performed or obtained in a country outside of the United States. Proposals must clearly indicate if any work will be performed outside the United States. Prior to award, approval by the Contracting Officer for such specific condition(s) must be in writing.

1.5.3 Principal Investigator

The primary employment of the Principal Investigator (PI) must be with the SBC under the SBIR Program, while under the STTR Program the PI may be employed by either the SBC or RI. Primary employment means that more than half of the PI's total employed time (including all concurrent employers, consulting, and self-employed time) is spent with the SBC. 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, the offeror must explain how these requirements will be met if the proposal is selected for contract negotiations that may lead to an award. Co-PI's are not permitted.

REQUIREMENTS	SBIR	STTR
Primary Employment	PI must be with the SBC	PI must be employed with the RI or SBC
Employment Certification	The offeror must certify in the proposal that the primary employment of the PI will be with the SBC at the time of award and during the conduct of the project	If the PI is not an employee of the SBC, the offeror must describe the management process to ensure SBC control of the project
Co-Principal Investigators	Not Acceptable	Not Acceptable
Misrepresentation of Qualifications	Will result in rejection of the proposal or termination of the contract	Will result in rejection of the proposal or termination of the contract
Substitution of PIs	Must receive advanced written approval from NASA	Must receive advanced written approval from NASA

1.6 General Information

1.6.1 Solicitation Distribution

This 2010 SBIR/STTR Program Solicitation is available via the NASA SBIR/STTR Website (http://sbir.nasa.gov). SBCs are encouraged to check this website for program updates and information. Any updates or corrections to the Solicitation will be posted there. If the SBC has difficulty accessing the Solicitation, contact the Help Desk (Section 1.6.2).

1.6.2 Means of Contacting NASA SBIR/STTR Program

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

(2) The websites of the NASA Mission Directorates and the NASA Centers as listed in Section 1.3 provide information on NASA plans and mission programs relevant to understanding the topics/subtopics and needs described in Section 9.

(3) Help Desk:

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

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

(4) 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

1.6.3 Questions About This Solicitation

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

2. Definitions

2.1 Allocation of Rights Agreement

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

2.2 Commercialization

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

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

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

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

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

2.5 Essentially Equivalent Work

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

2.6 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.

2.7 Historically Underutilized Business Zone (HUBZone) Small Business Concern

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. See www.sba.gov/hubzone for more details.

2.8 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.

2.9 Innovation

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.

2.10 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 2.14), ideas, designs, know-how, business, technical and research methods, and 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.

2.11 Principal Investigator (PI)

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

2.12 Research and Development Equipment

Pertains to amounts for major equipment for research and development. Includes acquisition or design and production of movable equipment, such as spectrometers, research satellites, detectors, and other instruments. (For SBIR/STTR projects, major equipment for research or supplies not delivered to Government or consumed in the production of a prototype may be considered as capital equipment and will not be funded by the government. See appropriate sections of SBIR/STTR Budget Guidelines).

2.13 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.

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

Creative work 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).

2.15 SBIR/STTR Technical Data

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

2.16 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.

2.17 Service Disabled Veteran-Owned Small Business

A Service-Disabled Veteran-Owned SBC is a concern:

(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) The management and daily business operations of 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) That 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)

2.18 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.

2.19 Socially and Economically Disadvantaged Individual

A member of any of the following groups: African American, Hispanic American, Native American, Asian-Pacific American, Subcontinent-Asian American, other groups designated from time to time by SBA to be socially disadvantaged, or any other individual found to be socially and economically disadvantaged by SBA pursuant to Section 8(a) of the Small Business Act, 15 U.S.C. 637(a).

2.20 Socially and Economically Disadvantaged Small Business Concern

A socially and economically disadvantaged SBC is one that is: (1) at least 51 percent owned by (i) an Indian tribe or a native Hawaiian organization: or, (ii) one or more socially and economically disadvantaged individuals; and (2) whose management and daily business operations are controlled by one or more socially and economically disadvantaged individuals. See 13 CFR Parts 124.103 and 124.104.

2.21 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.

2.22 Technology Readiness Level (TRLs)

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

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

Additional information on TRLs is available in Appendix B.

2.23 United States

Means 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.

2.24 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.

2.25 Women-Owned Small Business

A women-owned SBC is a small business that is at least 51 percent owned by a woman or women who also control and operate it. "Control" in this context means exercising the power to make policy decisions. "Operate" in this context means being actively involved in the day-to-day management.

3. Proposal Preparation Instructions and Requirements

3.1 Fundamental Considerations

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

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

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 and 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.

Phase II contracts require the deliverable of reports. 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. The Phase II reports shall present (1) the work and results accomplished, (2) the scientific, technical and commercial merit and feasibility of the proposed innovation and Phase II results, (3) its relevance and significance to one or more NASA needs (Section 9), and (4) the progress towards transitioning the proposed innovation and Phase II results into follow-on investment, development, testing and utilization for NASA mission programs and other potential customers.

Report deliverables for Phase I and Phase II shall be submitted electronically via the SBIR/STTR website. NASA requests the submission of report deliverables in PDF format. Other acceptable formats are MS Word, MS Works, and WordPerfect.

3.2 Phase I Proposal Requirements

3.2.1 General Requirements

A competitive proposal will clearly and concisely (1) describe the proposed innovation relative to the state of the art, (2) address the scientific, technical and commercial merit and feasibility of the proposed innovation and its relevance and significance to NASA needs as described in Section 9, and (3) provide a preliminary strategy that addresses key technical, market, 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.

Page Limitation
A Phase I proposal shall not exceed a total of 25 standard 8 1/2 x 11 inch (21.6 x 27.9 cm) pages inclusive of the technical content and the required forms. Proposal items required in Section 3.2.2 will be included within this total.

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). **Proposals exceeding the 25-page limitation are subject to rejection during administrative screening.**

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

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

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

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

3.2.2 Format Requirements

All required items of information must be covered in the proposal. The space allocated to each part of the technical content will depend on the project chosen and the offeror's approach.

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

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

3.2.3 Forms

3.2.3.1 Cover Sheet (Form A)

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

3.2.3.2 Proposal Summary (Form B)

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

Technical Abstract
Summary of the offeror’s proposed project is limited to 200 words and shall summarize the implications of the approach and the anticipated results of both Phase I and Phase II including an assessment of technology readiness

levels (TRLs) at the beginning and end of the Phase I contract. ***NASA will reject a proposal if the technical abstract is judged to be non-responsive to the subtopic.***

Technology Taxonomy
Selections for the technology taxonomy are limited to technologies supported or relevant to the specific proposal. The listing of technologies for the taxonomy is provided at the end of Section 9.

Potential NASA and non-NASA commercial applications of the technology must also be presented.

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

3.2.3.3 Budget Summary (Form C)

The offeror shall complete the Budget Summary, following the instructions provided with the form (Section 8). The total requested funding for the Phase I effort shall not exceed $100,000. 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 budget is fair and reasonable. The government is not responsible for any monies expended by the applicant before award of any contract. Form C counts as one page towards the 25-page limit.

Property
Proposed costs for materials may be included. "Materials" means property that may be incorporated or attached to a deliverable end item or that may be consumed or expended in performing the contract. It includes assemblies, components, parts, raw materials, and small tools that may be consumed in normal use. Any purchase of equipment or products under an SBIR/STTR contract using NASA funds should be American-made to the extent possible. The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Material costs should be broken out by individual items including the price, quantity and reason it is required. Firms should be prepared to justify all material costs during negotiations. See section 5.16 for further guidance.

Subcontracts
The use of a subcontractor or consultant may be proposed. Any such arrangement should be documented in the subcontractor section of Form C

Phase I Travel
The NASA SBIR/STTR program does not anticipate travel will occur during the performance of a Phase I contract. If travel is required during Phase I the contractor must provide rationale for the trip as well as the duration, number of personnel traveling, and the cost associated with the travel must be included in the contractor budget (Form C). All travel must be approved by the technical monitor.

Phase I Delivery Schedule
The standard reporting requirements for Phase I are a technical report due at contract mid-point after award, a final report and new technology report due upon contract completion plus any other required deliverables. A prototype or demonstration is not required nor anticipated for any Phase I contract.

Profit
A profit or fee may be included in the proposed budget as noted in Section 5.11.

Cost Sharing
See Section 5.10.

3.2.4 Technical Content

This part of the submission shall not contain any budget data and must consist of all eleven parts listed below in the given order. All parts must be numbered and titled; parts that are not applicable must be noted as "Not Applicable."

Part 1: Table of Contents
The technical content shall begin with a brief table of contents indicating the page numbers of each of the parts of the proposal. The required table of contents is provided below:

Phase I Table of Contents

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.

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. At the offeror's option, this section may include bibliographic references.

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

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

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

Qualifications: The qualifications and capabilities of the proposed PI and the basis for PI selection are to be clearly presented in the proposal. NASA has the sole right to accept or reject a substitute 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 (Section 1.5.3), and indicate the extent to which other proposals recently submitted or planned for submission in 2010 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.

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: Company Facilities and Information
Provide adequate information to allow the evaluators to assess the ability of the offeror to carry out the proposed Phase I and projected Phase II and Phase III activities. The offeror should describe the relevant facilities and equipment, their availability, and those to be acquired, to support the proposed activities. The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Special tooling may be allowed. (Section 5.16)

The capability of the offeror to perform the proposed activities and to accomplish the commercialization of the proposed innovation and R/R&D results must be presented. Qualifications of the offeror in performing R/R&D activities and technology commercialization must be presented.

Note: Government wide SBIR and STTR policies restrict the use of any SBIR/STTR funds for the use of Government equipment and facilities. This does not preclude an SBC from utilizing a Government facility or Government equipment, but any charges for such use may not be paid for with SBIR/STTR funds (SBA SBIR Policy Directive, Section 9 (f)(3)). NASA may not and cannot fund the use of the Federal facility or personnel for the SBIR project with non-SBIR money. In rare and unique circumstances, SBA may issue a case-by-case waiver to this provision after review of an agency's written justification. NASA cannot guarantee that a waiver from this policy can be obtained from SBA.

The following information is required for consideration of a waiver:

(1) An explanation of why the SBIR 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.
(2) The concurrence of the SBC's chief business official to use the Federal facility or personnel.

If a proposed project or product demonstration requires the use of unique Government facilities or equipment to be funded by the SBIR 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. The proposal should also include relevant information on the funding source(s) private, internal, or other Government. Failure to provide this explanation and the site manager's written authorization of use may invalidate any proposal selection. If the offeror proposes the use of SBIR/STTR funds for Government equipment or facilities, this explanation will be provided to SBA during the Agency waiver process.

Additional information on the use of NASA facilities, facility programs, and equipment is available at http://sbir.nasa.gov/SBIR/facilities.html.

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

SBIR	STTR
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 (Item 6 in the Budget Summary, Total Costs), deducting cost sharing or fee/profit and any proposed travel, materials, equipment and special tooling.)	The proposed subcontracted business arrangements with individuals or organizations other than the RI must not exceed 30 percent of the 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 (Item 6 in the Budget Summary, Total Costs), deducting cost sharing or fee/profit and any proposed travel, materials, equipment and special tooling.)

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 11: Similar Proposals and Awards
A firm may elect to submit proposals for essentially equivalent work to other Federal program solicitations (Section 2.5). Firms may also choose to resubmit previously unsuccessful Phase I proposals to NASA. However, it is unlawful to receive funding for essentially equivalent work already funded under any Government program. The offeror must inform NASA of related proposals and awards and clearly state whether the SBC has submitted currently active proposals for similar work under other Federal Government program solicitations, or intends to submit proposals for such work to other agencies. For all such cases, the following information is required:

(1) The name and address of the agencies to which proposals have been or will be submitted, or from which awards have been received (including proposals that have been submitted to previous NASA SBIR Solicitations);
(2) Dates of such proposal submissions or awards;
(3) Title, number, and date of solicitations under which proposals have been or will be submitted or awards received;
(4) The specific applicable research topic for each such proposal submitted or award received;
(5) Titles of research projects;
(6) Name and title of the PI/project manager for each proposal that has been or will be submitted, or from which awards have been received;
(7) If resubmitting to NASA, please briefly describe how the proposal has been changed and/or updated since it was last submitted.

Note: All eleven (11) parts of the technical proposal must be included. 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.

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

The Cooperative R/R&D Agreement (different from the Allocation of Rights Agreement, Section 4.1.4) is a single-page document electronically submitted and endorsed by the SBC and Research Institution (RI). A model agreement is provided, or firms can create their own custom agreement. The Cooperative R/R&D Agreement should be submitted as required in Section 6. This agreement counts toward the 25-page limit.

3.2.6 Prior Awards Addendum (Applicable for SBIR Awards Only)

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

3.2.7 Phase III Awards Resulting From NASA SBIR/STTR Awards

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

3.2.8 Briefing Chart

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

3.3 Phase II Proposal Requirements

3.3.1 General Requirements

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

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

Page Limitation
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. All items required in Section 3.3.2 will be included within this total. 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). **Proposals exceeding the 50-page limitation are subject to rejection during administrative screening.**

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.

3.3.2 Format Requirements

All required items of information must be covered in the proposal. The space allocated to each part of the technical content will depend on the project and the offeror's approach.

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

(1) Cover Sheet (Form A), electronically endorsed, counts as 1 page towards the 50 page limit;
(2) Proposal Summary (Form B), counts as 1 page towards the 50 page limit;
(3) Budget Summary (Form C), counts as 1 page towards the 50 page limit;
(4) Cooperative R/R&D Agreement between the SBC and RI **(STTR only)**, counts as 1 page towards the 50 page limit;

(5) Technical Content (11 Parts in order as specified in Section 3.3.4, **not to exceed 47 pages for SBIR and 46 pages for STTR**), including all graphics, and starting with a table of contents,
(6) Briefing Chart (Not included in the 50-page limit and must not contain proprietary data).

3.3.3 Forms

3.3.3.1 Cover Sheet (Form A)

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

3.3.3.2 Proposal Summary (Form B)

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

Technical Abstract
Summary of the offeror's proposed project is limited to 200 words and shall summarize the implications of the approach and the anticipated results of both Phase I and Phase II including an assessment of technology readiness levels (TRLs) at the beginning and end of the Phase II contract.

Technology Taxonomy
Selections for the technology taxonomy are limited to technologies supported or relevant to the specific proposal. The listing of technologies for the taxonomy is provided at the end of Section 9.

Potential NASA and non-NASA commercial applications of the technology must also be presented.

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

3.3.3.3. Budget Summary (Form C)

The offeror shall complete the Budget Summary, following the instructions provided with the form (Section 8), not to 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 budget is fair and reasonable. The Government is not responsible for any monies expended by the applicant before award of any funding agreement. Form C counts as one page towards the 50-page limit.

Property
Proposed costs for materials may be included. "Materials" means property that may be incorporated or attached to a deliverable end item or that may be consumed or expended in performing the contract. It includes assemblies, components, parts, raw materials, and small tools that may be consumed in normal use. Any purchase of equipment or products under an SBIR/STTR contract using NASA funds should be American-made to the extent possible. The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Material costs should be broken out by individual items, including the price, quantity and reason it is required. Firms should be prepared to justify all material costs during negotiations. See section 5.16 for further guidance.

Subcontracts
The use of a subcontractor or consultant may be proposed. Any such arrangement should be documented in the subcontractor section of Form C.

Phase II Travel
Travel during a Phase II contract is an acceptable cost when it is part of accomplishing the work. Proposed travel expenses will be reviewed for reasonableness. Proposed travel shall describe the purpose, benefit and necessity for proving technical feasibility. The proposed budget shall include a detailed breakdown of all proposed travel expenses, including the reason and duration and the basis for estimate of the cost. All travel and related expenses are subject to negotiation and approval by the Contracting Officer and COTR.

Phase II Deliverables
All proposed deliverables (other than reports) must be listed. This may include a prototype unit, software package, or a complete product or service, for NASA testing and utilization. At a minimum, Phase II requires quarterly reporting. The timing of reports must coincide with the end of each fiscal year.

Profit
A profit or fee may be included in the proposed budget as noted in Section 5.11.

Cost Sharing
See Section 5.10.

Requirement for Approved Accounting System
Offerors should have an accounting system that in the Defense Contract Audit Agency's (DCAA) opinion is adequate for accumulating costs. An approved accounting system can track costs to final cost objectives and segregate costs between direct and indirect. If you currently do not have an adequate accounting system, it is recommended that you take action to implement such a system. For more information about cost proposals and accounting standards, please see the DCAA publication entitled "Information for Contractors" which is available at http://www.dcaa.mil/dcaap7641.90.pdf.

3.3.4 Technical Proposal

This part of the submission shall not contain any budget data and must consist of all eleven parts listed below in the given order. All parts must be numbered and titled; parts that are not applicable must be noted as "Not Applicable."

Part 1: Table of Contents
The technical content shall begin with a brief table of contents indicating the page numbers of each of the parts of the proposal. The required table of contents is provided below:

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

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

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

Part 4: Work Plan
Provide a detailed work plan defining specific tasks, performance schedules, project milestones, and deliverables

Part 5: Related R/R&D
Describe R/R&D related to the proposed work and affirm that the stated objectives have not already been achieved and that the same development is not presently being pursued elsewhere under contract to the Federal Government.

Part 6: Key Personnel
Identify the key technical personnel for the project, confirm their availability for Phase II, and discuss their qualifications in terms of education, work experience, and accomplishments relevant to the project.

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 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: Company Facilities and Information
Describe the capability of the offeror to carry out Phase II and Phase III activities, including its organization, operations, number of employees, R/R&D capabilities, and experience in technological innovation, commercialization and other areas relevant to the work proposed. The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Special tooling may be allowed. (Section 5.16)

Note: Government-wide SBIR and STTR policies restrict the use of any SBIR/STTR award funds for the use of Government equipment and facilities. This does not preclude an SBC from utilizing a Government facility or Government equipment, but any charges for such use cannot be paid for with SBIR/STTR funds (SBA SBIR Policy Directive, Section 9 (f)(3)). NASA will not and cannot fund the use of the Federal facility or personnel for the SBIR project with non-SBIR money. In rare and unique circumstances, SBA may issue a case-by-case waiver to this provision after review of an agency's written justification. NASA cannot guarantee that a waiver from this policy can be obtained from SBA. The following information is required for consideration of a waiver:

(1) An explanation of why the SBIR 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.
(2) The concurrence of the SBC's chief business official to use the Federal facility or personnel.

If a proposed project or product demonstration requires the use of unique Government facilities or equipment that will be funded with SBIR dollars, 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. The proposal should also include relevant information on the funding source(s) private, internal, or other Government. Failure to provide this explanation and the site manager's written authorization of use may invalidate any proposal selection. If the offeror proposes the use of SBIR/STTR funds for Government equipment or facilities, this explanation will be provided to SBA during the Agency waiver process.

Additional information on the use of NASA facilities, facility programs, and equipment is available at http://sbir.nasa.gov/SBIR/facilities.html.

Part 9: Subcontracts and Consultants
Subject to the restrictions set forth below**,** the SBC may establish business arrangements with other entities or individuals to participate in performance of the proposed R/R&D effort. The offeror must describe all subcontracting or other business arrangements, and identify the relevant organizations and/or individuals with whom arrangements are planned. The expertise to be provided by the entities must be described in detail, as well as the functions, services, number of hours and labor rates. Offerors are responsible for ensuring that all organizations and individuals proposed to be utilized are actually available for the time periods required.

Subcontract costs should be documented in the subcontractor/consultant budget section in Form C. Subcontractors' and consultants' work must be performed in the United States. The following restrictions apply to the use of subcontracts/consultants:

SBIR Phase II Proposal	STTR Phase II Proposal
A minimum of 50 percent of the research and/or analytical work must be performed by the proposing SBC (as determined by the total cost of subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (Item 6 in the Budget Summary, Total Costs), deducting cost sharing or fee/profit and any proposed travel, materials, equipment and special tooling.)	A minimum of 40 percent of the research or analytical work must be performed by the proposing SBC and 30 percent by the RI (as determined by the total cost of the subcontracting effort (to include the appropriate OH and G&A) in comparison to the total effort (Item 6 in the Budget Summary, Total Costs), deducting cost sharing or fee/profit and any proposed travel, materials, equipment and special tooling.)

Part 10: Potential Post Applications (Commercialization)
Building upon Section 3.3.4, 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 11: Similar Proposals and Awards
If applicable, provide updated material (Reference Phase I Proposal Requirements, Part 11).

3.3.5 Capital Commitments Addendum Supporting Phase II and Phase III

Describe and document capital commitments from non-SBIR/STTR sources or from internal SBC funds for pursuit of Phase II and Phase III. 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 Phase II from parties other than the proposing firm. Funding support commitments must show that a specific, 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 Phase III will be funded internally, offerors should describe their financial position.

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

3.3.6 Phase III Awards resulting from NASA SBIR/STTR Awards

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

3.3.7 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 example chart is provided in Appendix A.

4. Method of Selection and Evaluation Criteria

All Phase I and II proposals will be evaluated and judged on a competitive basis. Proposals will be initially screened to determine responsiveness. Proposals passing this initial screening will be technically evaluated by NASA personnel to determine the most promising technical and scientific approaches. Each proposal will be judged 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 Phase I Proposals

Proposals judged 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 evaluated by evaluators with knowledge of the subtopic area.

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 plans to select for award those proposals offering the best value 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 judged 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 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 be shown to be adequate and any reliance on external sources, such as Government Furnished Equipment or Facilities, addressed (Section 5.16).

Factor 3: Effectiveness of the Proposed Work Plan
The work plan will be reviewed for its comprehensiveness, effective use of available resources, cost management and 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.

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

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

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.

4.1.3 Selection

Proposals recommended for award 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 as well as overall NASA priorities, program balance and available funding. 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 and award will be made to those offerors determined to be responsible.

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.

4.1.4 Allocation of Rights Agreement (STTR awards only)

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

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

4.2 Phase II Proposals

4.2.1 Evaluation Process

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

4.2.2 Evaluation Factors

NASA plans to select for award those proposals offering the best value to the Government and the SBIR/STTR program. The evaluation of Phase II proposals under this Solicitation will apply the following factors:

Factor 1: Scientific/Technical Merit and Feasibility
The proposed R/R&D effort will be evaluated on its innovativeness, originality, and potential technical value, including the degree to which Phase I objectives were met, the feasibility of the innovation, 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 be shown to be adequate and any reliance on external sources, such as Government Furnished Equipment or Facilities, addressed (Section 5.16).

Factor 3: Effectiveness of the Proposed Work Plan
The work plan will be reviewed for its comprehensiveness, effective use of available resources, cost management and proposed schedule for meeting the Phase II objectives. The methods planned to achieve each objective or task should be discussed in detail.

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 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.

4.2.3 Evaluation and Selection

Factors 1, 2, and 3 will be scored numerically with Factor 1 worth 50 percent and Factors 2 and 3 each worth 25 percent. The sum of the scores for Factors 1, 2, and 3 will comprise the Technical Merit score. Proposals receiving numerical scores of 85 percent or higher will be evaluated and rated for their commercial potential using the criteria listed in Factor 4 and by applying the same adjectival ratings as set forth for Phase I proposals. Where technical evaluations are essentially equal in potential, cost to the Government and the offeror's past performance may be considered in determining successful offerors. For Phase II proposals, commercial merit is a critical factor.

Recommendations for award 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, past performance and award will be made to those contractors determined to be responsible. Past performance evaluation will consider the contractor's performance under the Phase I effort.

Note: Companies with Prior NASA SBIR/STTR Awards

NASA has instituted a comprehensive commercialization survey/data gathering process for companies with prior NASA SBIR/STTR awards. Information received from SBIR/STTR awardees completing the survey is kept confidential, and will not be made public except in broad aggregate, with no company-specific attribution.

Responding to the survey is strictly voluntary. However, the SBIR/STTR Source Selection Official does see the information contained within the survey as adding to the program's ability to use past performance in decision making as well as providing a database of SBIR/STTR results for management.

If you have not completed a survey, or if you would like to update a previously submitted response, please go on-line at http://sbir.nasa.gov/SBIR/survey.html.

4.3 Debriefing of Unsuccessful Offerors

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

Debriefings will not disclose the identity of the proposal evaluators, proposal scores, the content of, or comparisons with, other proposals.

4.3.1 Phase I Debriefings

For Phase I proposals, debriefings will be automatically e-mailed to the designated business official within 60 days of the selection announcement. If you have not received your debriefing by this time, contact the SBIR/STTR Program Support Office at sbir@reisys.com.

4.3.2 Phase II Debriefings

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

5. Considerations

5.1 Awards

5.1.1 Availability of Funds

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

SBIR

- NASA plans to announce the selection of approximately 300 proposals resulting from this Solicitation, for negotiation of Phase I contracts with values not exceeding $100,000. Following contract negotiations and awards, Phase I contracts will be fixed price and contractors will have up to 6 months to carry out their programs, prepare their final reports, and submit Phase II proposals.

- NASA anticipates that approximately 45 percent of the successfully completed Phase I projects from the SBIR 2010 Solicitation will be selected for Phase II. Phase II agreements will be fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $750,000.

STTR

- NASA plans to announce the selection of approximately 30 proposals resulting from this Solicitation, for negotiation of Phase I contracts with values not exceeding $100,000. Following contract negotiations and awards, Phase I contracts will be fixed price and contractors will have up to 12 months to carry out their programs, prepare their final reports, and submit Phase II proposals.

- NASA anticipates that approximately 45 percent of the successfully completed Phase I projects from the STTR 2010 Solicitation will be selected for Phase II. Phase II agreements will be fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $750,000.

5.1.2 Contracting

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

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

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

Note: Costs incurred prior to and in anticipation of award of a contract are entirely the risk of the contractor in the event that a contract is not subsequently awarded.

5.2 Phase I Reporting

The technical reports are required as described in the contract. These reports shall document progress made on the project and activities required for completion to provide NASA the basis for determining whether the payment is warranted.

A final report must be submitted to NASA upon completion of the Phase I R/R&D effort in accordance with applicable contract provisions. It shall elaborate the project objectives, work carried out, results obtained, and assessments of technical merit and feasibility. The final report shall include a single-page summary as the first page, in a format provided in the Phase I contract, identifying the purpose of the R/R&D effort and describing the findings and results, including the degree to which the Phase I objectives were achieved, and whether the results justify Phase II continuation. The potential applications of the project results in Phase III either for NASA or commercial purposes shall also be described. The final project summary is to be submitted without restriction for NASA publication.

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

5.3 Payment Schedule for Phase I

All NASA SBIR and STTR contracts are firm-fixed-price contracts.

The exact payment terms for Phase I will be included in the contract, but payments are normally authorized as follows: $30,000.00 at the time of award, $30,000.00 at project mid-point, and the remainder upon acceptance of the final report, new technology report and any other deliverables by NASA. NASA will make payment within thirty days of NASA acceptance and approval of all required deliverables associated with the payment.

Invoices: All invoices submitted by the SBC shall be marked with the payment number for the invoice. For example, if the invoice submitted is the first submitted for a contract, it shall be marked as the First Invoice. All final invoices shall be marked Final Invoice. All invoices are required to be submitted electronically via the SBIR/STTR Website.

5.4 Payment Schedule for Phase II

All NASA SBIR and STTR contracts are firm-fixed-price contracts.

The exact payment terms for Phase II will be included in the contract. The progress payment method will not be authorized. Quarterly payment will be authorized upon receipt and acceptance of each quarterly report along with other applicable deliverables. Upon receipt and acceptance of the final report, final new technology report and/or final new technology summary report and any other deliverables, the final payment will be authorized. NASA will make payment within thirty days of NASA acceptance and approval of all required deliverables associated with the payment.

Invoices: All invoices submitted by the SBC shall be marked with the contract number and invoice number. For example, if the invoice submitted is the first submitted for a contract, it shall be marked as the First Invoice. All final invoices shall be marked Final Invoice. All invoices are required to be submitted electronically via the SBIR/STTR Website.

5.5 Release of Proposal Information

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

5.6 Access to Proprietary Data by Non-NASA Personnel

5.6.1 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.

5.6.2 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 access to proposals to other NASA contractor and subcontractor personnel. NASA will provide access to such data only under contracts that contain an appropriate Handling of Data clause that requires the contractors to fully protect the information from unauthorized use or disclosure.

5.7 Final Disposition of Proposals

The Government retains ownership of proposals accepted for evaluation, and such proposals will not be returned to the offeror. Copies of all evaluated Phase I proposals will be retained for a minimum of one year after the Phase I selections have been made. Successful proposals will be retained in accordance with contract file regulations.

5.8 Proprietary Information in the Proposal Submission

Information contained in unsuccessful proposals will remain the property of the applicant. The Government will, however, retain copies of all proposals. Public release of information in any proposal submitted will be subject to existing statutory and regulatory requirements. If proprietary information is provided by an applicant in a proposal, which constitutes a trade secret, proprietary commercial or financial information, confidential personal information or data affecting the national security, it will be treated in confidence to the extent permitted by law. This information must be clearly marked by the applicant as confidential proprietary information. NASA will treat in confidence pages listed as proprietary in the following legend that appears on Cover Sheet (Form A) of the proposal:

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

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

5.9 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. Any request to modify or eliminate this clause may substantially delay contract award and funding. The following is a brief description of FAR 52.227-20.

5.9.1 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. These 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.

5.9.2 Proprietary Data

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

5.9.3 Non Disclosure Period

For a period of 4 years after acceptance of all items to be delivered under this 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.

5.9.4 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.

5.9.5 Patents

The contractor may normally elect title to any inventions made in the performance of an SBIR/STTR contract. The Government receives a nonexclusive license to practice or have practiced for or on behalf of the Government each such invention throughout the world. Small business concerns normally may retain the principal worldwide patent rights to any invention developed with Government support. The Government receives a royalty-free license for Federal Government use, reserves the right to require the patent holder to license others in certain circumstances, and requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically.

In accordance with FAR 52.227-11 Patent Right – Ownership by the Contractor, SBIR/STTR contractors must disclose all subject inventions, which means 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 disclosed, the contractor has up to 2 years to decide whether to elect title. If the contractor fails to do so within the 2-year time period, 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 allowable time to file a patent.

5.9.6 Invention Reporting

NASA SBIR and STTR contracts will include the invention reporting requirements in FAR 52.227-11 Patent Rights – Ownership by the Contractor, SBIR/STTR that contractors must disclose all subject inventions to NASA within two (2) months of the inventor's report to the awardees. This means 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 disclosed, the contractor has up to 2 years to decide whether to elect title. If the contractor fails to do so within the 2-year time period, the Government has the right to obtain title. To the extent authorized by 35 USC 205, the Government will not make public any information disclosing such inventions, allowing the contractor the permissible time to file a patent.

The notification to NASA of an invention shall be provided in the form of a "New Technology Report" (NTR) by accessing the NASA eNTRe Website at http://invention.nasa.gov. This should be done for final reports where a new discovery or invention has been determined. If there is no invention, a New Technology Summary Report (NTSR) must be submitted to eNTRe. Both reports shall also be uploaded to the SBIR/STTR Electronic Handbook (EHB) at https://ehb8.gsfc.nasa.gov/contracts/public/firmHome.do

5.10 Cost Sharing

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

5.11 Profit or Fee

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

5.12 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 2.18. A statement of how the workload will be distributed, managed, and charged should be included in the proposal. A copy or comprehensive summary of the joint venture agreement or partnership agreement should be appended to the proposal. This will not count as part of the 25-page limit for the Phase I proposal.

5.13 Similar Awards and Prior Work

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

5.14 Contractor Commitments

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

5.14.1 Standards of Work

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

5.14.2 52.246-9 Inspection of Research and Development (Short Form)

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

5.14.3 52.215-2 Audit and Records - Negotiations

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

5.14.4 52.213-4 Term and Conditions – Simplified Acquisition (Other Than Commercial Items) and 52.249-9 Default (Fixed Price Research and Development)

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

5.14.5 52.213-4 Term and Conditions – Simplified Acquisition (Other Than Commercial Items 52.249-2, Termination for Convenience of the Government (Fixed-Price)

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

5.14.6 52.233-1Disputes

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

5.14.7 52.222-4 Contract Work Hours and Safety Standards Act – Overtime Compensation

The contractor may not require a non-exempt employee to work more than 40 hours in a workweek unless the employee is paid for overtime.

5.14.8 52.222-26 Equal Opportunity for Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

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

5.14.9 52.222-35 Equal Opportunity for Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

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

5.14.10 52.222-36 Affirmative Action for Workers with Disabilities

The contractor will not discriminate against any employee or applicant for employment because he or she is physically or mentally handicapped.

5.14.11 52.203-12 Limitation on Payments to Influence Certain Federal Transactions

No member of or delegate to Congress shall benefit from an SBIR or STTR contract.

5.14.12 52.203-5 Covenant Against Contingent Fees

No person or agency has been employed to solicit or to secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the contractor for the purpose of securing business.

5.14.13 52.203-3 Gratuities

The contract may be terminated by the Government if any gratuities have been offered to any representative of the Government to secure the contract.

5.14.14 52.227-2 Notice and Assistance Regarding Patent and Copyright Infringement

The contractor shall report to NASA each notice or claim of patent infringement based on the performance of the contract.

5.14.15 52.225-1 Buy American Act - Supplies

Equipment or products purchased under an SBIR or STTR contract must be American-made whenever possible.

5.14.16 1852.225-70 Export Licenses

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

5.15 Additional Information

5.15.1 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.

5.15.2 Evidence of Contractor Responsibility

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.

5.15.3 Required Registrations and Submissions

5.15.3.1 Central Contractor Registration

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

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

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

5.15.3.2 52.204-8 Annual Representations and Certifications

Offerors should be aware of the requirement that the Representation and Certifications required from government contractors must be completed through the Online Representations and Certifications Application (ORCA) website https://orca.bpn.gov/login.aspx. FAC 01-26 implements the final rule for this directive and requires all offerors to 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.

5.15.3.3 52.222-37 Employment Reports on Special Disabled Veterans, Veterans of the Vietnam-Era, and Other Eligible Veterans

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

5.15.4 Software Development Standards

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

5.16 Property and Facilities

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. Special tooling required for a project may be allowed via a waiver described below.

When an SBC cannot furnish its own facilities to perform required tasks, an SBC may propose to acquire the use of available non-Government facilities. Rental or lease costs may be considered as direct costs as part of the total funding for the project. If unique requirements force an offeror to acquire facilities under a NASA contract, they will be purchased as Government Furnished Equipment (GFE) and will be titled to the Government.

An offeror may propose the use of unique or one-of-a-kind Government facilities if essential for the research.

If a proposed project or product demonstration requires the use of unique Government facilities or equipment that will be funded with SBIR dollars, 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. The proposal should also include relevant information on the funding source(s) private, internal, or other Government. Failure to provide this explanation and the site manager's written authorization of use may invalidate any proposal selection. If the offeror proposes the use of SBIR/STTR funds for Government equipment or facilities, this explanation will be provided to SBA during the Agency waiver process.

Contractors are ordinarily required to furnish all property necessary to perform Government contracts. In compliance with FAR Part 45, Contracting Officers will only approve use of Government property or Government facilities when the justification provided in the proposal meets the requirements at FAR 45.102. Proposers are notified that the NASA SBIR and STTR programs cannot assist in the approval process for use of Government property or facilities. Further, any proposer requiring the use of government property or facilities must, within five (5) days of notification of selection, provide to the NASA Shared Services Center Contracting Officer all required documentation, to include, an Agreement by and between the Contractor and the appropriate Government facility, executed by the Government official authorized to approve such use. The Agreement must delineate the terms of use, associated costs, property and facility responsibilities and liabilities. Proposers are advised that the exceptions to government property responsibility and liability stipulated at FAR 45.104 do not apply to NASA SBIR and STTR contracts.

Additional information on the use of NASA facilities, facility programs, and equipment is available at http://sbir.nasa.gov/SBIR/facilities.html.

5.17 Human and/or Animal Subject

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

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

5.18 Toxic Chemical

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

5.19 Hazardous Materials

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

5.20 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.

5.21 False Statements

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

6. Submission of Proposals

6.1 Submission Requirements

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

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

6.2 Submission Process

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

For successful proposal submission, SBCs must complete all three forms online, upload their technical proposal in an acceptable format, and have the Business Official electronically endorse the proposal. Electronic endorsement of the proposal is handled online with no additional software requirements. The term "technical proposal" refers to the part of the submission as described in Section 3.2.4 for Phase I and 3.3.4 for Phase II.

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

6.2.1 What Needs to Be Submitted

The entire proposal including Forms A, B, C, and the briefing chart must be submitted via the Submissions EHB located on the NASA SBIR/STTR website.

(1) Forms A, B, and C are to be completed online.
(2) The technical proposal is uploaded from your computer via the Internet utilizing secure communication protocol.
(3) Firms must also upload a briefing chart, which is not included in the page count (See Sections 3.2.8 and 3.3.7).

Note: Other forms of submissions such as postal, paper, fax, diskette, or e-mail attachments are not acceptable.

6.2.2 Technical Proposal Submissions

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

Graphics
For reasons of space conservation and simplicity the offeror is encouraged, but not required, to embed graphics within the document. For graphics submitted as separate files, the acceptable file formats (and their respective extensions) are: Bit-Mapped (.bmp), Graphics Interchange Format (.gif), JPEG (.jpg), PC Paintbrush (.pcx),

WordPerfect Graphic (.wpg), and Tagged-Image Format (.tif). Embedded animation or video will not be considered for evaluation.

Virus Check

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

6.2.3 Technical Proposal Uploads

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

Sample E-mail for Successful Upload of Technical Proposal

Subject: Successful Upload of Technical Proposal

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

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

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

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

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

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

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

NASA SBIR/STTR Program Support Office

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

6.3 Deadline for Phase I Proposal Receipt

All Phase I proposal submissions must be received no later than 5:00 p.m. EDT on Thursday, September 2, 2010, via the NASA SBIR/STTR Website (http://sbir.nasa.gov). The server/electronic handbook will not be available for Internet submissions after this deadline. Any proposal received after that date and time shall be considered late and handled according to NASA FAR Supplement 1815.208.

6.4 Acknowledgment of Proposal Receipt

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

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

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

Confirmation No. __________________

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

SBIR/STTR 2010 Phase I xx.xx-xxxx (Title)
Form A completed on:
Form B completed on:
Form C completed on:
Technical Proposal Uploaded on:
    File Name:
    File Type:
    File Size:
Briefing Chart completed on:
Proposal endorsed electronically by:

This is your official confirmation of receipt. Please save this email for your records, as no other receipt will be provided. The official selection announcement is currently scheduled for November 22, 2010, and will be posted via the SBIR/STTR website (http://sbir.nasa.gov).

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

NASA SBIR/STTR Program Support Office

6.5 Withdrawal of Proposals

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

6.6 Service of Protests

Protests, as defined in Section 33.101 of the FAR, that are filed directly with an agency, and copies of any protests that are filed with the General Accounting Office (GAO) shall be served on the Contracting Officer by obtaining written and dated acknowledgement of receipt from the NASA SBIR/STTR Program contact at the address 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 information 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 Innovative Partnerships Program (IPP): http://www.ipp.nasa.gov/
NASA SBIR/STTR Programs: http://sbir.nasa.gov

7.2 United States Small Business Administration (SBA)

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

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

7.3 National Technical Information Service

The National Technical Information Service, an agency of the Department of Commerce, is the Federal Government's largest central resource for government-funded scientific, technical, engineering, and business related information. For information about 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

Form A – SBIR Cover Sheet

Subtopic Number

1. PROPOSAL NUMBER: **10 -** _ _ . _ _ - _ _ _ _
2. SUBTOPIC TITLE:
3. PROPOSAL TITLE:
4. SMALL BUSINESS CONCERN (SBC):
   NAME:
   MAILING ADDRESS:
   CITY/STATE/ZIP:
   PHONE: FAX:
   EIN/TAX ID: DUNS + 4: CAGE CODE:
5. AMOUNT REQUESTED $ ________________ DURATION: __________ MONTHS
6. CERTIFICATIONS: OFFEROR CERTIFIES THAT:

As defined in Section 1 of the Solicitation, the offeror certifies:		
a. The Principal Investigator is "primarily employed" by the organization as defined in the SBIR Solicitation. Note: Co-PI is not acceptable.	Yes	No
As defined in Section 2 of the Solicitation, the offeror qualifies as a:		
b. SBC Number of employees: _____	Yes	No
c. The firm is owned and operated in the United States	Yes	No
d. Socially and economically disadvantaged SBC	Yes	No
e. Women-owned SBC	Yes	No
f. HUBZone-owned SBC	Yes	No
g. Veteran-Owned SBC	Yes	No
h. Service Disabled Veteran-Owned SBC	Yes	No
As defined in Section 3.2.4 Part 11 of the Solicitation indicate if		
i. Work under this project has been submitted for Federal funding only to the NASA SBIR Program.	Yes	No
If no, provide name of agency and date submitted: *Agency:* *Date Submitted:*		
j. Funding has been received for work under this project by any other Federal grant, contract, or subcontract	Yes	No
As described in Section 3 of this solicitation, the offeror meets the following requirements completely:		
k. All 11 parts of the technical proposal are included in part order and the page limitation is met	Yes	No
l. Subcontracts/consultants proposed?	Yes	No
i) If yes, limits on subcontracts/consultants met	Yes	No
m. Government equipment or facilities required (cannot use SBIR funds)?	Yes	No
i) If yes, signed statement enclosed in Part 8	Yes	No
ii) If yes, non-SBIR funding source identified in Part 8?	Yes	No
In accordance with Section 5.14.16 of the Solicitation as applicable:		
n. The offeror will comply with export control regulations	Yes	No

In accordance with Section 5 of the Solicitation as applicable, indicate if any of the following will be used (must comply with federal regulations):		
o. Human Subject	Yes	No
p. Animal Subject	Yes	No
q. Toxic Chemicals	Yes	No
r. Hazardous Materials	Yes	No
As referenced in Section 1.2 of the Solicitation, indicate if the R&D to be performed is related to:		
s. Manufacturing	Yes	No
t. Renewable Energy	Yes	No

7. ACN NAME: PHONE: E-MAIL:

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

9. ENDORSEMENT BY SBC OFFICIAL:

NAME: TITLE:
PHONE: E-MAIL:
ENDORSED BY: DATE:

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

Guidelines for Completing SBIR Cover Sheet

Complete Cover Sheet Form A electronically.

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

2. Subtopic Title: Enter the title of the subtopic that this proposal will address. Use abbreviations as needed.

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

4. Small Business Concern: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.
   Address: Must match CCR address. Address where mail is received.
   City, State, Zip: City, 2-letter State designation (i.e. TX for Texas), 9-digit Zip code (i.e. 20705-3106)
   Phone, Fax: Number including area code
   EIN/Tax ID: Employer Identification Number/Taxpayer ID
   DUNS + 4: 9-digit Data Universal Number System plus a 4-digit suffix given by parent concern
   CAGE Code: Commercial Government and Entity Code (Issued by Central Contractor Registration (CCR))
5. Amount Requested: Proposal amount from Budget Summary. The amount requested should not exceed $100,000 (see Sections 1.4.1, 5.1.1).

   Duration: Proposed duration in months. The requested duration should not exceed 6 months (see Sections 1.4.1, 5.1.1).

6. Certifications: Answer Yes or No as applicable for certifications 6a – 6t (see the referenced sections for definitions). Where applicable, SBCs should make sure that their certifications on Form A agree with the content of their technical proposal.

   6i. SBCs should answer Yes or No as applicable. If work under this project has been submitted to other Federal agencies/programs for funding, then the SBC must provide the name of the Agency and date submitted in the text box provided.

   6j. SBCs should choose "No" to confirm that work under this project has not been funded under any other Federal grant, contract or subcontract.

   6l. Subcontracts/consultants proposed? By answering yes, the SBC certifies that subcontracts/consultants have been proposed and arrangements have been made to perform on the contract, if awarded.

      i) If yes, limits on subcontracting and consultants met: By answering yes, the SBC certifies that business arrangements with other entities or individuals do not exceed one-third of the work (amount requested including cost sharing if any, less fee, if any) and is in compliance with Section 3.2.4, Part 9.

   6m. Government furnished equipment required? By answering yes, the SBC certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities (see Sections 3.2.4 Part 8, 3.3.4 Part 8, 5.16). By answering no, the SBC certifies that no such Government Furnished Facilities or Government Furnished Equipment is required to perform the proposed activities.

i) If yes, signed statement enclosed in Part 8: By answering yes, the SBC certifies that a statement describing the uniqueness of the facility and its availability to the offeror at specified times, signed by the appropriate Government official, is enclosed in the proposal.

ii) If yes, non-SBIR funding source identified in Part 8: By answering yes, the SBC certifies that it has a confirmed, non-SBIR funding source for whatever charges may be incurred when utilizing the required Government facility.

6n. Offerors are responsible for ensuring compliance with export control and International Traffic in Arms (ITAR) regulations. All employees who will work on this contract must be eligible under these regulations or the offeror must have in place a valid export license or technical assistance agreement. Violations of these regulations can result in criminal or civil penalties.

7. ACN Name, Telephone Number and E-mail: Name, telephone number and e-mail address of Authorized Contract Negotiator.

8. Endorsement of this form certifies understanding of this statement.

9. Endorsement: An official of the firm must electronically endorse the proposal cover.

Form B – SBIR Proposal Summary

Subtopic Number

1. Proposal Number **10 -** _ _ . _ __ _ _ _ _.
2. Subtopic Title
3. Proposal Title
4. Small Business Concern
   Name:
   Address:
   City/State:
   Zip:
   Phone:
5. Principal Investigator/Project Manager
   Name:
   Address:
   City/State:
   Zip:
   Phone:
   E-mail:
6. Estimated Technology Readiness Level (TRL) at beginning and end of contract:
7. Technical Abstract (Limit 2,000 characters, approximately 200 words)
8. Potential NASA Application(s): (Limit 1,500 characters, approximately 150 words)
9. Potential Non-NASA Application(s): (Limit 1,500 characters, approximately 150 words)
10. Technology Taxonomy (Select only the technologies relevant to this specific proposal)

Guidelines for Completing SBIR Proposal Summary

Complete Proposal Summary Form B electronically.

1. **Proposal Number:** Same as Cover Sheet.

2. **Subtopic Title:** Same as Cover Sheet.

3. **Proposal Title:** Same as Cover Sheet.

4. **Small Business Concern:** Same as Cover Sheet.

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

6. **Technology Readiness Level (TRL):** Provide the estimated Technology Readiness Level (TRL) at beginning and end of contract. See Section 2.22 and Appendix B for TRL definitions.

7. **Technical Abstract:** Summary of the offeror's proposed project in 200 words or less. The abstract must not contain proprietary information and must describe the NASA need addressed by the proposed R/R&D effort.

8. **Potential NASA Application(s):** Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. Limit your response to 150 words or 1,500 characters, whichever is less.

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

10. **Technology Taxonomy:** Selections for the Technology Taxonomy are limited to technologies supported or relevant to the specific proposal.

Form C – SBIR Budget Summary

PROPOSAL NUMBER:
SMALL BUSINESS CONCERN:

DIRECT LABOR:

Category	Hours	Rate	Cost
		TOTAL DIRECT LABOR: (1)	$ ____________

OVERHEAD COST
______% of Total Direct Labor or $ ______

OVERHEAD COST: (2) $ ____________

OTHER DIRECT COSTS (ODCs):

Category		Cost
	$	

(Note: Separate Budget Summaries must be completed for all proposed Subcontractors/Consultants)

TOTAL OTHER DIRECT COSTS: (3) $ ____________

Explanation of ODCs
____
____
____

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

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

G&A COSTS: (5) $ ____________

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

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

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

GOVERNMENT FACILITIES OR EQUIPMENT:

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

____

AUDIT AGENCY:

Please complete the following:

( ) I do not know the cognizant audit agency

( ) The cognizant audit agency is:

Agency: ____

Office Location: __________________________________

Name of Point of Contact and Phone Number: ____

Email address: ____

Accounting System:

( ) The audit agency has approved the accounting system on:

Date of approval: ____

( ) Accounting System is not approved

Negotiated Rate Agreement and/or overhead, and/or incurred cost audit:

( ) A rate agreement was negotiated with the audit agency on:

Date of the negotiated rate agreement:____

( ) There is no negotiated rate agreement.

( ) Overhead and/or incurred cost audit was performed on:

Date of the audit: Overhead ______________________________

Incurred cost ____________________________

( ) There is no negotiated rate agreement.

( ) No overhead and/or incurred cost audits have been conducted

( ) The rates listed in the negotiated rate agreement were used to prepare the budget summary.

( ) Other rates were used to prepare the budget summary.

Please explain:

Guidelines for Preparing SBIR Budget Summary

Complete Budget Summary Form C electronically.

The offeror electronically submits to the Government a pricing proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting and estimating system.

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

Firm: Same as Cover Sheet.

Proposal Number: Same as Cover Sheet.

Direct Labor: Enter labor categories proposed (e.g., Principal Investigator/Project Manager, Research Assistant/Laboratory Assistant, Analyst, Administrative Staff), labor rates and the hours for each labor category. Explain the basis for the estimated hours (i.e. how were the estimated hours derived).

Overhead Cost: Specify current rate and base. Use current rate(s) negotiated with the cognizant Federal-auditing agency, if available. If no rate(s) has (have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I for acceptance by NASA. Show how this rate is determined to include historical actual rates for the past three years. The offeror may use whatever number and types of overhead rates are in accordance with the firm's accounting system and approved by the cognizant Federal-negotiating agency, if available. Multiply Direct Labor Cost by the Overhead Rate to determine the Overhead Cost.

<u>Example</u>: A typical SBC might have an overhead rate of 30 percent. If the total direct labor costs proposed are $50,000, the computed overhead costs for this case would be .3x50,000=$15,000, if the base used is the total direct labor costs.

or provide a number for total estimated overhead costs to execute the project.

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

Other Direct Costs (ODCs):
- Materials and Supplies: Indicate types and quantities required and estimate costs.
- Documentation Costs or Page Charges: Estimate cost of preparing and publishing project results.
- Subcontracts/Consultants: The Subcontractor/Consultant Budget Summary must be completed for each subcontract/consultant proposed and must include hours, rates, overhead cost, ODC’s, G&A and profit and justification for estimated costs for each subcontractor. (Section 3.2.4, Part 9.)
- Computer Services: Computer equipment leasing is included here to include basis for estimated costs.

List all other direct costs that are not otherwise included in the categories described above.

Explanations of all items identified as ODCs must be provided under “Explanation of ODCs.” Offeror should include the basis used for estimating costs (vendor quote, catalog price, etc.) For example, if “Materials” is listed as an ODC, include a description of the materials, the quantity required and basis for the proposed cost. Note that travel expenses shall not be included in the proposed budget for a Phase I proposal, and any travel expenses listed for a Phase II proposal must include a detailed accounting of all said expenses to include purpose of proposed trips , number of trips, travelers per trip, as well as meals, hotel, and rental car costs estimated .

Note: The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Material costs should be broken out by individual items, including the price, quantity and reason it is required. Firms should be prepared to justify all material costs during negotiations. See section 5.16 for further guidance.

Subtotal (4): Sum of (1) Total Direct Labor, (2) Overhead and (3) ODCs

General and Administrative (G&A) Costs (5): Specify current rate and base. Use current rate negotiated with the cognizant Federal-negotiating agency, if available. If no rate has been negotiated, a reasonable indirect cost (G&A) rate may be requested for acceptance by NASA. Show how this rate is determined and, if possible, include historical actual G&A rate for the past three years. If a current negotiated rate is not available, NASA will negotiate a reasonable rate with the offeror. Multiply (4) subtotal (Total Direct Cost) by the G&A rate to determine G&A Cost.

Or provide an estimated G&A costs number for the proposal.

Total Costs (6): Sum of Items (4) and (5). Note that this value will be used in verifying the minimum required work percentage for the SBC.

Profit/Cost Sharing (7): See Sections 5.10 and 5.11. Profit to be added to total cost, shared costs to be subtracted from total cost, as applicable.

Amount Requested (8): Sum of Items (6) and (7), not to exceed $100,000.

Audit Information (9): Complete the Audit Agency and Accounting System Sections of Form C.

SBIR Check List

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

1. **The entire proposal including any supplemental material shall not exceed a total of 25 8.5 x 11 inch pages** (Section 3.2.1).
2. The proposal and innovation is submitted for one subtopic only (Section 3.1).
3. The entire proposal is submitted consistent with the requirements and in the order outlined in Section 3.2.
4. The technical proposal contains all eleven parts in order (Section 3.2.4).
5. The 1-page briefing chart does not include any proprietary data (Section 3.2.8).
6. Certifications in Form A are completed, and agree with the content of the technical proposal.
7. Proposed funding does not exceed $100,000 (Sections 1.4.1, 5.1.1).
8. Proposed project duration does not exceed 6 months (Sections 1.4.1, 5.1.1).
9. Entire proposal including Forms A, B, and C submitted via the Internet.
10. Form A electronically endorsed by the SBC Official.
11. **Proposals must be received no later than 5:00 p.m. EDT on Thursday, September 2, 2010** (Section 6.3).

Form A – STTR Cover Sheet

1. PROPOSAL NUMBER: **10 -** _ _ . _ _ - _ _ _ _
2. RESEARCH TOPIC:
3. PROPOSAL TITLE:
4. SMALL BUSINESS CONCERN (SBC)
   NAME:
   ADDRESS:
   CITY/STATE/ZIP:
   PHONE: FAX:
   EIN/TAX ID:
   DUNS + 4: CAGE CODE:

   RESEARCH INSTITUTION (RI)
   NAME:
   ADDRESS:
   CITY/STATE/ZIP:
   PHONE: FAX:
   EIN/TAX ID:
5. AMOUNT REQUESTED: $____________________ DURATION: _________ MONTHS

6. CERTIFICATIONS: THE ABOVE SBC CERTIFIES THAT:

As defined in Section 2 of the Solicitation, the offeror qualifies as a:		
a. SBC Number of employees: ____	Yes	No
b. The firm is owned and operated in the United States	Yes	No
c. Socially and economically disadvantaged SBC	Yes	No
d. Woman-owned SBC	Yes	No
e. HUBZone-owned SBC	Yes	No
f. Veteran-Owned SBC	Yes	No
g. Service Disabled Veteran-Owned SBC	Yes	No
As described in Section 2.13 of the Solicitation, the partnering institution qualifies as a:		
h. FFRDC	Yes	No
i. Nonprofit research institute	Yes	No
j. Nonprofit college or university	Yes	No
As described in Section 3 of the Solicitation, the offeror meets the following requirements completely:		
k. Cooperative Agreement signed by the SBC and RI enclosed	Yes	No
l. All 11 parts of the technical proposal included in part order within page limitations	Yes	No
m. Subcontracts/consultants proposed? (Other than the RI)	Yes	No
i) If yes, limits on subcontracts/consultants met	Yes	No
n. Government equipment or facilities required (cannot use STTR funds)?	Yes	No
i) If yes, signed statement enclosed in Part 8	Yes	No
ii) If yes, non-STTR funding source identified in Part 8?	Yes	No
o. A signed Allocation of Rights Agreement will be available for the Contracting Officer at time of selection	Yes	No
As defined in Section 3.2.4 of the Solicitation, indicate if:		
p. Work under this project has been submitted for funding only to the NASA STTR Program. If no provide name of agency and date submitted	Yes	No
If no, provide name of agency and date submitted: *Agency:* *Date Submitted:*		
q. Funding has been received for work under this project by any other Federal grant, contract, or subcontract	Yes	No
In accordance with Section 5.14.16 of the Solicitation as applicable:		
r. The offeror will comply with export control regulations	Yes	No
In accordance with Section 5 of the Solicitation as applicable, indicate if any of the following will be used (must comply with federal regulations):		
s. Human Subject	Yes	No

t. Animal Subject	Yes	No
u. Toxic Chemicals	Yes	No
v. Hazardous Materials	Yes	No
As referenced in Section 1.2 of the Solicitation, indicate if the R&D to be performed is related to:		
w. Manufacturing	Yes	No
x. Renewable Energy	Yes	No

7. ACN NAME: PHONE: E-MAIL:

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

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

10. ENDORSEMENT BY SBC OFFICIAL:
    NAME: TITLE:
    PHONE: E-MAIL:
    ENDORSED BY: DATE:

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

Guidelines for Completing STTR Cover Sheet

Complete Cover Sheet Form electronically.

1. Proposal Number: This number does not change. The proposal number consists of the program year (i.e. 04) and unique four-digit system-generated number.

2. Research Topic: NASA research topic number and title (Section 9).

3. Proposal Title: A brief, descriptive title, avoid words like "development of" and "study of," and do not use acronyms or trade names.

4. Small Business Concern: Full name and address of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

   Research Institution: Full name and address of the research institute.

Mailing Address:	Must Match CCR Address. Address where mail is received
City, State, Zip:	City, 2-letter State designation (i.e. TX for Texas), 9-digit Zip code (i.e. 20705-3106)
Phone, Fax:	Number including area code
EIN/TAX ID:	Employer Identification Number/Taxpayer ID
DUNS + 4:	9-digit Data Universal Number System plus a 4-digit suffix given by parent concern
CAGE Code:	Commercial Government and Entity Code (Issued by Central Contractor Registration (CCR)

5. Amount Requested: Proposal amount from Budget Summary. The amount requested should not exceed $100,000 (see Sections 1.4.1, 5.1.1).

   Duration: Proposed duration in months. The requested duration should not exceed 12 months (see Sections 1.4.1, 5.1.1).

6. Certifications: Answer Yes or No as applicable for certifications 6a – 6v (see Section 2 for definitions). Where applicable, SBCs should make sure that their certifications on Form A agree with the content of their technical proposal.

   6k. Cooperative Agreement signed by the SBC and RI: By answering yes, the SBC/RI certifies that a completed Cooperative Agreement, electronically endorsed by both SBC Official and RI Official, is submitted with the proposal (see Sections 3.2.2, 3.2.5).

   6m. Subcontracts/consultants proposed? By answering yes, the SBC/RI certifies that subcontracts/consultants have been proposed and arrangements have been made to perform on the contract, if awarded.

      i) If yes, limits on subcontracting and consultants met: By answering yes, the SBC/RI certifies that business arrangements with other entities or individuals do not exceed 30 percent of the work (amount requested including cost sharing if any, less fee, if any) and is in compliance with Section 3.2.4, Part 9.

   6n. Government furnished equipment required? By answering yes, the SBC/RI certifies that unique, one-of-a-kind Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities (see Sections 3.2.4 Part 8, 3.3.4 Part 8, 5.16). By answering no, the SBC/RI certifies that no such Government Furnished Facilities or Government Furnished Equipment are required to perform the proposed activities.

i) If yes, signed statement enclosed in Part 8: By answering yes, the SBC/RI certifies that a statement describing the uniqueness of the facility and its availability to the offeror at specified times, signed by the appropriate Government official, is enclosed in the proposal.

ii) If yes, non-SBIR funding source identified in Part 8. By answering yes, the SBC certifies that it has confirmed, non-SBIR funding source for whatever charges may be incurred when utilizing the required Government facility.

6p. SBCs should answer Yes or No as applicable. If work under this project has been submitted to other Federal agencies/programs for funding, then the SBC must provide the name of the Agency and date submitted in the text box provided.

6q. SBCs should choose “No” to confirm that work under this project has not been funded under any other Federal grant, contract or subcontract.

6r. Offerors are responsible for ensuring compliance with export control and International Traffic in Arms (ITAR) regulations. All employees who will work on this contract must be eligible under these regulations or the offeror must have in place a valid export license or technical assistance agreement. Violations of these regulations can result in criminal or civil penalties.

7. ACN Name, Telephone Number and E-mail: Name, telephone number and e-mail address of Authorized Contract Negotiator.

8. Proposals submitted in response to this Solicitation must be jointly developed by the SBC and the RI, and at least **40 percent** of the work (amount requested including cost sharing, less fee, if any) is to be performed by the SBC as the prime contractor, and at least **30 percent** of the work is to be performed by the RI (see Section 3.2.4).

9. Endorsement of this form certifies understanding of this statement.

10. Endorsements: An official of the firm must electronically endorse the proposal cover.

Form B – STTR Proposal Summary

1. Proposal Number **10 -** _ _ . _ _ _ _ _ _.

2. Research Topic:

3. Proposal Title:

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

5. Research Institution
   Name:
   Address:
   City/State:
   Zip:
   Phone:

6. Principal Investigator/Project Manager:

7. Estimated Technology Readiness Level (TRL) at beginning and end of contract:

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

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

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

11. Technology Taxonomy (Select only the technologies relevant to this specific proposal)

Guidelines for Completing STTR Proposal Summary

Complete Form B electronically.

1. **Proposal Number:** Same as Cover Sheet

2. **Research Topic:** Same as Cover Sheet.

3. **Proposal Title:** Same as Cover Sheet.

4. **Small Business Concern:** Same as Cover Sheet.

5. **Research Institution:** Same as Cover Sheet.

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

7. **Technology Readiness Level (TRL):** Provide the estimated Technology Readiness Level (TRL) at beginning and end of contract. See Section 2.22 and Appendix B for TRL definitions.

8. **Technical Abstract:** Summary of the offeror's proposed project in 200 words or less. The abstract must not contain proprietary information and must describe the NASA need addressed by the proposed R/R&D effort.

9. **Potential NASA Application(s):** Summary of the direct or indirect NASA applications of the innovation, assuming the goals of the proposed R/R&D are achieved. Limit your response to 150 words or 1,500 characters, whichever is less.

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

11. **Technology Taxonomy:** Selections for the Technology Taxonomy are limited to technologies supported or relevant to the specific proposal.

Form C – STTR Budget Summary

PROPOSAL NUMBER:
SMALL BUSINESS CONCERN:

DIRECT LABOR:

Category	Hours	Rate	Cost
		TOTAL DIRECT LABOR:	
		(1)	$ ____________

OVERHEAD COST
______% of Total Direct Labor or $ ______

OVERHEAD COST:
(2) $ ____________

OTHER DIRECT COSTS (ODCs) including RI budget:

Category	Cost
	$

(Note: Separate Budget Summaries must be completed for the Research Institution and all proposed Subcontractors/Consultants)

TOTAL OTHER DIRECT COSTS:
(3) $ ____________

Explanation of ODCs
____
____
____

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

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

G&A COSTS:
(5) $ ____________

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

ADD PROFIT or SUBTRACT COST SHARING (As applicable)

PROFIT/COST SHARING:
(7) $ ____________

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

GOVERNMENT FACILITIES OR EQUIPMENT:

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

____

AUDIT AGENCY:

Please complete the following:

(   ) I do not know the cognizant audit agency

(   ) The cognizant audit agency is:

Agency: ____

Office Location: ___________________________________

Name of Point of Contact and Phone Number: ____

Email address: ____

Accounting System:

(   ) The audit agency has approved the accounting system on:

Date of approval: ____

(   ) Accounting System is not approved

Negotiated Rate Agreement and/or overhead, and/or incurred cost audit:

(   ) A rate agreement was negotiated with the audit agency on:

Date of the negotiated rate agreement:____

(   ) There is no negotiated rate agreement.

(   ) Overhead and/or incurred cost audit was performed on:

Date of the audit: Overhead _______________________________

Incurred cost _____________________________

(   ) There is no negotiated rate agreement.

(   ) No overhead and/or incurred cost audits have been conducted

(   ) The rates listed in the negotiated rate agreement were used to prepare the budget summary.

(   ) Other rates were used to prepare the budget summary.

Please explain:

Guidelines for Preparing STTR Budget Summary

Complete Summary Budget Form C electronically.

The offeror electronically submits to the Government a pricing proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting and estimating system.

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

Small Business Concern - Same as Cover Sheet.

Principal Investigator/Project Manager - Same as Cover Sheet.

Direct Labor - Enter labor categories proposed (e.g., Principal Investigator/Project Manager, Research Assistant/Laboratory Assistant, Analyst, Administrative Staff), labor rates and the hours for each labor category. Explain the basis for the estimated hours (i.e. how were the estimated hours derived).

Overhead Cost - Specify current rate and base. Use current rate(s) negotiated with the cognizant Federal-auditing agency, if available. If no rate(s) has (have) been audited, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I for acceptance by NASA. Show how this rate is determined to include historical actual rates for the past three years. The offeror may use whatever number and types of overhead rates are in accordance with the firm's accounting system and approved by the cognizant Federal-negotiating agency, if available. Multiply Direct Labor Cost by the Overhead Rate to determine the Overhead Cost.

<u>Example</u>: A typical SBC might have an overhead rate of 30%. If the total direct labor costs proposed are $50,000, the computed overhead costs for this case would be .3x50,000=$15,000, if the base used is the total direct labor costs.

or provide a number for total estimated overhead costs to execute the project.

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

Other Direct Costs (ODCs) -
Include total cost for the Research Institution. Note that the proposal should include sufficient information from the Research Institution to determine how their budget was calculated.

- Materials and Supplies: Indicate types and quantities required and estimate costs.
- Documentation Costs or Page Charges: Estimate cost of preparing and publishing project results.
    - Subcontracts/Consultants: The Subcontractor/Consultant Budget Summary must be completed for each subcontract/consultant proposed and must include hours, rates, overhead cost, ODC’s, G&A and profit and justification for estimated costs for each subcontractor. (Section 3.2.4, Part 9.)
    - Computer Services: Computer equipment leasing is included here to include basis for estimated costs.

List all other direct costs that are not otherwise included in the categories described above.

Explanations of all items identified as ODCs must be provided under “Explanation of ODCs.” Offeror should include the basis used for estimating costs (vendor quote, catalog price, etc.) For example, if “Materials” is listed as an ODC, include a description of the materials, the quantity required and basis for the proposed cost. Note that travel expenses shall not be included in the proposed budget for a Phase I proposal, and any travel expenses listed for a Phase II proposal must include a detailed accounting of all said expenses to include purpose of proposed trips , number of trips, travelers per trip, as well as meals, hotel, and rental car costs estimated .

Note: The purchase of equipment, instrumentation, or facilities under SBIR/STTR must be justified by the offeror and approved by the government during contract negotiations. Material costs should be broken out by individual items, including the price, quantity and reason it is required. Firms should be prepared to justify all material costs during negotiations. See section 5.16 for further guidance.

Subtotal (4) - Sum of (1) Total Direct Labor, (2) Overhead and (3) ODCs

General and Administrative (G&A) Costs (5)- Specify current rate and base. Use current rate negotiated with the cognizant Federal-negotiating agency, if available. If no rate has been negotiated, a reasonable indirect cost (G&A) rate may be requested for acceptance by NASA. Show how this rate is determined and, if possible, include historical actual G&A rate for the past three years. If a current negotiated rate is not available, NASA will negotiate a reasonable rate with the offeror. Multiply (4) subtotal (Total Direct Cost) by the G&A rate to determine G&A Cost.

or provide an estimated G&A costs number for the proposal.

Total Costs (6) - Sum of Items (4) and (5). Note that this value will be used in verifying the minimum required work percentage for the SBC and RI.

Profit/Cost Sharing (7) - See Sections 5.10 and 5.11. Profit to be added to total cost, shared costs to be subtracted from total cost, as applicable.

Amount Requested (8) - Sum of Items (6) and (7), not to exceed $100,000.

Audit Information (9) - Complete the Audit Agency and Accounting System sections of Form C.

Model Cooperative R/R&D Agreement

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

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

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

Please direct all questions and comments to ______________(Small Business Concern representative) at ________(Phone Number)______________

________Signature____________________

________Name/title____________________

________Small Business Concern__________

________Signature____________________

________Name/title____________________

________Research Institution____________

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

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

1. Applicability of this Agreement.

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

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

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

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

2. Background Intellectual Property.

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

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

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

(2) The following Background Intellectual Property of RI may be used nonexclusively and, except as noted, without compensation by SBC in connection with research or development activities for this STTR project

(if "none" so state): ____
____;

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

3. Project Intellectual Property.

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

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

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

SBC Percent: ________ RI Percent: ________

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

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

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

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

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

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

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

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

4. Follow-on Research or Development.

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

5. Confidentiality/Publication.

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

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

6. Liability.

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

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

7. Termination.

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

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

AGREED TO AND ACCEPTED--

Small Business Concern

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

Research Institution

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

STTR Check List

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

1. **The entire proposal including any supplemental material shall not exceed a total of 25 8.5 x 11 inch pages, including Cooperative Agreement** (Sections 3.2.1, 3.2.5).
2. The proposal and innovation is submitted for one subtopic only (Section 3.1).
3. The entire proposal is submitted consistent with the requirements and in the order outlined in Section 3.2.
4. The technical proposal contains all eleven parts in order (Section 3.2.4).
5. The 1-page briefing chart does not include any proprietary data (Section 3.2.8).
6. Certifications in Form A are completed, and agree with the content of the technical proposal.
7. Proposed funding does not exceed $100,000 (Sections 1.4.1, 5.1.1).
8. Proposed project duration does not exceed 12 months (Sections 1.4.1, 5.1.1).
9. Cooperative Agreement has been electronically endorsed by both the SBC Official and RI (Sections 3.2.5, 6.2).
10. Entire proposal including Forms A, B, C, and Cooperative Agreement submitted via the Internet.
11. Form A electronically endorsed by the SBC Official.
12. **Proposals must be received no later than 5:00 p.m. EDT on Thursday, September 2, 2010** (Section 6.3).
13. Signed Allocation of Rights Agreement available for Contracting Officer at time of selection.

9. Research Topics for SBIR and STTR

9.1 SBIR Research Topics

Introduction

The SBIR Program Solicitation topics and subtopics are developed by the NASA Mission Directorates and Centers in coordination with the NASA SBIR/STTR programs.

There are four NASA Mission Directorates (MDs):

Aeronautics Research
Exploration Systems
Science
Space Operations

9.1.1 AERONAUTICS RESEARCH

NASA's Aeronautics Research Mission Directorate (ARMD) expands the boundaries of aeronautical knowledge for the benefit of the Nation and the broad aeronautics community, which includes the Agency's partners in academia, industry, and other government agencies. ARMD is conducting high-quality, cutting-edge research that will lead to revolutionary concepts, technologies, and capabilities that enable radical change to both the airspace system and the aircraft that fly within it, facilitating a safer, more environmentally friendly, and more efficient air transportation system. At the same time, we are ensuring that aeronautics research and critical core competencies continue to play a vital role in support of NASA's goals for both manned and robotic space exploration.

ARMD conducts cutting-edge research that produces concepts, tools, and technologies that enable the design of vehicles that fly safely through any atmosphere at any speed. In addition, ARMD is directly addressing fundamental research challenges that must be overcome in order to implement the Next Generation Air Transportation System (NextGen). This research will yield revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the National Air Space. In conjunction with expanding air traffic management capabilities, research is being conducted to help address substantial noise, emissions, efficiency, performance, and safety challenges that are required to ensure vehicles can support the NextGen vision.

NASA's Aeronautics Research Mission Directorate (ARMD) supports the Agency's goal (Goal 3) of developing a balanced overall program of science, exploration, and aeronautics, consistent with the redirection of the human spaceflight program to focus on exploration. The ARMD research plans directly support the National Aeronautics Research and Development Policy and accompanying Executive Order signed by the President on December 20, 2006.

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

TOPIC: A1 Aviation Safety

The Aviation Safety Program focuses on the Nation's future aviation safety challenges. This vigilance for safety must continue in order to meet the projected increases in air traffic capacity and realize the new capabilities envisioned for the Next Generation Air Transportation System (NextGen). The Aviation Safety Program will conduct research to improve the intrinsic safety attributes of legacy and future aircraft and their operations in the Next Generation Air Transportation system, and to eliminate safety-related technology barriers.

The program has focused on furthering our understanding of the fundamental questions that need to be addressed for mid- and long-term improvements to aviation safety through engineering analysis and technology design. The results at the fundamental level will be integrated at the discipline and multi-discipline levels to ultimately yield system-level integrated capabilities, methods, and tools for analysis, optimization, prediction, and design that will enable improved safety for a range of operating concepts, vehicle classes, and crew configurations. The Aviation Safety Program is divided into four complementary and highly interlinked projects:

- The Aircraft Aging and Durability Project performs foundational research in aging science that will ultimately yield multi-disciplinary analysis and optimization capabilities that will enable system-level integrated methods for the detection, prediction, and mitigation/management of aging-related hazards for future civilian and military aircraft.
- The Integrated Intelligent Flight Deck Project develops tools, methods, principles, guidelines, and technologies for revolutionary flight deck systems that enable transformations toward safer operations.
- The Integrated Resilient Aircraft Control Project conducts research to advance the state of aircraft flight control to provide onboard control resilience for ensuring safe flight in the presence of adverse conditions.
- The Integrated Vehicle Health Management Project develops validated tools, technologies and techniques for automated detection, diagnosis and prognosis that enable mitigation of adverse events during flight.

Examples areas of program interest include research directed at fundamental knowledge of legacy and future aircraft structures and systems durability; on-board detection, diagnosis, prognosis, prediction and mitigation of system failures and faults; monitoring vehicle and airspace issues to identify problems before they become accidents; understanding aircraft dynamics of current and future vehicles in damaged and upset conditions; robust control systems; aircraft guidance for emergency operation; airborne sensors and sensor systems for the detection and monitoring of external hazards to aircraft (e.g., in-flight icing conditions, wake vortices); design of robust collaborative work environments; effective and robust human-automation systems; and information management for effective decision making. In addition, general methods for dramatically advancing the community’s capability for thorough, cost-effective and time-effective verification and validation of safety-critical systems are of interest to the program as a whole, including rigorous methods for validating design requirements for vehicles and aviation operations, verifying integrated and distributed aircraft and air traffic systems (including assumptions about human performance), and verifying software-intensive systems.

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 Mitigation of Aircraft Aging and Durability-Related Hazards
Lead Center: GRC
Participating Center(s): ARC, LaRC

The mitigation and management of aging and durability-related hazards in future civilian and military aircraft will require advanced materials, concepts, and techniques. NASA is engaged in the research of materials (metals, ceramics, and composites) and characterization/validation test techniques to mitigate aging and durability issues and to enable advanced material suitability and concepts.

Proposals are sought for the development of moisture-resistant resins and new surface treatments/primers. Novel chemistries are sought to improve the durability of aerospace adhesives with potential use on subsonic aircraft. This research opportunity is focused on the development of novel chemistries for coupling agents, surface treatments for adherends and their interfaces, leading to aerospace structural adhesives with improved durability. Work may involve chemical modification and testing of adhesives, coupling agents, surface treatments or combinations thereof and modeling to predict behavior and guide the synthetic approaches. Examples of adhesive characteristics to model and/or test may include, but are not limited to, hydrolytic stability of the interfacial chemistry, moisture permeability at the interface, and hydrophobicity of coupling agents and surface primers. Examples of adherends to model and/or test include carbon fiber/epoxy composites used in structural applications on subsonic aircraft, and aluminum, as well as their respective surface treatments. Additionally, proposals are sought for test techniques to fully characterize aging history and strain rate effects on thermoset and/or thermoplastic resins as well as on advanced composites manufactured of such resins and reinforced with 3D fiber preforms such as the triaxial braid used in advanced composite fan containment structures. Technology innovations may take the form of tools, models, algorithms, prototypes, and/or devices.

Proposals are sought for the development of validated models to capture the evolution of residual stresses and cold work at machined features of compressor and turbine powder metallurgy superalloy disks. This research opportunity is focused on quantifying, modeling and validating residual stress and cold work evolution at stress concentration features during simulated service in aerospace gas turbine engine disk materials. Work may involve use of notched fatigue specimens to simulate stress concentration features utilizing varied surface finish conditions including as-machined, electro-polished, and shot peened surfaces. The simulated load history and temperature gas turbine engine conditions should approximate turbine service history reflective of the new generation of gas turbine engines and include the effect of superimposed dwell cycles. NASA will be an active participant in Phase I of the research effort by providing the notched specimens, and performing the mechanical testing. Technology innovations may take the form of the unique quantification of the effect of service history on residual stress and cold work depth profile evolutions within notches, and include analytical modeling descriptions of the evolution of these parameters as a function of simulated service history. The technology innovations may also include models and algorithms extrapolating the predicted residual stresses and cold work to service conditions outside of those tested during the program.

A1.02 Sensing and Diagnostic Capability for Aircraft Aging and Damage
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC, MSFC

Many conventional nondestructive evaluation (NDE) techniques have been used for flaw detection, but have shown little potential for much broader application. One element in NASA’s effort to ensure the integrity of future vehicles is research to identify changes in fundamental material properties as indicators of material aging-related hazards before they become critical. For example, composites can exhibit a number of micromechanisms such as fiber buckling and breakage, matrix cracking and delaminations as precursor to failure. For complex metallic components an inability to determine residual stress state limits the validity of predictions of the fatigue life of the component.

To further these goals, NDE technologies are being sought for the nondestructive characterization of age-related degradation in complex materials and structures. Innovative and novel approaches to using NDE technologies to measure properties related to manufacturing defects, flaws, and material aging. Measurement techniques, models, and analysis methods related to quantifying material thermal properties, elastic properties, density, microcrack formation, fiber buckling and breakage, etc. in complex composite material systems, adhesively bonded/built-up and/or polymer-matrix composite sandwich structures are of particular interest. Other NDE technologies being sought are those that enable the quantitative assessment of the strength of an adhesive region of bonded joints and repairs or enable the rapid, full-field inspection of large area structures. The anticipated outcome of successful proposals would be both a Phase II prototype NDE technology for the use of the developed technique and a demonstration of the technology showing its ability to measure a relevant material property in the advanced materials and structures in subsonic aircraft.

A1.03 Prediction of Aging Effects
Lead Center: LaRC
Participating Center(s): ARC, GRC

In order to assess the long-term effects of potential hazards and aging-related degradation of new and emerging material systems/fabrication techniques, NASA is performing research to anticipate aging and to predict its effects on the designs of future aircraft. To support this predictive capability, structural integrity analytical tools, lifing methods, and material durability prediction tools are being developed. Physics-based and continuum-based models encapsulated as computational methods (software) are needed to provide the basis for these higher level (e.g., design) tools. Proposals are sought that apply innovative computational methods, models and analytic tools to the following specific applications:

- Probabilistic computational code is sought for improved structural analysis of complex metallic and composite airframe components. The methods used in these solutions need to detail the initiation and progression of damage to determine accurate estimates of residual life and/or strength of complex airframe structures.
- Software tools are needed to predict the onset and rates of type-II hot corrosion attack in nickel-based turbine disk superalloys that allow for prolonged disk operation at high temperatures. Typically hot corrosion of turbine alloys is a product of molten salt exposure and is manifested by a localized pitting corrosion attack. Prolonged high temperature exposures of turbine disk alloys to sulfur-rich low temperature melting eutectic salts can lead to an onset of Type II hot corrosion attack causing serious degradation to the durability of the turbine components.
- Computational software is sought to simulate of the response of advanced composite fan case/containment structures in aged conditions to jet engine fan blade-out events using impact mechanics and structural system dynamics modeling techniques.
- The anticipated outcome of successful Phase II proposals would be analytic code (software) delivered to NASA suitable for use in material evaluation studies.

A1.04 Aviation External Hazard Sensor Technologies
Lead Center: LaRC
Participating Center(s): DFRC, GRC

NASA is concerned with new and innovative methods for detection, identification, evaluation, and monitoring of in-flight hazards to aviation. NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-flight hazard avoidance and mitigation. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices.

A key objective of the NASA Aviation Safety Program is to support the research of technology, systems, and methods that will facilitate transformation of the National Airspace System to Next Generation Air Transportation System (NextGen) (information available at www.jpdo.gov). The general approach to the development of airborne sensors for NextGen is to encourage the development of multi-use, adaptable, and affordable sensors. 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. This subtopic solicits technology that is focused on developing capabilities to detect and evaluate hazards. The development of human interfaces, including displays and alerts, is not within the scope of this subtopic except where explicitly requested in association with special topics. Primary emphasis is on airborne applications, but in some cases the development of ground-based sensor technology may be supported. Approaches that use multiple sensors, such as new sensor technologies in conjunction with existing X-band airborne radar, to improve hazard detection and quantification of hazard levels are of interest.

At this time, the following hazards are of particular interest: in-flight icing conditions, wake vortices, turbulence, and object/obstacle detection on the runway or taxiway. Proposals associated with sensor investigations addressing these hazards are encouraged, and some suggestions follow. The emphasis given above is not intended to discourage proposals targeting other or additional hazards such as reduced visibility, terrain, airborne obstacles, convective weather, gust fronts, cross winds, and wind shear.

To enable the development and validation of remote detection and classification of icing hazards aloft for the future airspace system and emerging aircraft, NASA is soliciting proposals for the development of remote and in-situ sensor systems for the detection of icing (super-cooled liquid water cloud) conditions. Examples include the following systems:

- Low-cost, ground-based, scanning, 1 degree beamwidth, X-band radar that can operate unattended around the clock (24/7/365) and provide calibrated reflectivity and velocity data with hydrometer/cloud particle size and phase classification (based upon the reflectivity and velocity data).
- Very low-cost and low-weight cloud liquid water content and droplet sizing sensors that are compatible with use on expendable weather balloons (radiosondes). This instrumentation would provide in-situ datasets for further development and validation of ground-based icing remote sensors and algorithms.

Wake vortex detection in the terminal area is of particular interest, because closer spacing between aircraft is necessary to facilitate the high-density operations expected in NextGen. Airborne detection of wake vortices is considered challenging due to the fact that detection must be possible in nearly all weather conditions, in order to be practical, and because of the size and nature of the phenomena.

Proposals are encouraged for the development of novel coherent and direct detection lidar systems and associated components that allow accurate meteorological wind and aerosol measurements suitable for wake vortex characterization. Proposed techniques shall provide range-resolved clear air wind and aerosol measurements in the near-IR wavelength region from 1.5 microns to 2.1 microns. Wind and aerosol measurement with <30 m resolution is preferred. Lidar development includes, but is not limited to, novel transceiver architectures, efficient signal processing methodologies, wake processing algorithms and real time data reduction and display schemes. Enhancements in size, weight, range system efficiency, sensitivity, and reliability based on emerging technologies are desired.

NASA has made a major investment in the development of new and enhanced technologies to enable detection of turbulence to improve aviation safety. Progress has been made in efforts to quantify hazard levels from convectively induced turbulence events and to make these quantitative assessments available to civil and commercial aviation. NASA is interested in expanding these prior efforts to take advantage of the newly developing turbulence monitoring technologies, particularly those focused on clear air turbulence (CAT). NASA welcomes proposals that explore the methods, algorithms and quantitative assessment of turbulence for the purpose of increasing aviation safety and augmenting currently available data in support of NextGen operations.

A1.05 Crew Systems Technologies for Improved Aviation Safety
Lead Center: LaRC

NASA seeks proposals that will improve aerospace system safety through: the development of highly innovative, crew-centered, technologies that result in effective joint human-automation systems; and improved methods for evaluating such systems in the context of NextGen operations.

We seek proposals for the development of advanced technologies that:

- Effectively convey information and aid decisions which support novel NextGen operational requirements (e.g., 4D trajectory-based operations, visual operations in non-visual meteorological conditions, etc. as described in http://www.faa.gov/about/initiatives/nextgen/media/NGIP_0130.pdf);
- Foster the appropriate use of automation and complex information sources by, for example, conveying constraints on automation reliability and information certainty/timeliness;
- Support effective joint cognitive systems by improving the communication and collaboration among multiple intelligent agents (human and automated, proximal and remote);
- Characterize the operational status of the human crewmembers, effectively modulate this state, and/or effectively adapt interfaces and automation in response to functional status (e.g., situationally-aware display reconfiguration, aiding, and multi-modal presentation of information to maximize system performance and minimize information processing bottlenecks).

We also seek proposals with novel approaches to evaluating joint human-automation systems, particularly with adaptive automation, to assess team (human and automated agents), and system performance and reliability.

Proposals should describe novel technologies and evaluation tools with high potential to serve the objectives of the Operator Performance (http://www.aeronautics.nasa.gov/avsafe/iifd/op.htm) and Operator Characterization (http://www.aeronautics.nasa.gov/avsafe/iifd/ocm.htm) and/or Multimodal Interfaces (http://www.aeronautics.nasa.gov/avsafe/iifd/mmi.htm) elements of NASA's Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/index.htm). Successful Phase I proposals should culminate in a final report that specifies, and a Phase II proposal that would realize, technology that improves the effectiveness of joint human-automation systems in aviation, or improves the ability to assess the effectiveness and reliability of such systems.

A1.06 Technologies for Improved Design and Analysis of Flight Deck Systems
Lead Center: ARC
Participating Center(s): LaRC

Information complexity in flight deck systems is increasing exponentially, and flight deck designers need tools to understand, manage, and estimate the performance and safety characteristics of these systems early in the design process - this is particularly true due to the multi-disciplinary nature of these systems. NASA seeks innovative design methods and tools for representing the complex human-automation interactions that will be part of future flight deck systems. In addition, NASA seeks tools and methods for estimating, measuring, and/or evaluating the performance of these designs throughout the lifecycle from preliminary design to operational use - with an emphasis on the early stages of conceptual design. Specific areas of interest include the following:

- Computational/modeling approaches to support determining appropriate human-automation function allocations with respect to safety and reliability. Specifically these methods should focus on metrics that describe the robustness and resilience of a proposed human – automation function allocation;
- Design tools and methods that improve the application of human-centered design principles to the design and certification of mixed human-automated systems;
- Design and analysis methods or tools to better predict and assess human and system performance in relevant operational environments, particularly in regards to procedural errors.

Proposals should describe novel design methods, metrics, and/or tools with high potential to serve the objectives of the System Design and Analysis element of NASA's Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/sda.htm). Successful Phase I proposals should culminate in a final report that specifies, and a Phase II proposal that would realize, tools that improve the design process for human-automation systems in aviation, or improves the ability to assess effectiveness of such systems during the design phase. All proposals should discuss means for verification and validation of proposed methods and tools in operationally valid, or end-user, contexts.

A1.07 Adaptive Aeroservoelastic Suppression
Lead Center: DFRC
Participating Center(s): ARC, LaRC

NASA has initiated an Integrated Resilient Aircraft Control (IRAC) effort under the Aviation Safety Program. The main focus of the effort is to advance the state-of-the-art technology in adaptive controls to provide a design option that allows for increased resiliency to failures, damage, and upset conditions. These adaptive flight control systems will automatically adjust the control feedback and command paths to regain stability, maneuverability, and eventually a safe landing. One potential consequence of changing the control feedback and command paths is that an undesired aeroservoelastic (ASE) interaction could occur. The resulting limit cycle oscillation could result in structural damage or potentially total loss of vehicle control.

Current airplanes with non-adaptive control laws usually include roll-off or notch filters to avoid ASE interactions. These structural mode suppression filters are designed to provide 8 dB of gain attenuation at the structural mode frequency. Ground Vibration Testing (GVT), Structural Mode Interaction (SMI) testing, and finally full scale flight-testing are performed to verify that no adverse ASE interactions occur. Until a significant configuration or control system change occurs, the structural mode suppression filters provide adequate protection.

When an adaptive system changes to respond to off-nominal rigid body behavior, the changes in control can affect the structural mode attenuation levels. In the case of a damaged vehicle, the frequency and damping of the structural modes can change. The combination of changing structural behavior with changing control system gains results in a system with a probability of adverse interactions that is very difficult to predict a priori. An onboard, measurement based method is needed to ensure that the system adjusts to attenuate any adverse ASE interaction before a sustained limit cycle and vehicle damage are encountered. This system must work in concert with the adaptive control system to allow the overall goal of re-gaining rigid body performance as much as possible without exacerbating the situation with ASE interactions.

A1.08 Robust Propulsion Control
Lead Center: GRC

The object of this research topic is to develop approaches for robust propulsion control design to maintain engine operation in the presence of engine icing, foreign object damage such as ice ingestion and bird strikes, or extreme operating conditions such as high angle of attack.

Aircraft engines are designed to operate safely over a wide range of conditions. They can ingest small birds with little or no effect, and they are designed with enough stall margin available that the amount of inlet distortion encountered under normal circumstances is not detrimental. However, there is a limit to the variation that the engine can accept. In the case of larger than normal inlet distortion, large bird ingestion, or internal ice build-up, the engine's operation can be far enough from its design point that stability is compromised. In these cases it might still be possible to maintain basic engine function by moving bleed valves or variable stator vanes off of their nominal schedules. This requires the development of a robust control algorithm that delivers normal engine performance over the traditional operating range, but is capable of maintaining operation beyond normal conditions.

The expected outcome of the research will be a demonstrated robust propulsion control using a realistic engine model such as the NASA-developed Commercial Modular Aero-Propulsion System Simulation (C-MAPSS). Any modifications to the simulation required to accurately model the effects of engine ice, FOD, inlet distortion, etc., will be the responsibility of the contractor, and must be based on physical considerations.

NASA resources available for the research are the publicly available Commercial Modular Aero-Propulsion System Simulation (C-MAPSS) or a similar simulation. C-MAPSS is available upon request to US Citizens and permanent residents.

A1.09 Pilot Interactions with Adaptive Control Systems under Off-Nominal Conditions
Lead Center: DFRC

Adaptive control is a promising control technology that can enhance flight safety and performance. Adaptive control has been demonstrated to provide improved performance in many unmanned aerial systems. When operated in an autonomous mode such as in an autopilot, the behavior of an adaptive flight control system can be modeled and simulated with a sufficient degree of repeatability.

The presence of a pilot working in a closed-loop fashion with an adaptive flight control presents an important problem that has not been well addressed. Adaptive control generally requires sufficiently rich input signals to improve parameter convergence, as the adaptive control system adapts to parametric changes in the vehicle dynamics or exogenous disturbances. The condition for rich input signals is known as persistent excitation. During adaptation under off-nominal conditions such as aircraft with damage, the pilot provides persistently exciting signals to the adaptive control system. There is generally a trade-off between adaptation and stability due to persistent excitation. With a high persistent excitation in the pilot inputs, the speed of adaptation increases and in theory better handling performance could be achieved. However, in practice, the high persistent excitation in the control signals can potentially cause significant cross coupling between different flight control axes and or excite unmodeled dynamics such as aeroservoelastic modes. The overall effect of high persistent excitation could aggravate stability robustness of an adaptive flight control system with a pilot in the loop that results in poor handling qualities.

Another aspect of pilot interactions with an adaptive control system is the potential interactions between two adaptive elements in a closed-loop fashion, because the pilot can also be viewed as an adaptive control system with a learning ability. With the pilot adaptive element providing high persistently exciting inputs into an adaptive flight control system with a predetermined adaptation rate, the issue of stability can be important and difficult to assess.

To enable an adaptive flight control system to be operated with a pilot in the loop, it is necessary to develop new research techniques that can assess the effects of pilot interactions with an adaptive flight control system. These techniques should address pilot control responses via an adaptive model with features that can capture relevant interactions with an adaptive flight control system. Techniques for assessing pilot interactions via metrics that can quantify the pilot-vehicle system responses with an adaptive flight control system are also needed. Other aspects of the research can include new methods and tools that can provide an advisory function to limit the pilot control inputs in order to trade off between command-following performance and stability robustness.

Research in adaptive control methods will address the system requirements to provide good flying characteristics when the human operator closes the control loop. In the presence of damage, failures, etc. the adaptive system must trade the stability requirements with closed loop handling requirements. Methods for selecting the best achievable handling are needed. The adaptation system needs to find a good compromise between suppression of coupling between the axis (i.e. pitch into roll, etc) and good in-axis behavior. Better metrics to assess cross-coupled (asymmetric) behavior are needed. These metrics could provide a quantitative measurement of the severity of a given failure, as well as a measure of the improvement due to adaptation. As the adaptation changes the flying characteristics of the vehicle, some means of informing the operator is required to ensure that the system is not overdriven by a pilot who is expecting nominal performance.

A1.10 Detection of Aircraft Anomalies
Lead Center: GRC
Participating Center(s): ARC, DFRC, LaRC

Adverse events that occur in aircraft can lead to potentially serious consequences if they go undetected. This effort is to develop the technologies, tools, and techniques to detect in-flight anomalies from adverse events. This involves the integration of novel sensor and advanced analytical technologies for airframe, propulsion systems, and other subsystems within the aircraft. The emphasis of this work is not on diagnosing the exact nature of the failure but on identifying its presence. Proposals are solicited that address aspects of the following topics:

- Analytical and data-driven technologies required to interpret the sensor data to enable the detection of fault and failure events,
- Methods to differentiate sensor failure from actual system or component failure,
- Characterizing, quantifying, and interpreting multi-sensor outputs, and
- New sensors, sensory materials and sensor systems that improve the detection of an adverse event or permit increased sensory coverage for an adverse event.

Emphasis is on novel methods to detect failures in electrical, electromechanical, electronic, structural, and propulsion systems. Along with these system failures, condition sensors are desired for both the detection of internal engine icing as well as composite aircraft lightning strikes (location and intensity). Where possible, a rigorous mathematical framework should be employed to ensure the detection rates and detection time constants are acceptable according to published baselines as characterized by statistical measures. Understanding and addressing validation issues are critical components of this effort.

A1.11 Diagnosis of Aircraft Anomalies
Lead Center: LaRC
Participating Center(s): DFRC, GRC, SSC

The capability to identify faults is critical to determining appropriate mitigation actions to maintain aircraft safety. This effort is to develop innovative methods and tools for the diagnosis of aircraft faults and failures. It includes the development of integrated technologies, tools, and techniques to determine the causal factors, nature, and severity of an adverse event and to distinguish that event from within a family of potential adverse events. These requirements go beyond standard fault isolation techniques. The emphasis is on the development of mathematically rigorous diagnostic technologies that are applicable to structures, propulsion systems, software, and other subsystems within the aircraft. Technologies developed must be able to perform diagnosis given heterogeneous and asynchronous signals coming from the health management components of the vehicle and integrating information from each of these components.

The ability to actively query health management systems, use advanced decision making techniques to perform the diagnosis, and then assess the severity using these techniques are critical. As an example, the mathematical rigor of the diagnosis and severity assessment could be treated through a Bayesian methodology since it allows for characterization and propagation of uncertainties through models of aircraft failure and degradation.

Both computational and prototype hardware implementations of the diagnostic capabilities are expected\ outcomes of this effort. Other methods could also be employed that appropriately model the uncertainties in the subsystem due to noise, various stresses due to the aerodynamic forces inherent in flight, and other sources of uncertainty. The ability to actively query the underlying health management systems (whether they are related to detection or not) is critical to reducing the uncertainty in the diagnosis. As an example, if there is ambiguity in the diagnosis about the type and location of a particular failure in the aircraft structure, the diagnostic engine should be able to actively query that system or related systems to determine the true location and severity of the anomaly. An important element is the use of structural health monitoring tools based on the application of damage progression models with statistical inference and multivariate decision schemes to aid in the integration of multiple sensors for structural vibration and/or strain measurements in a noisy environment. Where possible, a rigorous mathematical framework should be employed to provide a rank ordered list of diagnoses, an assessment of the severity of each diagnosed event, and a measure of the uncertainty in the diagnosis. Understanding and addressing the system integration and validation issues are critical components of this effort.

A1.12 Prognosis of Aircraft Anomalies
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

The ability to accurately and precisely predict the remaining useful life (RUL) of aircraft components and subsystems enables decision making and action taking that can avert or mitigate failures, thereby enhancing aircraft safety. Furthermore, it can improve operational efficiency by facilitating condition-based maintenance and reducing unscheduled maintenance. This effort addresses the development of innovative methods, technologies, and tools for the prognosis of aircraft faults and failures. The assessment of the RUL could be used by other aircraft systems to place additional restrictions, such as a new operating envelope, on the flight control systems or it could be used by flight or maintenance personnel to take preventative actions. Areas of interest include developing methods for making predictions of RUL, which take into account operational and environmental uncertainties (pure data-driven approaches are discouraged); physics-based models of degradation; generation of aging and degradation datasets on relevant components or subsystems; and development of validation and verification methodologies for prognostics.

Research should be conducted to demonstrate technical feasibility during Phase I and to show a path toward a Phase II technology demonstration. Proposals are solicited that address aspects of the following areas:

- 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 composite or metallic airframe structures, engine turbomachinery and hot structures, avionics, electrical power systems, electromechanical systems, and electronics. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.
- Uncertainty representation and management (reduction of prediction uncertainty bounds) methods. Proposers are encouraged to consider uncertainties due to measurement noise, imperfect models and algorithms, as well as uncertainties stemming from future anticipated loads and environmental conditions. Methods can also consider the fusion of different techniques but must show how this helps to improve the uncertainty using appropriate metrics.
- Aircraft relevant test beds that can generate aging and degradation datasets for the development and testing 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.

A1.13 Healing Material System Concepts for IVHM
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

The development of integrated multifunctional self-sensing, self-repairing structures will enable the next generation of lightweight, reliable and damage-tolerant aerospace vehicle designs. Prototype multifunctional composite and/or metallic structures are sought to meet these needs, as are concepts for their analytical and experimental interrogation. Specifically, structural and material concepts are sought to enable in situ monitoring and repair of service damage (e.g., cracks, delaminations) to improve structural durability and enhance safe operation of aerospace structural systems. Emphasis is placed on the development of new materials and systems for the mitigation of structural damage and/or new concepts for activation of healing mechanisms using new or existing materials. These advanced structural and material concepts must be robust, consider all known damage modes for specific material systems and be validated through experiment.

A1.14 Verification and Validation of Flight-Critical Systems
Lead Center: ARC
Participating Center(s): DFRC, LaRC

The purpose of this subtopic is to invest in mid- and long-term research to establish rigorous, systematic, scalable, and repeatable verification and validation methods for flight-critical systems, with a deliberate focus on safety for NextGen (http://www.jpdo.gov/nextgen.asp). This subtopic targets NextGen safety activities and interests encompassing vehicles, vehicle systems, airspace, airspace concept of operations, and air traffic technologies, such as communication or guidance and navigation. Methods for assessing issues with technology, human performance and human-systems integration are all included in this sub-topic, nothing that multi-disciplinary research is required that does not focus on one type of component or phenomenon to the exclusion of other important drivers of safety.

Proposals are sought for the development of:

- Safety-case methods and supporting technologies capable of analyzing the system-wide safety properties suitable for civil aviation vehicles and for complex concepts of operation involving airborne systems, ground systems, human operators and controllers.
- Technologies and mathematical models that enable rigorous, comprehensive analysis of novel integrated, and distributed, systems interacting through various mechanisms such as communication networks and human-automation and human-human interaction.
- Techniques, tools and policies to enable efficient and accurate analysis of safety aspects of software-intensive systems, ultimately reducing the cost of software V&V to the point where it no longer inhibits many safety innovations and NextGen developments.
- Tools and techniques that can facilitate the use of formal methods in V&V throughout the lifecycle such as graphical-based development environments (e.g., eclipse plug-ins for static analyzers, model checkers, or theorem provers) or tools facilitating translation from design formats used in industry to formal languages supporting automated reasoning.

This subtopic is intended to address those flight-critical systems that directly conduct flight operations by controlling the aircraft, such as on-board avionics and flight deck systems, and safety-critical ground-based functions such as air traffic control and systems for communication, navigation and surveillance. It is not intended to cover V&V of computational models of physical systems (e.g. CFD codes or finite element analysis).

In Phase II, a functional system shall be delivered to NASA for its retention and ownership.

A1.15 Data Mining
Lead Center: ARC
Participating Center(s): LaRC

The fulfillment of the IVHM project’s goal requires the ability to transform the vast amount of data produced by the aircraft and associated systems and people into actionable knowledge that will aid in detection, diagnosis, prognosis, and mitigation at levels ranging from the aircraft-level, to the fleet-level, and ultimately to the level of the national airspace. The vastness of this data means that data mining methods must be efficient and scalable so that they can return results quickly. Additionally, much of this data will be distributed among multiple systems. Data mining methods that can operate on the distributed data where they are is critical because centralizing data will typically be impractical. However, these methods must be provably able to return the same results as what a comparable method would return if the data could be centralized because this is a critical part of verifying and validating these algorithms, which is important for aviation safety applications.

This topic will yield efficient and scalable data-driven algorithms for anomaly detection, diagnosis, prediction, and prognosis that are able to operate at levels ranging from the aircraft level to the fleet level. To that end, the methods must be able to efficiently learn from vast historical time-series datasets (at least 10 TB) that are heterogeneous (contain continuous, discrete, and/or text data). Distributed data-driven algorithms that provably return the same results as a comparable method that requires data to be centralized are also of great interest.

TOPIC: A2 Fundamental Aeronautics

The Fundamental Aeronautics Program (FAP) encompasses the principles of flight in any atmosphere, and at any speed. The program develops focused technological capabilities, starting with the most basic knowledge of underlying phenomena through validation and verification of advanced concepts and technologies at the component and systems level. Physics-based, multidisciplinary design, analysis, and optimization (MDAO) tools will be developed that make it possible to evaluate radically new vehicle designs and to assess, with known uncertainties, the potential impact of innovative technologies and concepts on a vehicle's overall performance. The development of advanced component technologies will realize revolutionary improvements in noise, emissions, and performance. The program also supports NASA's human and robotic exploration missions by advancing knowledge in aeronautical areas critical to planetary Entry, Descent, and Landing. NASA has defined a four-level approach to technology development: conduct foundational research to further our fundamental understanding of the underlying physics and our ability model that physics; leverage the foundational research to develop technologies and analytical tools focused on discipline-based solutions; integrate methods and technologies to develop multi-disciplinary solutions; and solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration.

Structurally, the FAP is composed of four projects: hypersonic flight, supersonic flight, subsonic fixed-wing aircraft and subsonic rotary-wing aircraft.

Hypersonics (HYP)

- Fundamental research in all disciplines to enable very-high speed flight (for airbreathing launch vehicles) and Entry, Descent and Landing into planetary atmospheres
- High-temperature materials, thermal protection systems (single and multi-use), airbreathing propulsion, aero-thermodynamics, multi-disciplinary analysis and design, guidance, navigation, and control GN&C, advanced experimental capabilities, and supersonic decelerator technologies

Supersonics (SUP)

- Eliminate environmental and performance barriers that prevent practical supersonic vehicles (cruise efficiency, noise and emissions, vehicle integration and control)

Subsonic Fixed Wing (SFW)

- Develop revolutionary technologies and aircraft concepts with highly improved performance while satisfying strict noise and emission constraints
- Focus on enabling technologies: acoustics predictions, propulsion / combustion, system integration, high-lift concepts, lightweight and strong materials, GNC

Subsonic Rotary Wing (SRW)

- Improve civil potential of rotary wing vehicles (vs. fixed wing) while maintaining their unique benefits
- Key advances in multiple areas through innovation in materials, aeromechanics, flow control, propulsion

Each project addresses specific discipline, multi-discipline, sub-system and system level technology issues relevant to that flight regime. A key aspect of the Fundamental Aeronautics Program is that many technical issues are common across multiple flight regimes and may be best resolved in an integrated coordinated manner. As such, the FAP subtopics are organized by discipline, not by flight regime, with a special subtopic for rotary-wing issues.

Additional information: http://www.aeronautics.nasa.gov/fap/index.html

A2.01 Materials and Structures for Future Aircraft
Lead Center: GRC
Participating Center(s): ARC, DFRC, LaRC

Advanced materials and structures technologies are needed in all four of the NASA Fundamental Aeronautics Program research thrusts (Subsonics Fixed Wing, Subsonics Rotary Wing, Supersonics, and Hypersonics) to enable the design and development of advanced future aircraft. Proposals are sought that address specific design and development challenges associated with airframe and propulsion systems. These proposals should be linked to improvements in aircraft performance indicators such as vehicle weight, fuel consumption, noise, lift, drag, durability, and emissions. In general, the technologies of interest cover five research themes:

- **Fundamental materials development, processing and characterization** – innovative approaches to enhance the durability, processability, performance and reliability of advanced materials (metals, ceramics, polymers, composites, nanostructured materials, hybrids and coatings). In particular, proposals are sought in:
    - Advanced high temperature materials for aircraft engine and airframe components and thermal protection systems, including advanced blade and disk alloys, ceramics and CMCs, polymers and PMCs, nanostructured materials, hybrid materials and coatings to improve environmental durability.
    - Adaptive materials such as piezoelectric ceramics, shape memory alloys, shape memory polymers, and variable stiffness materials and methods to integrate these materials into airframe and/or aircraft engine structures to change component shape, dampen vibrations, and/or attenuate acoustic transmission through the structure.
    - Multifunctional materials and structural concepts for engine and airframe structures, such as novel approaches to power harvesting and thermal management, lightning strike mitigating, self-sensing, and materials for wireless sensing and actuation.
    - New high strength fibers, in particular low density, high strength and stiffness carbon fibers.
    - Innovative processing methods to reduce component manufacturing costs and improve damage tolerance and reliability of ceramics, metals (especially oxide dispersion strengthened nickel-based alloys), polymers, composites, and hybrids, nanostructured and multifunctional materials and coatings.
    - Development of joining and integration technologies including fasteners and/or chemical joining methods for ceramic-to-ceramic, metal-to-metal, and metal-to-ceramic as well as solid state joining methods such as advanced friction stir welding.
    - Innovative methods for the evaluation of advanced materials and structural concepts (in particular multifunctional and/or adaptive) under simulated operating conditions, including combinations of electrical, thermal and mechanical loads.
    - Nondestructive evaluation (NDE) methods for the detection of as-fabricated flaws and in-service damage for textile polymeric, ceramic and metal matrix composites, nanostructured materials and hybrids. NDE methods that provide quantitative information on residual structural performance are preferred.

- **Structural analysis tools and procedures** – robust and efficient design methods and tools for advanced materials and structural concepts (in particular multifunctional and/or adaptive components) including variable fidelity methods, uncertainty based design and optimization methods, multi-scale computational modeling, and multi-physics modeling and simulation tools. In particular, proposals are sought in:
    - Multiscale design tools for aircraft and engine structures that integrate novel materials, mechanism design, and structural subcomponent design into systems level designs.
    - Life prediction tools for textile composites including fiber architecture modeling methods that enable the development of physics-based hierarchical analysis methods. Fiber architecture models that address yarn-to-yarn and ply-to-ply interactions covering a wide range of textile preform

structures in either a relaxed or compressed deformation state as well as tools to predict debonding and delamination of through thickness reinforced (stitched, z-pinned) composites are of particular interest.
  - Tools to predict durability and damage tolerance of new material forms including metallic-composite hybrids, friction stir-welded metallic materials and powder metallurgy-formed materials.
  - Meso scale tools to guide materials placement to enable tailored load paths in multifunctional structures for enhanced damage tolerance.

- **Computational materials development tools** – methods to predict properties, damage tolerance, and/or durability of both airframe and propulsion materials, thermal protection systems and ablatives based upon chemistry and processing for conventional as well as functionally graded, nanostructured, multifunctional and adaptive materials. In particular proposals are sought in:
  - Ab-initio methods that enable the development of coatings for multiple uses at temperatures above 3000°F in an air environment.
  - Computational tool development for structure-property modeling of adaptive materials such as piezoelectric ceramics, shape memory alloys, shape memory polymers to characterize their physical and mechanical behavior under the influence of an external stimulus.
  - Computational and analytical tools to enable molecular design of polymeric and/nanostructured materials with tailored multifunctional characteristics.
  - Computational microstructural and thermodynamic analysis tools and technique development for designing new lightweight alloy compositions for subsonic airframe and engines from first principles, functionally graded (chemically or microstructurally) materials, and/or novel metals processing techniques to accelerate materials development and understanding of processing-structure-property relationships.
  - Software tools to predict temperature dependent phase chemistries, volume fractions, shape and size distributions, and lattice parameters of phases in a broad range of nickel and iron-nickel based superalloys. Toolset should utilize thermodynamic and kinetic databases and models that are fully accessible, which allow modifications and user-input to expand experimental databases and refine model predictions.

- **Advanced Structural Concepts** – new concepts for airframe and propulsion components incorporating new light weight concepts as well as "smart" structural concepts such as those incorporating self-diagnostics with adaptive materials, multifunctional component concepts to reduce mass and improve durability and performance, lightweight, efficient drive systems and electric motors for use in advanced turboelectric propulsion systems for aircraft, and new concepts for robust thermal protection systems for high-mass planetary entry, descent and landing. In particular, proposals are sought in:
  - Innovative structural concepts, materials, manufacturing and fabrication leading to reliable, entry descent and landing systems including deployable rigid and flexible heat shields and structurally integrated multifunctional systems. Of particular interest are high temperature honeycombs, hat stiffeners, rigid fibrous and foam insulators, as well as high temperature adhesives, films and fabrics for advanced flexible heat shields.
  - Advanced mechanical component technologies including self lubricating coatings, oil-free bearings, and seals.
  - Advanced material and component technologies to enable the development of mechanical and electrical drive system to enable the development of turboelectric propulsion systems, which utilize power from a single turbine engine generator to drive multiple propulsive fans. Innovative concepts are sought for AC-tolerant, low loss (< 10 W/kA-m) conductors or superconductors for the stators of synchronous motors or generators operating at > 1.5 T field and 500 Hz electrical frequency; and high efficiency (≥ 30% of Carnot), low mass (<6kg/kW input) cryo-refrigerators for 20 to 65°K. Input power between 10 and 100 kW is envisioned in applications, but scalable small demonstrations are acceptable.

- o Novel structural designs for integrated fan cases that combine hardwall composite cases for blade containment with acoustic treatments as well as concepts that integrate the case with the fan inlet to maximize structural, acoustic attenuation and weight benefits.
- o Innovative approaches to structural sensors for extreme environments (>1800°F) including the development and validation of improved methods (i.e. adhesives, plasma spraying techniques, etc.) for attaching sensors to advanced high-temperature materials as well as approaches to measure strain, temperature, heat flux and/or acceleration of structural components.

A2.02 Combustion for Aerospace Vehicles
Lead Center: GRC
Participating Center(s): LaRC

Combustion research is critical for the development of future air-breathing aerospace vehicles. Vehicles for subsonic and supersonic flight regimes will be required to emit extremely low amounts of gaseous and particulate emissions to satisfy increasingly stringent emissions regulations. Hypersonic vehicles require combustion systems capable of sustaining stable and efficient combustion in very high-speed flow fields where fuel/air mixing must be accomplished very rapidly and residence times for combustion are extremely limited. Fundamental combustion research coupled with associated physics based model development of combustion processes will provide the foundation for technology development critical for aerospace vehicles. Combustion for aerospace vehicles typically involves multi-phase, multi-component fuel, turbulent, unsteady, 3D, reacting flows where much of the physics of the processes are not completely understood. CFD codes used for combustion do not currently have the predictive capability that is typically found for non-reacting flows. Practical aerospace combustion concepts typically require very rapid mixing of the fuel and air with a minimum pressure loss to achieve complete combustion in the smallest volume. Reducing emissions may require combustor operation where combustion instability can be an issue and active control may be required. Areas of specific interest where research is solicited includes:

- Development of laser-based diagnostics and novel experimental techniques for measurements in reacting flows;
- Development of ultra-sensitive instruments for determining the size-dependent mass of gas-turbine engine particle emissions;
- Development of nonintrusive instruments for determining the size of volatile gas-turbine engine particle emissions in a low pressure and temperature environment;
- High frequency actuators (bandwidth ~1000 Hz) that can be used to modulate fuel flow at multiple fuel injection locations (with individual Flow Numbers of 3 to 5) with minimal fuel pressure drop for active combustion control;
- Combustion instability modeling and experimental validation;
- Novel combustion simulation methodologies include, but not limited to, algorithms for combustion CFD that take advantage of graphics processing units, CFD-grade primary breakup models for (swirling) annular liquid sheets in both atmospheric and high ambient pressure conditions, CFD-grade primary breakup models for liquid jets in (swirling) cross flows in both atmospheric and high ambient pressure conditions;
- Enhanced mixing concepts, ignition and flame holding, vitiated-test media and facility-contamination effects;
- Novel combustor concepts that advance/enhance the state-of-the-art in hypersonic propulsion to improve system performance, operability, reliability and reduce cost. Both analytic and/or experimental efforts are encouraged, as well as collaborative efforts that leverage technology from on-going research activities;
- Novel concepts to reduce the weight and/or length of scramjet engines (either individual components or the compete geometry);
- Computational and experimental technologies for the accurate prediction of combined cycle phenomena such as shock trains in isolators, inlet unstart, and thermal choke.

A2.03 Aero-Acoustics
Lead Center: LaRC
Participating Center(s): ARC, GRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, and advanced aerospace vehicles. In support of the Fundamental Aeronautics Program, improvements in noise prediction, measurement methods and control are needed for subsonic and supersonic vehicles, including fan, jet, turbomachinery, engine core, prop fan, propeller and airframe noise sources. In addition, improvements in prediction and control of noise transmitted through aerospace vehicle structures are needed to reduce noise impact on passengers, crew and launch vehicle payloads. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid dynamics techniques for aeroacoustic analysis, which can be adapted for design codes;
- Prediction of aerodynamic noise sources including those from engine and airframe and sources which arise from significant interactions between airframe and propulsion systems;
- Prediction of sound propagation (including sonic booms) from the aircraft through a complex atmosphere to the ground. This should include interaction between noise sources and the airframe and its flow field;
- Computational and analytical structural acoustics prediction techniques for aircraft and advanced aerospace vehicle interior noise, particularly for use early in the airframe design process;
- Prediction and control of high-amplitude aeroacoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue;
- Innovative source identification techniques for engine (e.g., fan, jet, combustor, or turbine noise) and for airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise typical of jets, separated flow regions, vortices, shear layers, etc.;
- Concepts for active and passive control of aeroacoustic noise sources for conventional and advanced aircraft configurations, including adaptive flow control technologies, smart structures for nozzles and inlets, and noise control technology and methods that are enabled by advanced aircraft configurations, including integrated airframe-propulsion control methodologies;
- Technologies and techniques for active and passive interior noise control for aircraft and advanced aerospace vehicle structures;
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise, including sonic boom.

A2.04 Aeroelasticity
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

The NASA Fundamental Aeronautics program has the goal to develop system-level capabilities that will enable the civilian and military designers to create revolutionary systems, in particular by integrating methods and technologies that incorporate multi-disciplinary solutions. Aeroelastic behavior of flight vehicles is a particularly challenging facet of that goal.

The program's work on aeroelasticity includes conduct of broad-based research and technology development to obtain a fundamental understanding of aeroelastic and unsteady-aerodynamic phenomena experienced by aerospace vehicles in subsonic, transonic, supersonic, and hypersonic speed regimes. The program content includes theoretical aeroelasticity, experimental aeroelasticity, and advanced aeroservoelastic concepts. Of interest are aeroelastic, aeroservoelastic, and unsteady aerodynamic analyses at the appropriate level of fidelity for the problem at hand; aeroelastic, aeroservoelastic, and unsteady aerodynamic experiments to validate methodologies and to gain valuable insights available only through testing; development of computational-fluid-dynamic, computational-aeroelastic, and computational-aeroservoelastic analysis tools that advance the state of the art in aeroelasticity through novel and creative application of aeroelastic knowledge.

The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for assuring freedom from catastrophic aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the unsteady aerodynamic forces acting on the structure, and at times, active systems controlling the flight vehicle. Complex unsteady aerodynamic flow phenomena, particularly at transonic Mach numbers, are also very important because this is the speed regime most critical to encountering aeroelastic instabilities. In addition, aeroelasticity is presently being exploited as a means for improving the capabilities of high performance aircraft through the use of innovative active control systems using both aerodynamic and smart material concepts. Work to develop analytical and experimental methodologies for reliably predicting the effects of aeroelasticity and their impact on aircraft performance, flight dynamics, and safety of flight are valuable. Subjects to be considered include:

- Development of design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of methods to predict aeroelastic phenomena and complex steady and unsteady aerodynamic flow phenomena, especially in the transonic speed range. Aeroelastic phenomena of interest include flutter, buffet, buzz, limit cycle oscillations, divergence, and gust response; flow phenomena of interest include viscous effects, vortex flows, separated flows, transonic nonlinearities, and unsteady shock motions.
- Development of efficient methods to generate mathematical models of wind-tunnel models and flight vehicles for performing vibration, aeroelastic, and aeroservoelastic studies. Examples include (a) CFD-based methods (reduced-order models) for aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, and flutter issues and (b) integrated tool sets for fully coupled modeling and simulation of aeroservothermoelasticity / flight dynamic (ASTE/FD) and propulsion effects.
- Development of physics-based models for turbomachinery aeroelasticity related to highly separated flows, shedding, rotating stall, and non-synchronous vibrations (NSV). This includes robust, fast-running, accelerated convergence, reduced-order CFD approaches to turbomachinery aeroelasticity for propulsion applications. Development of blade vibration measurement systems (including closely spaced modes, blade-to-blade variations (mistuning), and system identification) and blade damping systems for metallic and composite blades (including passive and active damping methods) are of interest.
- Development of aeroservoelasticity concepts and models, including unique control concepts and architectures that employ smart materials embedded in the structure and/or aerodynamic control surfaces for suppressing aeroelastic instabilities or for improving performance.
- Development of techniques that support simulations, ground testing, wind-tunnel tests, and flight experiments of aeroelastic phenomena.
- Investigation and development of techniques that incorporate structure-induced noise, stiffness and strength tailoring, propulsion-specific structures, data processing and interpretation methods, non-linear and time-varying methods development, unstructured grid methods, additional propulsion systems-specific methods, dampers, multistage effects, non-synchronous vibrations, coupling effects on blade vibration, probabilistic aerodynamics and aeroelastics, actively controlled propulsion system core components (e.g. fan and turbine blades, vanes), and advanced turbomachinery active damping concepts.
- Investigation and development of techniques that incorporate lightweight structures and flexible structures under aerodynamic loads, with emphasis on aeroelastic phenomena in the hypersonic domain. Investigation of high temperatures associated with high heating rates, resulting in additional complexities associated with varying thermal expansion and temperature dependent structural coefficients. Acquisition of data to verify analysis tools with these complexities.

A2.05 Aerodynamics
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC, JSC, MSFC

The challenge of flight has at its foundation the understanding, prediction, and control of fluid flow around complex geometries - aerodynamics. Aerodynamic prediction is critical throughout the flight envelope for subsonic, supersonic, and hypersonic vehicles - driving outer mold line definition, providing loads to other disciplines, and enabling environmental impact assessments in areas such as emissions, noise, and aircraft spacing.

In turn, high confidence prediction enables high confidence development and assessment of innovative aerodynamic concepts. This subtopic seeks innovative physics-based models and novel aerodynamic concepts, with an emphasis on flow control, applicable in part or over the entire speed regime from subsonic through hypersonic flight.

All vehicle classes will experience subsonic flight conditions. The most fundamental issue is the prediction of flow separation onset and progression on smooth, curved surfaces, and the control of separation. Supersonic and hypersonic vehicles will experience supersonic flight conditions. Fundamental to this flight regime is the sonic boom, which to date has been a barrier issue for a viable civil vehicle. Addressing boom alone is not a sufficient mission enabler however, as low drag is a prerequisite for an economically viable vehicle, whether only passing through the supersonic regime, or cruising there. Atmospheric entry vehicles and space access vehicles will experience hypersonic flight conditions. Reentry capsules such as the new Crew Exploration Vehicle deploy multiple parachutes during descent and landing. Predicting the physics of unsteady flows in supersonic and subsonic speeds is important for the design of these deceleration systems. The gas-dynamic performance of decelerators for vehicles entering the atmospheres of planets in the solar system is not well understood. Reusable hypersonic vehicles will be designed such that the lower body can be used as an integrated propulsion system in cruise condition. Their performance is likely to suffer in off-design conditions, particularly acutely at transonic speeds. Advanced flow control technologies are needed to alleviate the problem.

This solicitation seeks proposals to develop and validate:

- Turbulence models capturing the physics of separation onset at Reynolds numbers relevant to flight, where relevant to flight is dependent on a targeted vehicle class and mission profile;
- Boundary-layer transition models suitable for direct integration with state-of-the-art flow solvers;
- Active flow control concepts targeted at separation control, shock wave manipulation, and/or viscous drag reduction with an emphasis on the development of novel, practical, lightweight, low-energy actuators;
- Innovative aerodynamic concepts targeted at vehicle efficiency or control;
- Physics-based models for simultaneous low boom/low drag prediction and design;
- Aerodynamic concepts enabling simultaneous low boom and low drag objectives;
- Innovative methods to validate both flow models and aerodynamic concepts with an emphasis on aft-shock effects which are hindered by conventional wind tunnel model mounting approaches;
- Uncertainty quantification methods suitable for use with state-of-the-art flow solvers;
- Accurate aerodynamic analysis and multidisciplinary design tools for multi-body flexible structures in the atmospheres of planets and moons including the Earth, Mars, and Titan;
- Advanced flow control technologies to alleviate off-design performance penalties for reusable hypersonic vehicles.

A2.06 Aerothermodynamics
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

Development of hypersonic flight vehicles for airbreathing access to space and for planetary entry poses several design challenges. One of the primary obstacles is the large uncertainty in predictive capability of the aerothermal environment to which these vehicles are subjected. For airbreathing access to space vehicles, predictions of boundary layer transition to turbulence and shock boundary layer interactions in a turbulent flow regime are sources of large aerothermal uncertainty and require conservative assumptions. For planetary entry vehicles with either rigid or flexible thermal protection systems (TPS), sources of large aerothermal uncertainty in high enthalpy conditions also include the catalytic or ablative properties of the TPS. The fluid dynamic and thermochemical interactions of a rough ablating surface with the aerothermal environment leads to many poorly understood coupled phenomena such as early boundary layer transition, turbulent heating augmentation, catalytic heating, radiation absorption, etc. At high entry speeds and large vehicle sizes, shock layer radiation becomes a large component of the aeroheating, with an increasing fraction of the radiation produced in the poorly understood vacuum ultraviolet part of the spectrum. The low confidence in the predictive capability is apparent in high enthalpy flows that are often difficult to adequately reproduce in a ground test facility.

The model uncertainties require designers to resort to large margins, resulting in reduced mission capabilities and increased costs. Future science and human exploration missions to Mars and other planets will require dramatic improvements in our current capability to land large payloads safely on these worlds. Research in aerothermodynamics focuses on solving some of the most difficult challenges in hypersonic flight. These include the development of predictive models via experimental validation for shock layer radiation phenomena, non-equilibrium thermodynamic and transport properties, catalycity, transition and turbulence, and ablation phenomena, as well as the development of new experimental datasets, especially in high enthalpy flow that can be used to validate theoretical and computational models.

Proposals suggesting innovative approaches to any of these problems are encouraged; specific areas of interest include:

- Advancement of NASA boundary layer transition tools, especially including high enthalpy effects.
- Development of shock turbulent boundary layer interaction models and validation with an experimental program.
- Development of radiation models supported by experimental validation in a laboratory (using shock tube, plasma torch, etc.) simulating extreme entry environments at Earth, Mars, Titan, and the Giant Planets.
- Development of high enthalpy RANS level turbulence models in a rough, ablating environment using experimentation or use of high fidelity computational techniques such as DNS or LES.
- Development of instrumentation for use in high-enthalpy flows to measure pressure, shear, radiation intensity, and off body flow quantities with enhanced capability such as high frequency measurements and/or high temperature tolerance.
- Development of tools and techniques that enable remote thermal imaging of entry vehicles with high temperature and spatial resolution, and lower uncertainty than the state-of-the art.
- Development of numerical techniques and computational tools that advance the start-of-the-art in computations of unsteady, turbulent separated flows with reasonable computational efficiency.

A2.07 Flight and Propulsion Control and Dynamics
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

NASA is conducting fundamental aeronautic research to develop innovative ideas that can lead to next generation aircraft design concepts with improved aerodynamic efficiency, lower emissions, less fuel burn, and reduced noise and carbon footprints. To realize these potential benefits, innovative vehicle design concepts can exhibit many complex modes of interactions due to many different effects of flight physics such as aerodynamics, vehicle dynamics, propulsion, structural dynamics, and external environment in all three flight regimes. Advanced flight control strategies for innovative aircraft design concepts are seen as an enabling technology that can harvest potential benefits derived from these complex modes of interaction. Towards this end, there is an interest in the following technology areas:

Active Aeroelastic Wing Shape Tailoring for Aircraft Performance and Control
Modern aircraft are increasingly designed with lightweight, flexible airframe structures. By employing distributed flight control surfaces, a modern wing structure (which implies aircraft wing, horizontal stabilizer, and vertical stabilizer) can be strategically tailored in-flight by actively controlling the wing shape so as to bring about certain desired vehicle characteristics. For example, active aeroelastic wing shape tailoring can be employed to control the wash-out distribution and wing deflection in such a manner that could result in improved aerodynamic performance such as reduced drag during cruise or increased lift during take-off. Another novel use of active aeroelastic wing

shape tailoring is for flight control. By actively controlling flexible aerodynamic surfaces differentially or collectively, the motion of an aircraft can be controlled in all three stability axes. In high speed supersonic or hypersonic vehicles, effects of airframe-propulsion-structure interactions can be significant. Thus, propulsion control can play an integral role with active aeroelastic wing shape tailoring control in high speed flight regimes.

This technology area involves the development of various technical elements including:

- Innovative aircraft concepts that can significantly improve aerodynamic performance and control by leveraging active aeroelastic wing shape tailoring.
- Sensor technology that will enable in-flight wing twist and deflection static and dynamic measurements for control development.
- Actuation methods that examine novel modes of actuation for actively controlling wing shape in-flight, and effective placements of distributed control effectors on a wing structure.
- Vehicle dynamic modeling capability for aero-propulsive-servo-elasticity that will provide a knowledge foundation upon which vehicle control and dynamics can be developed.
- Integrated approaches for active aeroelastic wing shape tailoring control with distributed control surfaces that will provide effective advanced control strategies to achieve aerodynamic performance and flight control objectives, taken into account airframe-propulsion-structure interactions that can exist in all three flight regimes.

Gust Load Alleviation Control

In a future NextGen operational concept, close separation between aircraft in super density operations could lead to more frequent wake vortex encounters. The increasing use of flexible airframe design in modern aircraft will inherently lead to a potential increase in vehicle dynamic response to turbulence and wake vortices. Gust load alleviation control technology can improve ride qualities and reduce undesired structural dynamic loading on flexible airframes that could shorten aircraft service life. Gust load alleviation control technology can be either reactive or predictive. In a traditional reactive control framework, flight control systems can be designed to provide sufficient aerodynamic damping characteristics that suppress vehicle dynamic response as rapidly as possible upon a turbulence encounter. There is a trade off, however, between increased damping for mode suppression and command-following objectives of a flight control system. Large damping ratios, while desirable for mode suppression, may result in poor flight control performance.

Predictive control can provide a novel gust load alleviation strategy for future aircraft design with lightweight flexible structures. Novel look-ahead sensor technology can measure or estimate turbulent intensity to provide such information to a predictive gust load alleviation control system which in turn would dynamically reconfigure flight control surfaces as an aircraft enters a turbulent atmospheric region. Technology development of predictive gust load alleviation control may include the following:

- Novel sensor technology for Optical Air Data Systems based on LIDAR or other novel detection methods that can measure near-field air turbulent velocity components directly in front of an aircraft in the order of one-body length scale to provide nearly instantaneous predictive capability to significantly improve the effectiveness of a gust load alleviation control system.
- Predictive gust load alleviation control technology that can reliably reconfigure flight control surfaces dynamically based on the sensor information of the near-field turbulence to mitigate the vehicle structural dynamic response upon a turbulence encounter. The predictive control strategies should be cognizant of potential adverse effects due to potential latency issues that can counteract the objective of gust load alleviation, or potential structural mode interactions due to control input signals that may contain frequencies close to the natural frequencies of the airframe.

Modular and Distributed Control for Propulsion Systems

Modular and flexible control architecture for propulsion systems is an essential technology, which will enable the full realization of turbine engine system performance. Distributed technology can alleviate the thermal constraints on engine control electronics by improving tolerance to elevated temperature and creating opportunities for relocating electronics to a more compatible environment. It will enable the implementation of more complex control law, paving the way for further integration of performance-enhancing control for reduced fuel burn, lower emissions, and operability. Directly, distributed control will reduce engine system weight. This is a multi-disciplinary research area involving high temperature electronics, sensing and actuation, control system integration, and engine system stability.

A2.08 Aircraft Systems Analysis, Design and Optimization
Lead Center: LaRC
Participating Center(s): ARC, GRC

One of the approaches to achieve the NASA Fundamental Aeronautics Program goals is to solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration. The needs to meet this approach can be defined by four general themes:

- Design Environment Development;
- Variable Fidelity, Physics-Based Design/Analysis Tools;
- Technology Assessment and Integration; and
- Evaluation of Advanced Concepts.

Current interdisciplinary design/analysis involves a multitude of tools not necessarily developed to work together, hindering their application to complete system design/analysis studies. Multi-fidelity, multi-disciplinary optimization frameworks, such as Numerical Propulsion System Simulation (NPSS), have been developed by NASA but have limited capabilities to simulate complete vehicle systems. Solicited topics are aligned with these four themes that will support this NASA research area.

Design Environment Development
Technology development is needed to provide complex simulation and modeling capabilities where the computer science details are transparent to the engineer. A framework environment is needed to provide a seamless integration environment where the engineer need not be concerned with where or how particular codes within the system level simulation will be run. Interfaces and utilities to define, setup, verify, determine the appropriate resources, and launch the system simulation are also needed.

Research challenges include the engineering details needed to numerically zoom (i.e., numerical analysis at various levels of detail) between multi-fidelity components of the same discipline, as well as, multi-discipline components of the same fidelity. A major computer science challenge is developing boundary objects that will be reused in a wide variety of simulations.

Proposals will be considered that enable coupling differing disciplines, numerical zooming within a single discipline, deploying large simulations, and assembling and controlling secure or non-secure simulations.

Variable Fidelity, Physics-Based Design/Analysis Tools
An integrated design process combines high-fidelity computational analyses from several disciplines with advanced numerical design procedures to simultaneously perform detailed Outer Mold Line (OML) shape optimization, structural sizing, active load alleviation control, multi-speed performance (e.g., low takeoff and landing speeds, but efficient transonic cruise), and/or other detailed-design tasks. Current practice still widely uses sequential, single-discipline optimization, at best coupling low-fidelity modeling of other relevant disciplines during the detailed design phase. Substantial performance improvements will be realized by developing closely integrated design procedures coupled with highest-fidelity analyses for use during detailed-design. Design procedures must enable rapid determination of sensitivities (gradients) of a design objective with respect to all design variables and constraints, choose search directions through design space without violating constraints, and make appropriate changes to the vehicle shape (ideally both external OML shape and internal structural element size). Solicitations are

for integrated design optimization tools that find combinations of design variables from more than one discipline and can vary synergistically to produce superior performance compared to the results of sequential, single-discipline optimization or repeated cut-and-try analysis.

Technology Assessment and Integration
Improved analysis capability of integrated airframe and propulsion systems would allow more efficient designs to be created that would maximize efficiency and performance while minimizing both noise and emissions. Improved integrated system modeling should allow designers to consider trade-offs between various design and operating parameters to determine the optimum design for various classes of subsonic fixed wing aircraft ranging from personal aircraft to large transports. The modeling would also be beneficial if it had enough fidelity to enable it to analyze both conventional and unconventional systems. Current analysis tools capable of analyzing integrated systems are based on simplified physical and semi-empirical models that are not fully capable of analyzing aircraft and propulsion system parameters that would be required for new or unconventional systems.

Analysis tools are solicited that are capable of analyzing new and unconventional aircraft and propulsion integrated systems. These include: (1) New combustor designs, alternate fuel operation, and the ability to estimate all emissions, and (2) Noise source models (e.g., fan, jet, turbine, core and airframe components). Analyses tools that are scalable, especially to small aircraft, are desired.

Evaluation of Advanced Concepts
Conceptual design and analysis of unconventional vehicle concepts and technologies is needed for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts. This capability will enable "virtual expeditions through the design space" for multi-mission trade studies and optimization. This will require an integrated variable fidelity concept design system. The aerospace flight vehicle conceptual design phase is, in contrast to the succeeding preliminary and detail design phases, the most important step in the product development sequence, because of its predefining function. However, the conceptual design phase is the least well understood part of the entire flight vehicle design process, owing to its high level of abstraction and associated risk, its multidisciplinary design complexity, its permanent shortage of available design information, and its chronic time pressure to find solutions. Currently, the important primary aerospace vehicle design decisions at the conceptual design level (e.g., overall configuration selection) are still made using extremely simple analyses and heuristics. An integrated, variable fidelity system would have large benefits. Higher fidelity tools enabling unconventional configurations to be addressed in the conceptual design process are solicited.

A2.09 Rotorcraft
Lead Center: ARC
Participating Center(s): GRC, LaRC

The challenge of the Subsonic Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop validated physics-based multidisciplinary design-analysis-optimization tools for rotorcraft, integrated with technology development, enabling rotorcraft with advanced capabilities to fly as designed for any mission. Technologies of particular interest are as follows:

Experimental Capabilities: Instrumentation and Techniques for Rotor Blade Measurements
Instrumentation and measurement techniques are encouraged for assessing scale rotor blade boundary layer state (e.g., laminar, transition, turbulent flow) in simulated hover and forward flight conditions, measurement systems for large-field rotor wake assessment, fast-response pressure sensitive paints applicable to blade surfaces, and methods to measure the rotor tip path plane angle of attack, lateral and longitude flapping, and shaft angle in flight and in the wind tunnel. Very low airspeed measurement systems for flight vehicles.

Acoustics: Interior and Exterior Rotorcraft Noise Generation, Propagation and Control
Interior noise topics of interest include, but are not limited to, prediction and/or experimental methods that enhance the understanding of noise generation and transmission mechanisms for cabin noise sources (e.g., power-train noise), active and combined active/passive methods to reduce cabin noise, and novel structural systems or materials to reduce cabin noise without an excessive weight penalty. Exterior noise topics of interest include, but are not limited to, noise prediction and/or experimental methods that address the understanding of issues such as noise generation, propagation, and control. These methods may address topics such as novel or drastically improved source noise prediction methods, novel or drastically improved noise propagation methods (e.g., through the atmosphere), novel or drastically improved experimental techniques (e.g., wind tunnel testing methods, flight testing of noise abatement paths and/or maneuvering acoustics, etc.) to understand and/or control noise sources and their impact on the community. Methods should address one or more of the major noise components such as: harmonic noise, broadband noise, blade-vortex interaction noise, high-speed impulsive noise, interactional noise, and/or low frequency noise (e.g., propagation, psychoacoustic effects, etc).

Rotorcraft Diagnostics and Condition Based Maintenance
Health management of rotorcraft power trains is critical. Predictive, condition-based maintenance improves safety, decreases maintenance costs, and increases system availability. Topics of interest include algorithm development, software tools and innovative sensor technologies to detect and predict the health and usage of rotorcraft dynamic mechanical systems in the engine and drive system. Automatic rotor imbalance detection and rotor smoothing is also of interest. Additionally, rotorcraft health management technologies can include, but are not limited, tools to: increase fault detection coverage and decrease false alarm rates; detect onset of failure, isolate damage, and assess damage severity; predict remaining useful life and maintenance actions required; integration of health monitoring information with maintenance processes and procedures; data management and automated techniques to acquire/process diagnostic information; system models, material failure models and correlation of failure under bench fatigue, seeded fault test and fielded data; data collection/management for analysis of operational data; in-flight pilot cueing and warning of impending catastrophic events.

Proposals on other rotorcraft technologies will also be considered as resources and priorities allow, but the primary emphasis of the solicitation will be on the above three identified technical areas.

A2.10 Propulsion Systems
Lead Center: GRC

This subtopic is divided into two parts. The first part is the Turbomachinery and Heat Transfer and the second part is Propulsion Integration.

Turbomachinery and Heat Transfer
There is a critical need for advanced turbomachinery and heat transfer concepts, methods and tools to enable NASA to reach its goals in the various Fundamental Aeronautics projects. These goals include drastic reductions in aircraft fuel burn, noise, and emissions, as well as an ability to achieve mission requirements for Subsonic Rotary Wing, Subsonic Fixed Wing, Supersonics, and Hypersonics Project flight regimes. In the compression system, advanced concepts and technologies are required to enable high stage loading and wider operating range while maintaining or improving aerodynamic efficiency. Such improvements will enable reduced weight and part count, and will enable advanced variable cycle engines for various missions. In the turbine, the very high cycle temperatures demanded by advanced engine cycles place a premium on the cooling technologies required to ensure adequate life of the turbine component. Reduced cooling flow rates and/or increased cycle temperatures enabled by these technologies have a dramatic impact on the engine performance.

Proposals are sought in the turbomachinery and heat transfer area to provide the following specific items:

- Advanced design concepts to enable increased high stage loading in single and multi-stage axial compressors while maintaining or improving aerodynamic efficiency and operability. Technologies are sought that would reduce dependence on traditional range extending techniques (such as variable inlet guide vane and variable stator geometry) in compression systems. These may include flow control techniques near the compressor end walls and on the rotor and stator blade surfaces. Technologies are sought to reduce turbomachinery sensitivity to tip clearance leakage effects where clearance to chord ratios are on the order of 5% or above.

- Advanced flow analysis tools to enable design optimization of highly loaded compression systems that can accurately predict aerodynamic efficiency and operability. This includes computer codes with updated models for losses, turbulence, and other models that can simulate the flow through turbomachinery components with advanced design features such as swept and bowed blade shapes, flow range extension techniques, such as flow control and transition control to maintain acceptable operability and efficiency.
- Novel turbine cooling concepts are sought to enable very high turbine cooling effectiveness especially considering the manufacturability of such concepts. These concepts may include film cooling concepts, internal cooling concepts, and innovative methods to couple the film and internal cooling designs. Concepts proposed should have the potential to be produced with current or forthcoming manufacturing techniques. The availability of advanced manufacturing techniques may actually enable improved cooling designs beyond the current state-of-the-art.
- Methods are sought to enable more efficient use of coolant air in the turbine through coolant flow modulation. These methods could consist of open-loop or closed-loop coolant flow modulation. Modulations could be high frequency with frequencies on the order of the turbine blade passing frequency or longer time scales on the order of engine thermal transients. Development of methods to measure turbine local and/or average surface temperatures to enable the closed-loop capability will be considered. Feedback control of the coolant flow rates and/or methods to produce modulation in actual turbine thermal environments are desired. Finally, a description of how the proposed technology will work in a vision modulated turbine cooling turbine system will be needed.

Propulsion Integration

Proposals for Propulsion Integration will address engine and engine integration topics as outlined in this section in support of the Fundamental Aeronautics Program.

One objective of the Subsonic Fixed Wing Project is to develop verified analysis capabilities for the key technical issues related to integrating embedded propulsion systems for "N+2" hybrid wing/body configurations. These key technical issues include: inlet technologies for distorted engine inflows related to embedded engines with boundary layer ingestion; fan-face flow distortion and its effects on fan efficiency and operability, noise, flutter stability and aeromechanical stress and life; wide operability of the fan and core with a variable area nozzle; issues related to the implementation of a thrust vectoring variable area nozzle; and duct losses related to long flow paths associated with embedded engines. Specifically, proposals are sought to provide advanced technology, prediction methods and tools. The supersonics project would like proposals to develop tools and propulsion technologies that will enable the design of high performance fans; high-efficiency, low-boom, and stable inlets; high-performance, low-noise exhaust nozzles; and intelligent sensors and actuators for supersonic aircraft. The supersonics project is interested in both computational and experimental research, aimed at evaluating and analyzing promising technologies as well as understanding the fundamental flow physics that will enable improved prediction methods.

A mission class of interest to the Hypersonics Project is the Reusable Airbreathing Launch Vehicle (RALV). The RALV mission was chosen to build on work started in NASA's Next Generation Launch Technology (NGLT) Program to provide new vehicle architectures and technologies to dramatically increase the reliability of future launch vehicles. The design of reusable entry vehicles that provide low-cost access to space is challenging in several technology areas. The development of hypersonic air-breathing propulsion systems and the integration of the propulsion system with the airframe impact vehicle performance and controllability and drive the need for an integrated physics-based design methodology.

For Propulsion Integration, topics will be solicited for design concepts and analysis tools that enable:

- Technologies and/or concepts to enable integrated, high-performance, lightweight supersonic inlets and nozzles that have minimal impact on an aircraft’s sonic boom signature.
- Technologies and/or concepts to enable high-pressure recovery, low distortion and low-weight subsonic diffusers.
- Practical, validated CFD models for flow control devices such as micro-ramps, vaned vortex generators, air jets, or synthetic jets.
- The reduction of system complexity of turbine-based combined-cycle propulsion systems.
- The rapid assessment of CFD solutions (e.g. automatically interpolating numerical solutions to the measurement locations, generating “metrics of goodness” for parameters of interest, etc.).
- Develop methodologies that provide installed propulsion performance, specifically nozzle conceptual level design/analysis methods, capable of addressing conventional and unconventional nozzle geometries. Geometries should be valid for subsonic, supersonic, and hypersonic flight applications. Documentation of methodologies should include: underlying theory and mathematical models, computational solution methods, source-code, validation data, and limitations.

TOPIC: A3 Airspace Systems

NASA's Airspace Systems Program (ASP) is investing in the development, validation and transfer of advanced innovative concepts, technologies and procedures to support the development of the Next Generation Air Transportation System (NextGen). This investment includes partnerships with other government agencies represented in the Joint Planning and Development Office (JPDO), including the Federal Aviation Administration (FAA) and joint activities with the U.S. aeronautics industry and academia. As such, ASP will develop and demonstrate future concepts, capabilities, and technologies that will enable major increases in air traffic management effectiveness, flexibility, and efficiency, while maintaining safety, to meet capacity and mobility requirements of NextGen. ASP integrates the two projects NextGen Concepts and Technology Development (CTD) and NextGen Systems Analysis Integration and Evaluation (SAIE), to directly address the fundamental research needs of NextGen vision in partnership with the member agencies of the JPDO. The CTD develops and explores fundamental concepts, algorithms, and air-borne and ground-based technologies to increase capacity and throughput of the national airspace system, to address demand-capacity imbalances, and achieve high efficiency in the use of resources such as airports, en route and terminal airspace. The SAIE Project is responsible for facilitating the Research and Development maturation of integrated concepts through evaluation in relevant environments, providing integrated solutions, characterizing airspace system problem spaces, defining innovative approaches, and assessing the potential system impacts and design ramifications of the program’s portfolio. Together, the projects will also focus NASA's technical expertise and world-class facilities to address the question of where, when, how and the extent to which automation can be applied to moving air traffic safely and efficiently through the NAS and technologies that address optimal allocation of ground and air technologies necessary for NextGen. Additionally, the roles and responsibilities of humans and automation influence in the ATM will be addressed by both projects. Key objectives of NASA's AS Program are to:

- Improve mobility, capacity, efficiency and access of the airspace system;
- Improve collaboration, predictability, and flexibility for the airspace users;
- Enable accurate modeling and simulation of air transportation systems;
- Accommodate operations of all classes of aircraft; and
- Maintain system safety and environmental protection.

A3.01 Concepts and Technology Development (CTD)
Lead Center: ARC
Participating Center(s): DFRC, LaRC

The Concepts and Technology Development (CTD) Project supports NASA Airspace Systems Program objectives by developing gate-to-gate concepts and technologies intended to enable significant increases in the capacity and efficiency of the Next Generation Air Transportation System (NextGen), as defined by the Joint Planning and Development Office (JPDO).

The CTD project develops and explores fundamental concepts, algorithms, and technologies to increase throughput of the National Airspace System (NAS) and achieve high efficiency in the use of resources such as airports, en route and terminal airspace. The CTD research is concerned with conducting algorithm development, analyses and fast-time simulations, identifying and defining infrastructure requirements, field test requirements, and conducting field tests.

Innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's CTD effort. The general areas of primary interest are:

Separation Assurance:
- Automated separation assurance concepts, both airborne and ground-based

Trajectory-based operations for surface, terminal area, and en route:
- Gate-to-gate trajectory-based operations concepts, technologies, and algorithms
- Trajectory design and conformance monitoring

Dynamic Airspace Configuration in En route and Terminal Airspace:
- Generic airspace operations, including human factors considerations and tool development to support a generic airspace concept
- Airspace design for NextGen operations
- Tubes concept development, including how to address equipage and dynamically change tubes

Methods and Methodologies:
- Algorithms and methods to satisfy multi-criteria design needs in air traffic management
- Integrated hardware/software tool for accelerating general optimization tasks

Unmanned Air Vehicles (UAVs):
- Methods to analyze the impact of UAVs in the NAS
- Human factors issues in UAV operations in the NAS

4D Weather Cube:
- Requirements, architecture and research required to achieve a Single Authoritative Source (SAS) for weather data that can be used in future ATM simulations. Phase II efforts would deliver prototype(s) of a cube for evaluation and NASA ownership and retention

NextGen Data Paths:
- Communication air-ground architectures utilizing JPDO envisioned NextGen Net-Centric Operations capabilities. Architectures would be used to increase fidelity of NextGen ATM simulations beyond current ADS(B) based modeling

Other:
- Derived sensor information from both ground-based radar trackers and ADS-B information for derivation of airspeed and local wind information

A3.02 Systems Analysis Integration Evaluation (SAIE)
Lead Center: LaRC
Participating Center(s): ARC, DFRC

In support of the program objectives, the major goal of the NextGen-SAIE Project is to enable the transition of key capacity and efficiency improvements to the NAS. Since many aspects of the NAS are unique to specific airport or airspace environments, demand on various parts of the NAS is not expected to increase equally as system demand grows. SAIE will provide systems level analysis of the NAS characteristics, constraints, and demands such that a suite of capacity-increasing concepts and technologies for system solutions are enabled and facilitated. The technical objectives in support of this goal are the following:

- Integration, evaluation, and transition of more mature concepts and technologies in an environment that faithfully emulates real-world complexities.
- Interoperability research and analysis of ASP technologies across ATM functions is performed to facilitate integration and take ASP concepts and technologies to higher Transition Readiness Level (TRL).
- Analysis is conducted on the program's concepts to identify the system benefits or impacts. System level analysis is conducted to increase understanding of the characteristics and constraints of airspace system and its' domains.

Inherent to the ASP approach is the integration of airborne solutions within the overall surface management optimization scheme.

In order to meet these challenges, innovative and technically feasible approaches are sought to advance technologies in relevant research areas. Specific research topics include:

Atmospheric Hazards
- Common situational awareness between flight deck and ground automation systems for weather avoidance
- Integrating weather products into decision support tools
- Airspace capacity estimation in presence of weather
- Development of wake vortex detection and hazard metric tools

System Level Concepts Development
- System safety assessment, graceful degradation and recovery

Trajectory Modeling and Uncertainty Prediction
- Analysis of growth of uncertainty as a function of look-ahead time on different phases of flight
- Development of methods to determine, for a target concept/system, the TP accuracy needed to be able to achieve the minimum acceptable system/concept performance as well as identify sources of errors
- Development of methods for managing/reducing trajectory uncertainty to meet specified performance requirements
- Identify critical aircraft behavior data for exchange for interoperability

Roles and Responsibilities in NextGen
- Means to measure controller and pilots workloads in order to optimize air-ground functional allocation
- Means to measure controller and pilots workloads in order to optimize human-automation functional allocation

Modeling and Simulation
- Developing probabilistic or dynamic methods of calculating airspace workload capacity

TOPIC: A4 Aeronautics Test Technologies

The Aeronautics Test Program (ATP) ensures the long term availability and health of NASA's major wind tunnels/ground test facilities and flight operations/test infrastructure that support NASA, DoD and U.S. industry research and development (R&D) and test and evaluation (T&E) requirements. Furthermore, ATP provides rate stability to the aforementioned user community. The ATP facilities are located at four NASA Centers made up of the Ames Research Center, Dryden Flight Research Center, Glenn Research Center and Langley Research Center. Classes of facilities within the ATP include low speed, transonic, supersonic, and hypersonic wind tunnels, hypersonic propulsion integration test facilities, air-breathing engine test facilities, the Western Aeronautical Test Range (WATR), support and test bed aircraft, and the simulation and loads laboratories. A key component of ensuring a test facility's long term viability is to implement and continually improve on the efficiency and effectiveness of that facility's operations along with developing new technologies to address the nation’s future aerospace challenges. To operate a facility in this manner requires the use of state-of-the-art test technologies and test techniques, creative facility performance capability enhancements, and novel means of acquiring test data. NASA is soliciting proposals in the areas of instrumentation, test measurement technology, test techniques and facility development that apply to the ATP facilities to help in achieving the ATP goals of sustaining and improving our test capabilities. Proposals that describe products or processes that are transportable across multiple facility classes are of special interest. The proposals will also be assessed for their ability to develop products that can be implemented across government-owned, industry and academic institution test facilities. Additional information is available at http://www.aeronautics.nasa.gov/atp/index.html.

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

NASA is seeking highly innovative and commercially viable test measurement technologies, test techniques, and facility performance technologies that would increase efficiency, capability, productivity for ground test facilities.
The types of technology solutions sought, but not limited to, are: skin friction measurement techniques; improved flow transition and quality detection methodologies; non-intrusive measurement technologies for velocity, pressure, temperature, and strain measurements; force balance measurement technology development; and improvement of current cutting edge technologies, such as Particle Based Velocimetry (LDV, PIV), Pressure Sensitive Paint (PSP), and focusing acoustic measurements that can be used more reliably in a production wind tunnel environment. Instrumentation solutions used to characterize ground test facility performance are being sought in the area of aerodynamics performance characterization (flow quality, turbulence intensity, mach number measurement, etc.). Of interest are subsonic, transonic, supersonic, and hypersonic speed regimes. Specialized areas may include cryogenic conditions, icing conditions, and rotating turbo machinery. Proposals that are applicable specifically to the ATP facilities (see http://www.aeronautics.nasa.gov/atp) and across multiple facility classes are especially important. The proposals will also be assessed for their ability to develop products that can be used in other aerospace ground test facilities.

A4.02 Flight Test Techniques and Measurement Technology
Lead Center: DFRC
Participating Center(s): ARC, GRC

NASA’s aeronautical flight test capabilities are reliant on a combination of both ground and flight research facilities. By using state-of-the-art test techniques, measurement technologies, and data acquisition systems to enhance and modernize these test facilities, NASA will be able to meet the needs of cutting-edge flight research and development programs for the nation.

Proposals submitted to this subtopic should address innovative methods and advanced technologies that would improve the health and test capabilities of NASA’s ground and flight facilities. Flight regimes of interest range from atmospheric low-speed, to high-altitude long-endurance to supersonic, to hypersonic and access-to-space. Ground support facilities include: the Western Aeronautical Test Range (WATR), Flight Loads Laboratory (FLL), and laboratories that conduct simulation and verification & validation (V&V) of flight systems including hardware-in-the-loop testing. Flight facilities include both piloted and unmanned test aircraft with various ranges of flight performance and capable of operating over a broad span of flight regimes.

NASA is committed to improve the ATP facility effectiveness to support and conduct flight research. This includes developing test techniques that improve the control of both ground-based and in-flight test conditions, expanding measurement and analysis methodologies, and improving test data acquisition and management with sensors and systems that have fast response, low volume, minimal intrusion, and high accuracy and reliability.

NASA requires improved measurement and analysis techniques for acquisition of real-time, in-flight data used to determine aerodynamic, structural, flight control, and propulsion system performance characteristics. These data will also be used to provide test conductors the information to safely expand the flight and test envelopes of aerospace vehicles and components. This requirement includes the development of sensors to enhance the monitoring of test aircraft safety and atmospheric conditions during flight testing.

Also of interest to NASA are innovative methods and analysis techniques to improve the correlation of data from ground test to flight test.

TOPIC: A5 Integrated System Research Project (ISRP)

The Integrated Systems Research Program (ISRP), a new program effort that began in FY10, will conduct research at an integrated system-level on promising concepts and technologies and explore, assess or demonstrate their benefits in a relevant environment. The integrated system-level research in this program will be coordinated with on-going long-term, foundational research within the three other research programs, as well as efforts within other Federal Government agencies. As the NextGen evolves to meet the projected growth in demand for air transportation, researchers must address the national challenges of mobility, capacity, safety, and energy and the environment in order to meet the expected growth in air traffic. In particular, the environmental impacts of noise and emissions are a growing concern and could limit the ability of the system to accommodate growth. ISRP will explore and assess new vehicle concepts and enabling technologies through system-level experimentation to simultaneously reduce fuel burn, noise and emissions, and will focus specifically on maturing and integrating technologies in major vehicle systems/subsystems for accelerated transition to practical application.

ISRP is comprised of one project - the Environmentally Responsible Aviation (ERA) Project.

Environmentally Responsible Aviation (ERA)
The project's primary goal is to select vehicle concepts and technologies that can simultaneously reduce fuel burn, noise and emissions; it contains three subprojects: Airframe Technology, Propulsion Technology and Vehicle Systems Integration.

- Testing unconventional aircraft configurations that have higher lift to drag ratio, reduced drag and reduced noise around airports;
- Achieving drag reduction through laminar flow;
- Developing composite (nonmetallic) structural concepts to reduce weight and improve fuel burn; and
- Testing advanced, fuel-flexible combustor technologies that can reduce engine NOx emissions.

A5.01 Laminar Flow Ground Testing
Lead Center: LaRC

Laminar flow enabling technologies are required to allow the Environmentally Responsible Aviation (ERA) Project to simultaneously achieve its aggressive fuel burn, noise, and emissions goals for the N+2 timeframe. To achieve these breakthrough achievements related to drag reduction, the system level requirements for viable aircraft configurations utilizing laminar flow technologies must be established. Although numerous flight tests have proven the aerodynamic possibilities, such flight tests are much too expensive to allow for extensive parametric exploration and optimization to reduce the risks. Therefore, one of the key contributions needed to further advance the technology readiness level of laminar flow technologies integrated into vehicle concepts is the ability to conduct ground-based testing at relevant chord and unit Reynolds numbers. To achieve this need, the ERA Project plans to use the National Transonic Facility (NTF). The NTF is a pressurized, cyrogenic wind tunnel capable of approximately 45 million chord Reynolds numbers at transonic speeds.

To date, testing has been done on a Natural Laminar Wing Model with mixed results. The preliminary results indicate contaminants in the flow path of the wind tunnel contributed to early boundary layer transition on the model. These contaminants are suspected to be a combination of minute frost particles, oil droplets, and dust. Based on the surface quality requirements for laminar flow testing at the conditions of the NTF contaminants as small as a few microns are sufficient to disrupt the stability of the boundary layer.

This solicitation seeks proposals to develop:

Wind tunnel circuit cleaning techniques/processes to remove oil and dust contaminates from the NTF and other similar facilities. Because of the cryogenic testing requirements for dry test circuits water-based approaches are discouraged. The proposed process needs to demonstrate that particles and oil at the micron level can be sufficiently captured and removed from the test environment.

Methods to polish, clean, and protect the surface quality of a wind tunnel model leading edge to sufficient levels to enable successful laminar flow testing at the NTF.

A5.02 Open Rotor Installed Thrust
Lead Center: DFRC

NASA's Environmentally Responsible Aviation (ERA) project seeks simultaneous, aggressive reductions in noise, emissions and fuel burn for transport category aircraft in the N+2 timeframe. A significant reduction in Specific Fuel Consumption (SFC) will be required to meet the goal of a 50% reduction in fuel burn.

One path that engine manufactures are proposing to meet the required SFC improvements is a return to the open rotor technology first tested in the 1980's. Many challenges to using open rotors on future generations of aircraft exist, both from the design and operations standpoint. One of the design challenges of the open rotor is determining the in-flight installed thrust of the open rotor on the aircraft.

Current practice with turbofans involves an extensive series of ground tests that determine corrections for the installed engine thrust relative to its measured uninstalled configuration. Currently, there is no acceptable method that has been proven to duplicate this for open rotors. Additionally, there is currently no way to directly measure thrust during flight on an installed engine for this class of aircraft.

This solicitation seeks proposals to develop and validate:

Develop methods and techniques to correct ground tested thrust measurements for installed, in-flight effects of an open rotor propulsion system.

Develop methods and conceptual designs for hardware that would allow for the direct measurement of thrust in flight, throughout the full flight envelope. This measurement system must be robust enough to withstand the full flight and maneuvering envelop used during flight testing of a new aircraft while being precise enough to measure the thrust at all power settings.

A5.03 Variable Cycle Propulsion
Lead Center: GRC

Proposals for the variable cycle propulsion subtopic will address engine and engine integration topics as outlined in this section in support of the Integrated System Research Program.

Variable cycle propulsion concepts can potentially help the Environmentally Responsible Aviation (ERA) Project reach its aggressive fuel burn, noise, and emissions goals for the N+2 timeframe by taking advantage of engine and engine/airframe integration concepts that allow the system to optimize over the entire flight envelope. For example, a variable cycle concept may allow the aircraft system to fly efficiently at multiple flight speeds or altitudes, shift noise and emissions production to less critical phases of the mission, or allow for more efficient operation within airspace constraints.

Proposals are solicited that address this opportunity by developing system analysis tools and applying them to variable cycle engine concepts that can address the mission fuel burn, noise, and emissions goals for the ERA Project. Proposed efforts should identify one or more specific variable cycle concepts and assess their impact upon all three ERA metrics (fuel burn, noise, and emissions) for at least one representative long range, subsonic transport, passenger or cargo mission profile (60,000 to 100,000 lbs equivalent payload carried for 6000 nmi, at approximately 0.78-0.85 Mach number). System analysis tools should be developed and employed to adequately capture the combined effects of engine architecture concepts and their integration into airframe designs envisioned for the N+2 timeframe. Specific enabling technologies for these variable cycle system concepts should be identified and prioritized for future development. Such enabling technologies may include, but are not limited to concepts related to engine inlet, fan, compressor, combustor, turbine, nozzle components and their integration.

9.1.2 EXPLORATION SYSTEMS

The Exploration Systems Mission Directorate (ESMD) develops capabilities and supporting research and technologies that will make sustained human and robotic exploration possible. The directorate also focuses on the human element of exploration by conducting research to ensure astronaut explorers are safe, healthy and can perform their work during long-duration space exploration.

ESMD focuses on technologies and capabilities enabling human spaceflight, ultimately expanding a human presence throughout the solar system. Missions will venture beyond low-Earth orbit to multiple destinations, including the moon, near-Earth objects, Lagrange points, and Mars and its moons.

To create the new capabilities and contribute to the knowledge that is required for humans to explore to these destinations ESMD is responsible for several key areas including:

- Conducting technology development and demonstrations to reduce cost and prove required capabilities for future human exploration
- Developing exploration precursor robotic missions to multiple destinations to cost-effectively scout human exploration targets
- Increasing investments in human research to prepare for long journeys beyond Earth
- Developing U.S. commercial human spaceflight capabilities.

More information is available at http://www.nasa.gov/exploration.

TOPIC: X1 In Situ Resource Utilization

The purpose of In-Situ Resource Utilization (ISRU) is to harness and utilize resources at the site of exploration to create products and services, which can enable and significantly reduce the mass, cost, and risk of near-term and long-term space exploration. the ability to make propellants, life support consumables, fuel cell reagents, and radiation shielding can significantly reduce the cost, mass, and risk of sustained human activities beyond Earth. The ability to modify the landscape for safer landing and transfer of payloads, creation of habitat and power infrastructure, and extraction of resources for construction, power, and in-situ manufacturing can also enable long-term, sustainable exploration of the solar system. Since ISRU can be performed wherever resources may exist, both natural and discarded, ISRU systems will need to operate in a variety of environments and gravitations. Also, because ISRU systems and operations have never been demonstrated before in missions, it is important that ISRU concepts and technologies be evaluated under relevant conditions (gravity, environment, and vacuum) as well as anchored through modeling to regolith/soil and environmental conditions. While the discipline of ISRU can encompass a large variety of different concept areas, resources, and products, the ISRU Topic has been divided into two subtopics dealing with the fundamental difference in technologies associated with solid in-situ material handling and processing versus gaseous and gaseous/solid processing. An attempt was made to minimize the potential overlap in technologies and processes between the two subtopics.

X1.01 Regolith/Soil Transfer, Handling, and Processing of Extraterrestrial Material
Lead Center: JSC
Participating Center(s): GRC, KSC, MSFC

The ability to extract resources from regolith and soil on the Moon, Mars, and Asteroids/Phobos can completely change robotic and human mission architectures through the extraction of oxygen, metals, and volatiles (water, hydrogen, etc.) for propulsion, life support, power, and in-situ manufacturing. Also, materials and resources at the site of exploration can also be used to protect crew and hardware and allow for alternatives for construction of structures and energy generation and storage to systems brought from Earth. By using in-situ materials and resources, mission mass and risk can be reduced. Proposals of interest are for concepts that will handle and process lunar, Mars, and asteroid/Phobos materials.

While NASA has focused on oxygen extraction from lunar regolith for the last several years, this subtopic is expanded to consider other techniques for oxygen and metal extraction, consider other planetary soil feedstock (Mars and asteroid/Phobos materials), consider concepts for removal of volatiles/water from regolith/soil feedstock, and begin consideration of early in-situ construction and energy related activities. The subtopic is seeking proposals for technologies, components, and subsystems that can be integration into existing and future system development and demonstration efforts so that critical functions and operations can be evaluated at the system level. Proposals must consider gravity, physical, mineral, and volatile/water properties and characteristics of the material/resource. Concepts that can operate in low-gravity (1/6-g and 3/8-g) and micro-gravity as well as multiple resources are of greater interest. Designs that are compatible for subsequent 1/6 g flight experiments and ground vacuum experiments are also of greater interest. The subtopic is asking for proposals in three areas of particular interest:

Regolith/Soil Transfer and Handling

- Long-life, light-weight, and minimum consumable technologies to move feedstock material from the surface or a collection hopper to processing reactors (at least 3m); High separation efficiency gas/solid particle separation techniques and regenerable particle filters
- Granular materials mixing and size separation for reactor feedstock conditioning: remove material > 0.5 cm diameter before dumping into storage bin during excavation operation for oxygen extraction from regolith
- Granular flow computer models, devices, and instruments to evaluate material flow and manipulation under low and micro-gravity flight and ground vacuum experimental conditions
- Mineral beneficiation concepts to separate iron oxide-bearing material from bulk regolith; up to 20 kg/hr based on hydrogen reduction

Regolith/Soil Processing To Extract Resources and Products of Interest

- Regolith/soil valve/seal concepts for processing systems with no gas leakage after 1000's of operating cycles with material. For processes that require elevated temperatures, thermal isolation or minimum heat loss is required
- Regolith/soil processing reactor concepts for extracting volatiles and water/ice
- Regolith/soil processing reactor concepts for extracting metals through electrolysis and/or metal/waste/salt removal and separation techniques.
- High temperature (≥1000 C), high efficiency insulation for regolith/soil processing reactors
- High temperature (≥1000 C) pressure sensors and instruments for process control and performance assessment
- Alternative thermal, chemical, and/or biological processing concepts for oxygen (and potentially metal) extraction from regolith/soil besides

Hydrogen Reduction and Carbothermal Reduction Processes

- Light-weight, deployable solar concentrator concepts and solar energy transfer methods into regolith/soil processing reactors
- Low energy loss methods for redirecting solar energy from concentrators and fiber optic cables to allow multiple users in series

Regolith/Soil Processing for Protection, Construction, and Energy

- Thermal energy storage and utilization using bulk or processed regolith
- Techniques for hardening or modifying in-situ materials so that landing pads and roads can be constructed to prevent landing plume debris damage and wear on surface mobility platforms

X1.02 Gas, Liquid, and Solid Processing to Produce Oxygen and Fuels from In-Situ Resources
Lead Center: JSC
Participating Center(s): ARC, GRC, KSC

Besides regolith/soil, atmospheric resources as well as discarded materials such as trash and crew waste (after life support system processing) are in-situ resources that provide synergistic opportunities to produce oxygen and fuels at the site of exploration. Besides covering the reactant and product separation and recycling aspects for oxygen extraction from regolith covered in previous solicitations, this subtopic has been expanded to also include Mars atmospheric collection and separation, and hydrocarbon fuel production from trash and Mars atmospheric feedstock. The subtopic is seeking proposals for technologies, components, and subsystems that can be integration into existing and future system development and demonstration efforts so that critical functions and operations can be evaluated at the system level. The subtopic is asking for proposals in three areas of particular interest:

Solid/Gas Processing to Support Oxygen and Fuel Production

- Gas Separators for lunar oxygen extraction from regolith that provide low pressure drop separation of the system and product gas streams from impurities (e.g. HCl, HF, H_2S, SO_2); the process should be regenerable and the output contaminant concentration should be less than 50 ppb
- Hydrogen gas pumps with rates (up to 6 scfm) for recirculation and pneumatic transport
- Carbon dioxide collection and separation from Mars atmosphere
- High efficiency carbon dioxide/carbon monoxide separation concepts with high quality carbon dioxide produced.
- Long-life carbon dioxide electrolysis/dissociation into carbon monoxide and oxygen concepts with high conversion efficiency at pressures greater than or equal to 1 bar.

Water Processing

- Water/gas separators that use the space environment for water condensation/separation with minimal energy usage; concepts that can operate in both low-gravity (1/6-g and 3/8-g) and micro-gravity are of greatest interest
- Removal of dissolved ions in water by methods other than de-ionization resins to meet water electrolysis purity requirements (minimum resistivity of 1M-Ohms-cm). Ions of interested are dissolved metal ions (Fe, Cr, Co, Ni, Zn) at concentration of 0.01% and dissolved anions (Cl, F, S) at concentrations of 0.01%-2%. The process should be regenerable, minimize consumables, and minimize water loss.
- Contaminate resistant, high temperature water electrolysis concepts

Trash/Waste Processing for Fuel Production

- Processing concepts for production of carbon monoxide, carbon dioxide, water, and methane from plastic trash and dried crew solid waste. Proposals must define use of solar or electrical energy during processing, and any reagents/consumables; recycling schemes for reactants/reagents used in the processing should be evaluated.
- Methods for waste/trash transfer and handling before and after processing.

TOPIC: X2 Advanced Propulsion

Human Exploration require advances in propulsion to get to the moon, Mars, and beyond. A major thrust of this research and development activity will be related to space launch propulsion technologies. This effort will include first stage engine development, non-toxic in-space engine demonstrations, and foundational propulsion research in areas such as new or largely untested propellants that can result in more capable and less expensive future rockets. NASA is interested in conducting foundational research to study the requirements and potential designs for advanced high-energy in-space propulsion systems to support exploration and to reduce travel time. These technologies could include nuclear propulsion and electric propulsion.

X2.01 Earth-to-Orbit Propulsion
Lead Center: MSFC
Participating Center(s): GRC, JPL, KSC, SSC

NASA is interested in innovative Earth-to-Orbit (ETO) propulsion systems and component technologies, as well as design and analysis tools used to support the assessment of the technical viability of those systems. Next generation launch systems will require propulsion systems that deliver high thrust-to-weight ratios, increased trajectory averaged specific impulse, reliable overall vehicle systems performance, low recurring costs, and other innovations required to achieve cost and crew safety goals.

Proposals should address technical issues related to Earth-to-Orbit (ETO) LOX/Hydrocarbon engines and LOX/Hydrogen second stage engines including engine and main propulsion systems design and integration, turbomachinery, combustion devices, valves, actuators, and ducts. Areas of specific interest for technology advancement and innovations include the following:

- Advancements in design and analysis tools applicable to assessment of ETO propulsion systems including engine systems, turbomachinery, valves, and combustion device concepts. Of particular interest are design and analysis tools that provide improved understanding and quantification of component, subsystem, and system operating environments and that significantly enhance the overall systems engineering evaluation of potential ETO propulsion concepts. Examples include low and high fidelity tools suitable for component and parameter sensitivity analysis and optimization, dynamic environment prediction, quantification of system benefits to changes.

- Improved propulsion systems stability prediction analysis and design tools, along with stability aid concepts and demonstration of approaches (i.e., rotordynamic coefficients, turbopump cavitation, instabilities, combustion stabilities, structural-acoustic, propellant management, and fluid dampers.)
- Innovative tools for predicting the complex fluid and structural interactions within rocket nozzles and experimental methods and data for validating these tools. Specific areas of interest include nozzle side loads induced by nozzle flow separation during engine start and shutdown transients and the effect of fluctuating pressure during engine main stage.
- Improvements to tools that predict the environments in and around the engine during booster operation.
- Data to validate the accuracy of high fidelity design and analysis tools used for the prediction of internal rocket engine environments.
- Design concepts that improve performance, reduce cost, reduce weight or improve reliability of the propellant feed systems, valves. Of particular interest are:
    - Design concepts for high power density turbines,
    - Design concepts for low net positive suction pressure pumps,
    - Design concepts for low cost, reliable valves and their actuation system,
    - Demonstration of robust bearing design concepts for large, high speed rotors,
    - Identification and demonstration of high strength materials that are resistant to combustion in a high pressure, oxygen rich environment.

X2.02 Non-Toxic In-Space Propulsion
Lead Center: GRC
Participating Center(s): JPL, JSC, MSFC

This solicitation intends to examine a range of key technology options associated with cryogenic and non-toxic storable propellant space engines. Non-toxic engine technology is desired for use in lieu of the currently operational NTO/MMH engine technology. Safety concerns with toxic propellants drive mission planners to the use of more costly propulsion modules that are fueled and sealed on the ground. Non-toxic engine technologies could range from reaction control class of 25-1000 lbf to main engines of up to 60,000 lbf with both pump fed or pressure fed systems. Specific technologies of interest to meet proposed engine requirements include:

- Non-toxic bipropellant or monopropellants that meet performance targets (as indicated by high specific impulse and high specific impulse density) while improving safety and reducing handling operations as compared to current state-of-the-art storable propellants.
- Low-mass propellant injectors that provide stable, uniform combustion over a wide range of propellant inlet temperature and pressure conditions.
- High temperature materials, coatings and/or ablatives for injectors, combustion chambers, nozzles, and nozzle extensions.
- Combustion chamber thermal control technologies such as regenerative, transpiration, swirl or other cooling methods, which offer improved performance and adequate chamber life.
- Technologies are also solicited that enable deep-throttling turbopumps to operate at off-design flow coefficients while eliminating flow instabilities such as cavitating surge.
- Highly-reliable, long-life, fast-acting propellant valves that tolerate long duration space mission environments with reduced volume, mass, and power requirements is also desirable.
- Cryogenic instrumentation such as pressure and temperature sensors that will operate for months/years instead of hours.

Note to Proposer: Subtopic S3.04 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.04.

X2.03 Nuclear Thermal Propulsion
Lead Center: GRC
Participating Center(s): JPL, MSFC

NASA is interested in the development of critical technologies for first in-space applications of solid core nuclear thermal propulsion (NTP) systems for use in future exploration missions. For short round trip missions to MARS, NTP systems may be enabling by helping to reduce launch mass to reasonable values and by also increasing the payload delivered for Mars exploration missions.

Preliminary solid core NTP system concepts could be based on a high thrust/high ISP (~850-950s) NTP system that would use a fission reactor with U-235 fuel as its source of thermal energy. During the short primary propulsion maneuvers of a typical conceptual mission, large quantities of thermal power (100's of MWt) would be produced within the NTP system and removed using liquid hydrogen propellant that is pumped through the engine's reactor core. The superheated hydrogen gas is then exhausted out the engine's nozzle to generate thrust. Representative ranges of engine performance include: (1) hydrogen exhaust temperatures ~2500 – 2900K, (2) propellant flowrates ~7 – 13 kg/s, (3) chamber pressures ~500 – 1500 psi, and (4) nozzle expansion area ratios ~200:1 – 500:1.

Proposals are sought to further improve factors contributing to safety, performance, reliability, and life as well as reduce projected weight and costs for the first in-space NTP systems, subsystems, and components beyond that in previously achieved ground test systems. Proposals are solicited in the following key technology/concept areas:

- High temperature, low burn-up carbide- and ceramic-metallic (cermet)-based nuclear fuels with improved coatings and /or claddings to reduce fission product gas release into the engine's hydrogen exhaust stream;
- Reliable, high temperature materials, fabrication techniques, and concepts for non-reactor portions of NTP systems;
- Light-weight, multi-use shielding materials and designs;
- High temperature, 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 desired;
- Long life, lightweight, reliable hydrogen turbopump designs and technologies;
- Lightweight, long life, heat flux thrust chambers, regenerative-cooled nozzles and radiation-cooled skirt extensions that are compatible with hot hydrogen;
- Radiation tolerant materials compatible with above engine subsystem applications and operating environments.

X2.04 Electric Propulsion Systems
Lead Center: GRC
Participating Center(s): JPL, MSFC

The goal of this subtopic is to develop innovations in high-power (100 kW to MW-class) electric propulsion systems. High-power (high-thrust) electric propulsion may enable dramatic mass and cost savings for lunar and Mars cargo missions, including Earth escape and near-Earth space maneuvers. At very high power levels, electric propulsion may enable piloted exploration missions as well. Improved performance of propulsion systems that are integrated with associated power and thermal management systems and that exhibit minimal adverse spacecraft-thruster interaction effects are of interest. Innovations are sought that increase system efficiency, increase system and/or component life, increase system and/or component durability, reduce system and/or component mass, reduce system complexity, reduce development issues, or provide other definable benefits. Desired specific impulses range from a value of 2000 s for Earth-orbit transfers to over 6000 s for planetary missions. System efficiencies in excess of 50% and system lifetimes of at least 5 years (total impulse > 1 x107 N-sec) are desired. Specific technologies of interest in addressing these challenges include:

- Long-life, high-current cathodes (100,000 hours);
- Electric propulsion designs employing fuels that are more readily available (whether from Earth or in situ space resources) and easy to store/handle;
- Electrode thermal management technologies;
- Innovative plasma neutralization concepts;
- Metal propellant management systems and components;
- Cathodes for metal propellants;
- Low-mass, high-efficiency power electronics for RF and DC discharges;
- Lightweight, low-cost, high-efficiency power processing units;
- Low-voltage, high-temperature wire for electromagnets;
- High-temperature permanent magnets and/or electromagnets;
- Application of advanced materials for electrodes and wiring;
- Highly accurate propellant control devices/schemes;
- Miniature propellant flow meters;
- Lightweight, long-life storage systems for krypton and/or hydrogen;
- Fast-acting, very long-life valves and switches for pulsed inductive thrusters;
- Superconducting magnets;
- Lightweight thrust vector control for high-power thrusters; and
- High fidelity methods of determining the thrust of ion, Hall, and advanced plasma engines without using conventional thrust-stands.

Note to Proposer: Subtopic S3.04 under the Science Mission Directorate also addresses in-space propulsion. Proposals more aligned with science mission requirements should be proposed in S3.04.

TOPIC: X3 Life Support and Habitation Systems

Life support and habitation encompasses the process technologies and equipment necessary to provide and maintain a livable environment within the pressurized cabin of crewed spacecraft. Functional areas of interest to this solicitation include thermal control and ventilation, atmosphere resource management and particulate control, water recovery systems, solid waste management, habitation systems, environmental monitoring and fire protection systems. Technologies must be directed at long duration missions in microgravity, including earth orbit and planetary transit. Requirements include operation in microgravity and compatibility with cabin atmospheres of up to 34% O_2 by volume and pressures ranging from 1 atmosphere to as low as 7.6 psia. Systems external to the spacecraft will be at vacuum. 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 show feasibility of the technology and approach. A resulting Phase II contract should lead to development, evaluation and delivery of prototype hardware. Specific technologies of interest to this solicitation are addressed in each subtopic.

X3.01 Process Technologies for Life Support System Loop Closure
Lead Center: MSFC
Participating Center(s): ARC, GRC, JSC, KSC

Process loop closure within life support systems is a critical enabling feature in the NASA's efforts to extend crewed space exploration beyond low Earth orbit. Specific process technology needs are sought in the technical areas of atmosphere revitalization, and water recovery. Specifics pertaining to each technical need area are the following:

Atmosphere Revitalization Process Technologies

Regenerative CO_2 Reduction Reactors: Carbon dioxide reduction processes based on the Bosch series of reactions suffer from catalyst coking and subsequent deactivation. A novel process where the catalyst is either resistant to coking and/or may be regenerated in-situ is sought.

Alternatives to Pyrolysis for CH_4 Management: Process technologies are sought that convert CH_4 into either elemental products (carbon and H_2) or other useful commodities (fuel, organic synthesis precursor, or other) by reaction with available cabin resources such as O_2, N_2, or other readily available reactant.

Gas Separations: CO_2 reduction processes involve complex feed, recycle, and effluent gas mixtures. Process technologies and techniques for separating H_2, CH_4, and CO from complex effluent gas streams to facilitate their recycle and further reaction are sought.

Regenerable Particulate Matter Filters and Separators: Efficient methods of regenerating particulate filters and separators are sought to reduce crew maintenance time and eliminate the need for consumable filter elements. These units should be self-cleaning in-place (preferable) or off-line. Targeted technologies should be compact and lightweight, easily integrated with the spacecraft life support system, and provide viable methods for disposing of collected particulate matter while minimizing or eliminating direct contact by the crew.

Water Recovery Process Technologies

Efficient technologies are desired for recovering and purifying wastewater to potable quality. Emphasis is on the development of technology that is capable of operation in microgravity. In addition, the use of power and consumable components or chemicals should be minimized. Wastewater requiring treatment on spacecraft may consist of one or more waste streams including urine, brines, humidity condensate, hygiene water, and/or laundry water. Areas of emphasis are the following:

Removal of Dissolved and Suspended Solids from Wastewater: Process technologies suitable for serving as primary or secondary treatment stages to provide alternative treatment options to the vacuum compression distillation process equipment used on the International Space Station are sought. The dissolved and suspended solids may be composed of organic or inorganic compounds. The wastewater may have a total organic carbon concentration as high as 2000 mg-C/l and conductivity up to 12 mS/cm. Performance of proposed process technologies should be insensitive to solids precipitation.

Water Recovery from Brines: Many systems used for wastewater recovery produce clean water while concentrating contaminants into a highly concentrated brine waste. Microgravity-compatible process technologies capable of recovering a product water containing <100 mg/l total organic carbon from brine are sought. Also, techniques for storing the residual brine solids, which minimize or eliminate handling by the crew are sought.

Oxidation Technologies for Disinfection of Recovered Potable Water: Techniques for reducing the concentration of bacteria in potable water to less than 50 CFU/ml are sought that require minimal consumables resupply and are demonstrated to be compatible with the spacecraft cabin environment and life support systems.

X3.02 Human Accommodations and Interfaces with Spacecraft Life Support
Lead Center: ARC
Participating Center(s): GRC, JSC, KSC, MSFC

Critical gaps exist with respect to interfaces between human accommodations and closed loop life support systems for long duration human missions with limited resupply in microgravity. New technologies are needed for clothing and laundry, collection of human metabolic wastes, recovery of resources such as water, stabilization of wastes, ventilation with low noise fans, and crew hygiene systems. Proposals should explicitly describe the expected weight, power, volume, and microgravity performance advantages.

Clothing
The requirements for crew clothing are balanced between appearance, comfort, wear, flammability and toxicity. Ideally, crew clothing should have durable flame resistance in a 34% O_2 (by volume) enriched atmospheric environment. Fabrics must enable multiple crew wear cycles before cleaning/disposal.

Laundry
The laundry system should remove/stabilize combined perspiration salt, organic, dander and planetary dust contaminants, preserve flame resistance properties of the fabrics, and use cleaning agents compatible with water recovery technologies including biological processes. Proposals using water for cleaning should use significantly less than 10 kg of water per kg of clothing cleaned.

Human Metabolic Waste Collection and Processing
Advanced methods of collection (human interfaces) and management are needed. Microgravity technology is needed to collect, provide odor control, stabilize, process for water recovery, reduce volume and dispose of feces. Areas of emphasis include: stabilization, water removal and recovery, and volume reduction. Human urine or water collection systems that require minimal/no airflow and allow >99% capture efficiency with non-contact crew interfaces are needed. Systems should include ability to separate liquid and air without rotary separators and be tolerant of urine precipitates and particulates from the crew cabin (originating from the crew, clothing, and equipment).

Quiet Ventilation Fans
Ventilation fans with inherent minimal acoustic generation in the range of human hearing are desired. Fans must not rely on passive acoustic mufflers, duct treatments, or mass for acoustic attenuation. Fans must have intrinsic aero-mechanical, rotary support, and electrical drive elements that reduce acoustic generation and provide high efficiency. Fans should be tolerant (prevent deterioration of flow performance or be periodically self cleaning) of particulates from the crew cabin (originating from the crew, clothing and equipment).

X3.03 Monitoring and Control for Spacecraft Environmental Quality and Fire Protection
Lead Center: JPL
Participating Center(s): ARC, GRC, JSC, KSC, MSFC

Monitoring and Control Technology Needs
Long duration human missions far from Earth and operation of closed loop life support systems have critical needs for monitoring and control for environmental quality and certifying recycled life support consumables. Monitoring technologies are employed to assure that the chemical and microbial content of the air and water environment of the astronaut crew habitat falls within acceptable limits, and that the life support system is functioning properly and efficiently. The sensors may also provide data to automated control systems. All proposed technologies should have a 3 year shelf-life, including any calibration materials (liquid or gas). The technologies will need to function in microgravity and low pressure environments (~8 psi), and may see unpressurized storage. Significant improvements are sought in miniaturization and operational reliability, as well as long life, in-line operation, self-calibration, reduction of expendables, low energy consumption, and minimal operator time/maintenance for monitoring and controlling the life-support processes.

- Process control sensors for closed loop life support systems: Targeted sensors include humidity in gases such as O_2, H_2, and CO_2; volatile organic compounds in O_2 and CO_2 (VOCs in CO_2 would be in the CO_2 removal/concentration product that would feed to any CO_2 reduction process); composition of CO_2 reduction effluent gases (CO_2, CO, CH_4, and H_2O) from either a Sabatier- or Bosch-based CO_2 reduction process; and combustible gas sensors for H_2 in an O_2 background and O_2 in an H_2 background from electrolysis.
- Trace toxic metals in water.
- Microbial monitoring of water and surfaces using minimal consumables.

- Optimal system control methods. Operate the life support system with optimal efficiency and reliability, using a carefully chosen suite of feedback and health monitors, and the associated control system.
- Sensor suites. Develop an approach for selecting number, types and placement of sensors in a distributed network for optimal environmental monitoring. Develop an approach to efficiently analyze data from a suite of sensors within a distributed network for optimal environmental monitoring.

Spacecraft Fire Protection Technology Needs

The overheating or combustion of spacecraft materials can introduce many types of particulate and gaseous contaminants into the cabin atmosphere. Technologies that not only detect smoke particulate but identify important characteristics such as particulate size and composition would be extremely useful for rapid identification of the fire source. These must be of suitable size, mass, and volume for a distributed sensor array in spacecraft systems. Also, catalytic or sorbent technologies suitable for the rapid removal of gases, especially CO, and particulate during a contingency response are desired.

X3.04 Thermal Control Systems for Human Spacecraft
Lead Center: JSC
Participating Center(s): GRC, GSFC, JPL, LaRC, MSFC

Future spacecraft will require more sophisticated thermal control systems that can dissipate a wide range of heat loads with widely varying environments while using fewer of the limited spacecraft mass, volume and power resources. The thermal control system designs must accommodate high input heat fluxes at the heat acquisition source and harsh thermal environments at the heat rejection sink. Advances are sought for microgravity thermal control in the areas of:

- Innovative multi-environment multimode thermal management systems that are capable of meeting widely varying thermal control requirements of various human exploration mission scenarios;
- Low temperature external working fluids (a temperature limit of less than 150K with favorable thermophysical properties – e. g., viscosity and specific heat);
- Internal working fluids that are non-toxic, have favorable thermophysical properties, and are compatible with aluminum tubing (i.e., no corrosion for up to 10 years);
- Low mass thermal switches;
- Microgravity gas-liquid separators;
- Long-life, light-weight, pumps capable of producing relatively high pressure head (~4 atm) for use in mechanically pumped, single-phase thermal control loops;
- Variable emissivity coatings (near unity emissivity with the ability to reduce emissivity by at least a factor of ten);
- Variable area radiators (e. g., variable capacity heat pipe radiators or drainable radiators);
- Microgravity thermal energy storage systems and transient/cyclic thermal management systems that use a phase change material;
- Condensing heat exchangers that preclude microbial growth and/or allow passive condensate separation;
- Small, efficient, highly reliable, heat pumps for condensate control that would accept heat at 273 to 278K and reject it at 300 to 310K.

TOPIC: X4 Extra-Vehicular Activity Technology

Advanced Extra Vehicular Activity (EVA) systems are necessary for the successful support of the International Space Station (ISS) beyond 2020 and future human space exploration missions. Advanced EVA systems include the space suit pressure garment, airlocks, the Portable Life Support System (PLSS), Avionics and Displays, and EVA Integrated Systems. Future human space exploration missions will require innovative approaches for maximizing human productivity and for providing the capability to perform useful tasks, such as assembling and servicing large in-space systems and exploring surfaces of the Moon, Mars, and small bodies. Top level requirements include reduction of system weight and volume, low or non-consuming systems, increased hardware reliability, durability, operating life, increased human comfort, and less restrictive work performance in the space environment. All proposed Phase I research must lead to specific Phase II experimental development that could be integrated into a functional EVA system.

X4.01 Space Suit Pressure Garment and Airlock Technologies
Lead Center: JSC
Participating Center(s): GRC

The space suit pressure garment requires innovative technologies that increase the life, comfort, mobility, and durability of gloves, self sealing materials to minimize the effects of small punctures or tears, and materials that are resistant to abrasion. Innovative garments that provide direct thermal control to crew member that minimize consumables are needed as well as materials for helmets that are scratch resistant or prevent fogging. Technologies for space suit flexible thermal insulation suitable for use in vacuum and low ambient pressure are also needed.

Due to the expected large number of space walks that will be performed on the ISS beyond 2020 and future human space exploration missions, innovative technologies and designs for both microgravity and surface airlocks will also be needed. Technology development is needed for minimum gas loss airlocks providing quick exit and entry that can accommodate an incapacitated crew member, suit port/suit lock systems for docking a space suit to a dust mitigating entry/hatch in order for the space suit to remain in the airlock and prevent dust from entering the habitable environment.

X4.02 Space Suit Life Support Systems
Lead Center: JSC
Participating Center(s): GRC

Exploration missions will require a robust, lightweight, and maintainable Primary Life Support System (PLSS), also commonly referred as the space suit backpack. The PLSS attaches to the space suit pressure garment and provides approximately an 8 hour supply of oxygen for breathing, suit pressurization, ventilation and CO_2 removal, and a thermal control system for crew member metabolic heat rejection. Innovative technologies are needed for high-pressure O_2 delivery, crewmember cooling, heat rejection, and removal of expired CO_2 and water vapor. Technology development and design for lightweight PLSS packaging and materials that hold and protection PLSS components are needed. Regenerable trace contaminant control technologies for the PLSS ventilation system are needed.

X4.03 Space Suit Radio, Displays, Cameras, and Integrated Systems
Lead Center: JSC
Participating Center(s): GRC

NASA seeks to advance space suit technologies in five key areas: radios, displays, sensors, cameras, and integrated systems. For future missions, the next-generation EVA radio will be pivotal in enhancing crew mobility and operations. Three key enablers are: (1) highly programmable frontends, (2) highly programmable digital basebands with the Medium Access Control (MAC) implementation for multiple protocols, and power-aware processing. With a total dc power budget under 4 watts and extreme miniaturization, this reconfigurable radio platform must be power efficient, frequency agile, and highly adaptive. Operating at S-band (2.4-2.483 GHz) with RF transmit power under 2 watts, the radio will deliver voice, telemetry, and high-definition imagery transmissions. To achieve the overarching EVA radio goals of small form factor, ultra-power, and re configurability, NASA needs to extend the state-of-the art as follows:

Tunable RF Front End and Transceiver
A major impetus behind the MEMS technology stems from compactness, which leads to lower power dissipation, higher levels of integration, lower weight, volume, and cost. To shrink form factor and enable efficient surface

operations, one of the cornerstone components of this radio is the tunable filter. Recent advances in RF MEMs filters and resonator technology have permitted very high quality factors (>1000) at GHz frequencies. Achieving high and excellent tuning range (>2:1) to bandwidth ratio without cryogenic cooling is now viable for the S-band frequency. For reliability, the tunable filter should employ a contact-less tuning scheme.

Power-Aware Processing
To support Quality of Service (QoS) of different applications, it's inadequate to optimize power at design time, but dynamic power management must be employed to ensure power efficiency. To maximize power efficiency, the radio must be able to adjust power and update rates to suit for diverse missions. Users should have the ability to specify QoS for different data streams. The radio must have the capability to scale power, select optimum modes of operation, and minimum energy profiles. During low-rate-processing intensive modes, including local processing and compression of telemetry data and voice, highly energy-efficient low-voltage, low-performance modes must be used. For high-rate-processing intensive modes, like advance signal encoding of high definition imagery, medium performance modes must be used; and during active communication modes (which may have a low duty-cycle), ultra-high-performance modes must be used. Accordingly, the digital platform must be highly agile and use-case aware to continuously minimize energy. Below are some desirable features to consider:

Variation-Tolerant, Performance-Scalable Architectures
Hardware must sense its own limitation at a dynamically varying, performance-driven optimal energy operating point, and reconfigure accordingly. If variability is stressed at the low-voltage operating point, redundant hardware should be used to improve reliability; if throughput is stressed at the high-performance operating point, redundant hardware should be used to increase parallelism.

Energy-Aware Algorithms for Adaptive Hardware
Algorithms must be aware of the different hardware operating-points and associated architecture. For instance, during low-power modes targeting voice and data (for telemetry), occasional high through-put applications (like high-rate imagery) should dynamically switch to algorithms employing extreme parallelism in order to support a minimum operating voltage.

Modularity and Extensibility
Enabling platform must support open architecture and accommodate rapid upgrades, multiple protocols, new technology advances, complete re-configurability of functionality, and evolution of planetary communications and network infrastructure.

<u>Phase I Deliverables</u>: Given maximum range of 4km, telemetry, voice at 8 kbps, high definition imagery at 20 Mbps, and S-band frequency operating at 2.4 - 2.483 GHz, assess radio ultimate mass, size, and power. This should be backed with analyses and simulation to ensure achievable performance and power targets.

One significant prerequisite to Phase II is the development of a promising and novel MEMS-based radio architecture that comprises: a highly programmable frontend and highly programmable digital basebands with the MAC implementation of multiple protocols and Advanced Encryption Standard (AES) encryption. The offeror must demonstrate the ability to achieve significant advantages in compactness, power efficiency, and reliability.

<u>Phase II Deliverables</u>: Develop a reliable, intelligent, and power-efficient MEMS-based EVA radio prototype unit that demonstrates robust RF performance, frequency agility, re-configurability, and dynamic power management for voice, telemetry, and high definition imagery under power budget constraints.

Demonstrate a highly programmable frontend and digital basebands with the MAC implementation for multiple open standard protocols. Consider a three-node network configuration for interoperability.

Integrate AES encryption as well as power-aware technologies and ensure QoS applications fall within prescribed power constraints.

Displays
To surmount geometric constraints, compact external flat panel or helmet-mounted display technologies are needed to improve situational awareness, mobility, suit monitoring, and task management. Hands-free interactive control of visual information (text, graphics, images, and video) using conversational spoken dialogue can improve work efficiency over audio communications as well as increase productivity and safety. High resolution suit displays must be able to operate outside the protection of the suit in bright surroundings, thermal, radiation, and vacuum environments as well as internally without imposing ignition hazards due to 100 percent oxygen environment.

Sensors
Crew health and suit monitoring require advancement of lightweight CO_2, biomedical (heart rate, blood OX, EKG) and core temperature sensors with reduced size, increased reliability, and greater packaging flexibility. Consequently, technologies are needed to provide high accuracy, low mass, and low-power sensors that measure flow rate, pressure, temperature, and relative humidity or dew point. All sensors must operate in a low pressure 100% O_2 environment with high humidity and may be exposed to liquid condensate.

Because missions must be designed with appropriate radiation shielding and adjusted to keep the radiation doses within tolerable limits, real-time, accurate, instantaneous and integrated radiation dose measurements and readout are needed such as novel dosimeter sensors. Given sufficient warning, astronauts can move to a more shielded part of the space vehicle and lessen dose impact. As cosmic rays impinge upon the vehicle leaving the magnetosphere, sensors are needed to determine the type of radiation and dose as well as reduce the potential risk of biological tissue damage.

High Definition (HD) Cameras
Ultra-compact, low- power, HD cameras are needed to support both high definition motion and high resolution still imagery, providing low loss compressed digital data output for transmission over RF and/or IP networks. Key features include advanced wireless networking for transmitting video at high bandwidth, high-quality image compression algorithms, radiation tolerant image sensor and processing platform capable of running video compression in near real time. The cameras must provide excellent situational awareness for crew members and quality imagery for remote viewing, scientific research, exploration, and public relations. They will be mounted on space and planetary vehicles (e.g. rovers), so remote operation (pan, tilt, focus, zoom, light level controls) can be controlled by astronaut in a suit, and the image projected onto a helmet display or remotely for Earth-based operations.

Integrated Systems
A complete system of displays, cameras, sensors must be integrated under a common interface. A key enabler will be advanced spoken dialogs. Typing or using a touch menu is too cumbersome with space suit gloves. Voice commands are much more natural for the suited astronaut and can increase situational awareness. In case of voice failure, a backup system can be implemented to perform all critical functions. Not only can this capability reduce crew workload, but it can immensely enhance operational efficiency. Such functions can alert crew about progressive deterioration of equipment preceding failures. Sensor data can be read out to determine the heart rate, body temperature, and CO_2 levels. Cameras can be turned on, aimed at precise locations, and either still or motion imagery can be taken.

Rather than separate control interfaces, a total solution is needed for integrating a suite of space suit functions: displays, cameras, sensors, audio, and voice. Hands-free interaction requires automated planning, scheduling, consumable management, suit monitoring, and display presentation. Advanced spoken dialogue system which works in an acoustic environment of the space suit and provides an interface to control all space suit, display, camera, sensor, and audio functions will allow a natural operation of complex suite of space suit capabilities.

TOPIC: X5 Lightweight Spacecraft Materials and Structures

The SBIR topic area of Lightweight Spacecraft Materials and Structures centers on developing lightweight expandable structures, advanced manufacturing technologies for metallic and composite materials, structural sensoring techniques, in-situ non-destructive evaluation systems, and low-temperature mechanisms. Applications are expected to include space exploration vehicles including launch vehicles, crewed vehicles, and surface and habitat systems.

The area of expandable structures solicits innovative concepts to support the development of lightweight-structure technologies that would be viable solutions to high packaging efficiency and increasing the usable primary pressurized volume in habitats, airlocks, and other crewed vessels. Technologies are needed to minimize launch mass, size and costs, while maintaining the required structural performance for loads and environments.

Advanced fabrication and manufacturing of lightweight structures focuses on the development of metallic alloys and hybrid materials, processing and fabrication technologies related to near-net shape forming. The goal is to reduce structural weight, assembly steps, and minimize welds, resulting in increased reliability and reduced cost. Research should evaluate material compatibility with forming methods and establish fundamental microstructure/processing/property correlations to guide full-scale fabrication. Laboratory scale test methods are needed to accurately simulate the deformation modes experienced in large-scale manufacturing.

Polymer matrix composite (PMC) materials have been identified as a critical need for launch and in-space vehicles. The reduction of structural mass translates directly to additional performance, increased payload mass and reduced cost. PMC materials are also critical for other structures, such as cryogenic propellant tanks. Advances in PMC materials, automated manufacturing processes, non-autoclave curing methods, advances in damage-tolerant/repairable structures, and PMC materials with high resistance to microcracking at cryogenic temperatures are sought. The objective is to advance technology readiness levels of PMC materials and manufacturing for launch vehicle and in-space applications resulting in structures having affordable, reliable, and predictable performance.

Practical modular structural sensor systems and NDE technologies are sought for spaceflight missions. Smart, lightweight, low-volume, and stand-alone sensor systems should reduce the complexities of standard wires and connectors and enable sensing in locations not normally accessible. NDE sensor system technology should include modular, low-volume systems and have the ability to perform inspections with minimal human interaction. Systems need to provide the location and extent of damage with the minimal data transfer between the flight system and Earth. Mission application areas include space transportation vehicles, pressure vessels, ISS modules, inflatable structures, EVA suits, MMOD shields, and thermal protection structures.

Low-temperature mechanism technology is being developed for reliable and efficient operation of mechanisms in low temperature environments at -230°C and sustained performance thru temperature cycles of -230°C to +120°C. The goal is to enhance operation of mechanized parts by lowering the operating temperature of the component, and by improving performance at cold conditions under vacuum over the life of the mechanism. The targeted application of the technology is to provide for operation of motors and drive systems, lubricated mechanisms, and actuators of rovers, mobility systems, and robotic mechanisms.

Research under this topic should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a full-scale demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X5.01 Expandable Structures
Lead Center: LaRC

The Expandable Structures subtopic solicits innovative structural concepts that support the development of lightweight structures technologies for expandable exploration space modules and surface based habitats. The targeted structural concepts are desired for utilization in primary pressurized volumes and in secondary structures internal to the deployed primary volume. Innovations in expandable structures technology is desired to minimize launch mass, volume, and costs, while maximizing operational volume and structural performance of a crewed or material transfer pressure vessel.

Inflatable structures is a research area within expandable structures, which offers a viable solution for increasing the volume of habitats, airlocks, and other crewed vessels. Inflatable structure concerns, due to the low level of maturity include: consistent and reproducible mechanical behavior, durability in the presence of micrometeoroid impact, incorporation of material for radiation shielding, crew-induced damage, and repair techniques for long term survivability. Other areas of concern include, pre-integration solutions, storage of a pressurized volume within an expandable structure, and deployment techniques. Solicitations which address topics in these areas would be welcomed.

One remaining area of interest is the development of innovative deployable secondary structures that have minimal mass, high packaging efficiency, and multi-functional utilization. One simple example of a secondary structure could be a walkway internal to a lunar surface habitat, which could be reconfigured as a storage container or a radiation shield during a major solar flare event. These secondary multi-functional structures should provide highly robust, stiff and mass efficient surfaces that enable the useful outfitting and pre-integration of subsystems within the primary structural volume.

In general, development of structural concepts can include structural components, methods of validation, and/or predictive analysis capabilities. Analytical and numerical methods to analyze the behavior of soft-goods from a global scale, down to the fabric and strap level are desired. Methods and designs for integrating instrumentation into soft-goods, including the ability to detect damage, creep (strains), loads in the primary restraint layers, and temperatures are also desired. 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.

X5.02 Advanced Fabrication and Manufacturing of Metallic and Hybrid Materials for Lightweight Structures
Lead Center: LaRC
Participating Center(s): MSFC

This subtopic focuses on the development of advanced lightweight materials, materials processing, and related fabrication technology for structural application. Specific topics of interest include identification of metallic alloys and hybrid materials that, in combination with design modifications, can significantly reduce structural mass; computational modeling and simulation of forming methods; testing to characterize materials and validate manufacturing methods. Potential applications are expected to include all exploration space vehicles including launch vehicles, crewed vehicles, surface systems and habitat, and extended solar system exploration concepts. NASA's application focused manufacturing development usually occurs through full-scale fabrication trials combined with component testing. Proposals are sought that evaluate material compatibility with forming methods and establish fundamental microstructure/processing/property correlations to guide full scale fabrication development.

Fabrication technology topics should focus on near net shape manufacturing methods, which can reduce structural weight, processing, and assembly steps, and minimize welds, resulting in increased reliability and reduced cost. Materials topics should focus on lightweight monolithic or hybrid materials, characterization of material response to forming and joining methods, development of forming and thermo-mechanical treatments to optimize material microstructures, and verification of post-forming properties. Other interests include development of laboratory scale test methods to accurately simulate the deformation modes experienced in large scale manufacturing for use in screening material behavior.

Research should be conducted to demonstrate potential performance improvements resulting from material/processing/fabrication combinations and show a clear path toward a Phase II subscale component validation and projections for implementation of full scale manufacturing paths.

X5.03 Manufacturing of Polymer Matrix Composite (PMC) Structures
Lead Center: MSFC
Participating Center(s): ARC, GRC, KSC, 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 vehicle and in-space applications resulting in structures having affordable, reliable, 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; and materials with high resistance to microcracking at cryogenic temperatures.

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 up and down mass capability. Reliable large-scale composites structures will be critical to the "heavy lifter" 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.

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; and quantitative risk reduction capability. Research should be conducted to demonstrate novel approaches, technical feasibility, and basic performance characterization during Phase I, and show a path toward a Phase II design allowables and prototype demonstration. Emphasis should be on demonstrable 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.

X5.04 Spaceflight Structural Sensor Systems and NDE
Lead Center: JSC
Participating Center(s): ARC, LaRC, MSFC

As the use of various lightweight structures and materials continues to grow for existing and transformational spaceflight applications, the need is growing for the use of practical modular structural sensors and Non-Destructive Evaluation (NDE) sensor systems for use during spaceflight missions. The subtopic will address these two areas, for which proposals to either area will be considered equally:

Spaceflight Structural Sensor Systems
Technologies sought include: modular/low mass-volume systems, stand-alone smart sensor systems that provide answers as close to the sensor as practical, Surface Acoustic Wave (SAW)-based sensors, passive wireless sensor-tags, flexible sensors for highly curved surfaces and direct-write film sensors. These systems allow for additions or changes in instrumentation late in the design/development process and enable relocation or upgrade on orbit. They reduce the complexities of standard wires and connectors and enable sensing functions in locations not normally accessible with previous technologies. They allow NASA to gain insight into performance and safety of NASA vehicles as well as commercial launchers, vehicles and payloads supporting NASA missions.

Mission Application Areas (Interior or Exterior):

(1) Add-on in-space modular sensors for:

- Commercial human-rated transportation systems
- Composite Overwrapped Pressure Vessels (COPVs) and other pressure-vessels
- International Space Station (ISS) habitable modules and exterior structure
- Inflatable habitat modules

(2) Built-in flight monitoring systems for:

- New COPV and other pressure vessels
- New manned and unmanned spacecraft
- New propulsion system tankage and transfer systems
- New heavy-lift vehicles: fairings, transition sections, engines, Thermal Protection Systems (TPS), tanks
- New transformational habitats and structures like inflatables

(3) Mobile sensor interrogation systems - robotic, wireless network or interrogation which can:

- Program and download data from smart systems without wires
- Acquire active/passive sensor-tag data
- Determine real-time position/orientation for other sensors or tools

Performance Goals/Metrics:

Ability to establish new functionality in one of the 3 areas above, and:

- Increase number of sensor locations per pound of monitoring weight by 50%
- Decrease the system monitoring electronics weight by 50%
- Decrease total wiring required for monitoring by 50%
- Decrease the time to plan and install monitoring by 50%
- Decrease the overall life-cycle cost per sensor by 50%
- Decrease total data rate required from sensor data acquisition location by 50%
- Decrease the expected cost of instrumentation changes/upgrades by 50%

NDE Systems for use during Spaceflight
Technologies sought include: modular/low mass/volume smart NDE sensors systems and associated software that enable effective use with minimum crew training or re-familiarization after extended periods of no use. Systems should include ability to perform inspections with minimal human interaction. These systems need to provide reliable assessments of the location and extent of damage with the minimal data transfer between vehicle and Earth. Methods are desired to perform inspections in areas with difficult access in pressurized habitable compartments and external environments. Many applications require the ability to see through conductive and/or thermal insulating

materials without contacting the surface. Sensors that can dynamically and accurately determine position and orientation of the NDE sensor are needed to automatically register NDE results to precise locations on the structure. Structural design and material configurations are sought that can enhance NDE and monitoring. Advanced processing and displays are needed to reduce the complexity of operations for astronaut crews who may only use the NDE tool infrequently, but need to make important assessments quickly. Micro-miniature, low power NDE inspection sensors are needed for potential use on free-flying inspection platforms. Integration of wireless systems with NDE may be of significant utility.

Mission Application Areas:

Enabling NDE (Interior and Exterior):

(1) On-orbit NDE sensor systems (e.g.Visual, Laser, Micro-wave, Terrahertz, Infra-red, X-ray backscatter, eddy current or other) that have high resolution and small form-factor to inspect:

- Thermal protection - Multi-Layer Insulation (MLI) and TPS) structures
- Inflatable habitats, Extra-Vehicular Activity (EVA) suits and visiting vehicles
- Electronic systems, environmental control systems, and other vehicle systems
- Conductive structures, Micro-Meteoroid and Orbital Debris (MMOD) shields, primary structure, pressure vessels
- Structures(COPV, module walls) under MLI/MMOD shielding
- Be deployed/used without the need for robotic manipulators or EVA crew.

(2) On-orbit NDE sensor systems that can be used:

- In difficult access areas: flexible borescopes, micro-robots, smart sensors.
- To identify, locate and quantify potential damage areas: MMOD damage, module and pressure vessel leaks, corrosion, etc.
- On robotically operated platforms: free-flyers, micro-robots, dexterous robots, or remote manipulators.

Performance Goals/Metrics:

Ability to establish new functionality in one of the 2 areas above, and:

- Decrease total data/rate required from the NDE sensor by 50%
- Decrease time to perform NDE inspections by 50%
- Decrease the size, weight and power of NDE systems by 50%

X5.05 Low Temperature Mechanisms
Lead Center: GSFC
Participating Center(s): GRC, JPL, JSC, LaRC

This subtopic focuses on the development of medium and high power and high specific torque density actuators (e.g., motors ,position sensors, gear boxes, clutches and breaks) that will operate in thermally severe environments such as lunar surface, an asteroid, or moons such as Phoebus or Deimos. They will be exposed to exceptionally cold environments (to ~ 50K) as well as warmer environments due to a day/night cycle. These devices will need to operate reliably over a temperature range of approximately 50K to 400K. A five-year lifetime is desired. The component technologies developed in this effort will be utilized for in-situ resource utilization, surface robotic exploration, and site scouting. Specific applications may include, but not be limited to, rovers, cranes, instruments, drills, crushers, and other such facilities. Ideally the technologies developed herein should be translatable to applications for a variety of exploration precursor missions, and not just a single application. These components must operate in a hard vacuum with partial gravity, abrasive dust, and full solar and cosmic radiation exposure.

Additional requirements include high reliability, ease of maintenance, low-system volume, low mass, and minimal power requirements. Low out-gassing is desirable, as are modular design characteristics, fail-safe operation, and reliability for handling fluids, slurries, biomass, particulates, and solids. While dust mitigation is not specifically included in this Subtopic, proposed concepts should be cognizant of the need for such technologies.

Specific areas of interest include innovative long life, light weight, wide temperature range motors (in the range of one to five kWatts), position sensors (resolvers, encoders, etc.), gear boxes, clutches, breaks, lubricants, and closely related components that are suitable for the environments discussed above.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of a Phase II contract.

TOPIC: X6 Autonomous Systems and Avionics

NASA invests in the development of advanced avionics, automation software, integrated system health management, and robust software technology capabilities for the purpose of enabling complex missions and technology demonstrations. The avionics and software elements requested within this topic are critical to enhancing flight system functionality, reducing system vulnerability to extreme radiation and thermal environments, reducing system risk, and increasing autonomy and system reliability through processes, operations, and system management. As a cross-cutting technology area, avionics and software are applicable to broad areas of technology emphasis, including heavy lift launch vehicle technologies, robotic precursor platforms, utilization of the International Space Station, and flagship technology demonstrations performed to enable long duration space missions. All of these flight applications will require unique advances in avionic and software technologies such as integrated systems health management, autonomous systems for the crew and mission operations, radiation hardened processors, and reliable, dependable software. Exploration requires the best of the nation's technical community to step up to providing the technologies, engineering, and systems to regain the frontiers of the Moon, to extend our reach to Mars, and to explore the beyond.

X6.01 Automation for Vehicle and Crew Operations
Lead Center: ARC
Participating Center(s): JSC

Automation will be instrumental for decreasing workload, reducing dependence on Earth-based support staff, enhancing response time, and releasing crew and operators from routine tasks to focus on those requiring human judgment, leading to increased efficiency and reduced mission risk. To enable the application of intelligent automation and autonomy techniques, the technologies need to address two significant challenges: adaptability and software validation. Proposals are solicited in the areas of:

- **Automation Support Tools:** Support tools are needed to facilitate the authoring and validation of plans and execution scripts. Tools that are not tied specifically to one executive would provide NASA the most flexibility. Examples include: Graphical tool for monitoring and debugging plan execution and for creating and editing execution scripts; Tools for authoring and validating execution plans; User friendly abstraction of low-level execution languages by adding syntactic enhancements.
- **Decision Support:** Systems Decision support systems amplify the efficiency of operators by providing the information they need when and where they need it. Examples: Command and supervise complex tasks while projecting the outcome and identify potential problems; Understand system state, including visualization and summarization; Allow the system to interact with a user when generating the plan and allow evaluation of alternate courses of action; Integration of a planning and scheduling system as part of an on-board, closed loop controller.

- **Trustable Systems:** Systems that support or interact with crew require a very high level of reliability. Tools are needed that improve the reliability and trustworthiness of autonomous systems. These include: Ability to predict what the system will do; Guarantees of behavioral properties; Other properties that increase the operator's trust; Verifiability (e.g., restricted executive languages that facilitate model-based verification).

X6.02 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors
Lead Center: MSFC
Participating Center(s): GRC, GSFC, JPL, LaRC

Exploration flight projects, robotic precursors, and technology demonstrators that are designed to operate beyond low-earth orbit require avionic systems, components, and controllers that are capable of enduring the extreme temperature and radiation environments of deep space, the lunar surface, and eventually the Martian surface. Spacecraft vehicle electronics will be required to operate across a wide temperature range and must be capable of enduring frequent (and often rapid) thermal-cycling. Packaging for these electronics must be able to accommodate the mechanical stress and fatigue associated with the thermal cycling. Spacecraft vehicle electronics must be radiation hardened for the target environment. They must be capable of operating through a minimum total ionizing dose (TID) of 300 krads (Si), provide fewer Single Event Upsets (SEUs) than 10^{-10} to 10^{-11} errors/bit-day, and provide single event latchup (SEL) immunity at linear energy transfer (LET) levels of 100 MeV cm^2/mg (Si) or more. Electronics hardened for thermal cycling and extreme temperature ranges should perform beyond the standard military specification range of -55°C to 125°C, running as low as -230°C or as high as 350°C.

Considering these target environment performance parameters for thermal and radiation extremes, proposals are sought in the following specific areas:

- Low power, high efficiency, radiation-hardened processor technologies.
- Technologies and techniques for environmentally hardened Field Programmable Gate Array (FPGA)
- Innovative radiation hardened volatile and nonvolatile memory technologies.
- Tightly-integrated electronic sensor and actuator modules that include power, command and control, and processing.
- Radiation hardened analog application specific integrated circuits (ASICs) for spacecraft power management and other applications.
- Radiation hardened DC-to-DC converters and point-of-load power distribution circuits.
- Computer Aided Design (CAD) tools for predicting the electrical performance, reliability, and life cycle for low-temperature and wide-temperature electronic systems and components.
- Physics-based device models valid at temperature ranging from -230°C to +130°C to enable design, verification and fabrication of custom mixed-signal and analog circuits.
- Circuit design and layout methodologies/techniques that facilitate improved radiation hardness and low-temperature (-230°C) analog and mixed-signal circuit performance.
- Packaging capable of surviving numerous thermal cycles and tolerant of the extreme temperatures on the Moon and Mars. This includes the use of appropriate materials including substrates, die-attach, encapsulants, thermal compounds, etc.

TOPIC: X7 Human-Robotic Systems

This call for technology development is in direct support of the Exploration Systems Mission Directorate (ESMD). The purpose of this research is to develop component and subsystem level technologies to support robotic precursor exploration missions. To that end, it is the intent of this Topic to capitalize on advanced technologies that allow humans and robots to interact seamlessly and significantly increase their efficiency and productivity in space. The objective is to produce new technologies that will reduce the total mass-volume-power of equipment and materials required to support both short and long duration planetary missions. The proposals must focus on component and subsystem level technologies in order to maximize the return from current SBIR funding levels and timelines. Doing so increases the likelihood of successfully producing a technology that can be readily infused into existing robotic system designs. This research focuses on technology development for the critical functions that will ultimately enable surface exploration for the advancement of scientific research. Surface exploration begins with short duration missions to establish a foundation, which leads to extensible functional capabilities. Successive buildup missions establish a continuous operational platform from which to conduct scientific research while on the planetary surface. Reducing risk and ensuring mission success depends on the coordinated interaction of many functional surface systems including power, communications infrastructure, mobility and ground operations. This topic addresses technology needs associated with planetary surface systems infrastructure, interaction of humans and machines, mobility systems, payload and resource handling, and mitigation of environmental contaminations.

X7.01 Robotic Systems for Human Exploration
Lead Center: JSC
Participating Center(s): ARC, GRC, JPL, JSC

The objective of this subtopic is to provide advanced robotic capabilities for planetary surface system assets that deliver, handle, transfer, construct, and prepare site infrastructure for surface operations. This includes robust dexterous manipulation capabilities; large and small cargo transporters for delivery and deployment of construction materials, power generation systems, and inspection systems.

This subtopic seeks to develop technologies that facilitate remote robotic operations by ground control, from orbiting assets, as well as autonomous robotic operations. Robots may operate before, during, and after human missions. Automation and robotics capabilities include the ability to use robots for site setup and operations. Candidate tasks include: systematic site survey (engineering and/or science), inspection, emergency response, site preparation (clearing, leveling, excavation, etc.), instrument deployment, payload offloading, dexterous manipulation, and regolith handling for In-situ Resource Utilization.

Maximizing the useful life of surface assets is essential to a successful Exploration program. Material components must be robust and tolerate extreme temperature swings and endure harsh environmental effects due to solar events, micrometeorite bombardment, and abrasive planetary dust.

Proposals are sought for the following technology needs:

- Hybrid battery-ultra capacitor storage of electrical energy.
- Active suspension components/methods that convert mechanical energy absorbed through the suspension system into stored electrical energy.
- High power electronic motor drivers (30Kw peak power). Nominal 400 volt operating range. Design pathway that leads to radiation hardened components a must.
- Low temperature, low friction bearings – to 20 degrees K.
- Low temperature lubricants – to 20 degrees K.
- Low power sensors for inspection, surface navigation and obstacle avoidance with minimal mass and volume. Design pathway that leads to radiation hardened components a must.
- Robot user interfaces and monitoring software that enable more efficient interaction with, and operation of, robots that are remotely controlled over large time delays (5-10 seconds).
- Joint seals preventing contamination of bearing surfaces and lubricants that can tolerate long term exposure to abrasive soils and 20K to 400K temperature cycles.
- Material coatings which reduce or eliminate buildup of surface contaminants such as dust and are tolerant of harsh environmental effects, e.g., micrometeorite bombardment, ultraviolet exposure, 20K to 400K temperature cycles, abrasive dust.

- Active and passive cleaning methods which remove buildup of surface contaminants, e.g., dust, regolith, from exterior body panels and components such as solar panels. Emphasis is placed on minimizing volume, mass and power.
- Lunar regolith simulant development – proposals are requested in technology areas that improve simulant fidelities, reduce simulant manufacturing costs and schedules, and improve on simulant development processes and characterization techniques and methods.

TOPIC: X8 High-Efficiency Space Power Systems

This topic solicits technology development for high-efficiency power systems to be used for the human exploration of space. Technologies applicable to both space exploration and clean and renewable energy for terrestrial applications are of particular importance. Power system needs include: electric energy generation and storage for human-rated vehicles, electrical energy generation for in-space propulsion systems, and electric energy generation, storage, and transmission for planetary and lunar surface applications. Technology development is sought in: Electrochemical systems including fuel cells and electrolyzers; Battery technology including components for improved performance and safety; Nuclear power systems including fission and radioisotope power generation; Photovoltaic power generation including solar cell, blanket/component and array technology; Power conversion and management technologies including solar dynamic and high conversion efficiency thermodynamic systems; reliable, radiation tolerant devices, and wireless power transmission.

X8.01 Fuel Cells and Electrolyzers for Space Applications
Lead Center: GRC
Participating Center(s): JPL, JSC

Fuel Cells and Electrolyzers for Space Applications
Advanced primary fuel cell and regenerative fuel cell energy storage systems are enabling for various aspects of future Exploration missions. Proton Exchange Membrane (PEM) and Solid Oxide Based systems are of particular interest.

Proton Exchange Membrane (PEM) Fuel Cells and Electrolyzers
Proposals that address technology advances related to the following issues for PEM fuel cell, electrolysis, and regenerative fuel cell systems are desired.

<u>Oxidation resistant gas diffusion layers (GDLs)</u> for PEM fuel cell membrane-electrode-assemblies (MEAs)GDLs are integral to PEM fuel cell MEAs. Traditional carbon or graphite based GDLs are very susceptible to oxidation under certain operating conditions in the pure oxygen environment of space fuel cell systems. This results in MEA degradation and shortened life. Proposals addressing the development of oxidation resistant GDLs that remain stable to oxidation in a pure oxygen environment, and provide improved performance and longer life are desired.

<u>Passive liquid-feed high-pressure PEM electrolysis technology</u> - Water electrolysis technology is critical for water utilization and hydrogen/oxygen generation. Standard liquid-feed PEM electrolysis technology requires numerous mechanical ancillary components for reactant management functions, including pumps and two-phase water/gas separators. These components present life and reliability issues in addition to their inherent mass and volume penalties, and also require parasitic power for operation. Vapor-feed PEM electrolysis technology avoids the necessity of these ancillary components, but suffers from reduced electrochemical performance and operational constraints. Development of passive liquid-feed PEM electrolysis technology could offer the benefits of both aforementioned systems without the drawbacks. This would yield an electrolysis system with strong electrochemical performance and a minimum of ancillary components with their inherent system penalties.

<u>Oxidation resistant, electrically conductive, hydrophilic coatings</u> for internal cell components within PEM fuel cells and electrolyzers Liquid water is produced within the reactant cavities of PEM fuel cells and consumed within the

reactant cavities of PEM electrolyzers. In the case of a non-flow-through PEM fuel cell, the liquid product water moves across an open but supported gas cavity and through a water/gas separation barrier into a liquid cavity. If the supporting cell components within the gas cavity are hydrophobic, the water will be transported as droplets, which could impede gas flow and subsequently reduce electrochemical performance. If these supporting components are hydrophilic, the water is more likely to be transported as a film along the support structure and not impede gas flow. In the case of a PEM electrolyzer, water is moving in the opposite direction and therefore into the reactant cavity. A hydrophilic support structure would allow a flowing film of liquid water to reach the cell MEA while still maintaining an open reactant cavity relative to gas flow. In essence, an electrolysis cell assembly designed for vapor-feed operation could operate in a liquid-feed mode. This would yield a system with strong electrochemical performance and a minimum of ancillary components with their inherent system penalties.

Stable, highly efficient, long-life MEAs and catalysts for PEM fuel cells and electrolyzers - PEM fuel cells and electrolyzers are key technologies for space systems utilizing hydrogen, oxygen, or water as reactants. In order to improve the life and reliability of the electrochemical stacks within these systems, as well as to reduce overall system mass/volume and cost, development of MEAs and catalysts that are stable and highly efficient is critical. Techniques to accomplish this goal include, but are not limited to, alternative noble metal and mixed oxide catalysts with increased surface areas, advanced binders and catalyst layer application techniques, alternative ionomer formulations, and high-temperature membrane compatibility.

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.

Solid Oxide Fuel Cells and Electrolyzers

Advanced primary Solid Oxide Fuel Cells (SOFC) and Electrolyzers offer notable advantages in certain space applications when integrated with, respectively, CH_4/O_2 propulsion systems and systems for producing oxygen from planetary resources. Technology advances that reduce the weight and volume, improve the efficiency, life, safety, system simplicity and reliability of Solid Oxide Fuel Cells and Electrolyzers are desired. Proposals are sought which address the following areas:

Advanced Primary SOFC Systems: Their high temperature heat rejection and high efficiency power generation from methane and oxygen make primary SOFC's attractive for application to spacecraft with CH_4/O_2 propulsion systems. Research directed towards improving the durability, efficiency, and reliability of SOFC systems fed by propellant-grade methane and oxygen is desired.

Primary SOFC components and systems of interest:

- Have power outputs in the 1 to 3 kW range.
- Offer thermodynamic efficiencies of at least 70% (fuel source-to-DC output) when operating at the current draw corresponding to optimized specific power.
- Operate as specified after at least 300 start-up cycles (from cold to operating temperature within 5 minutes) and 300 shut-down cycles (from operating temperature to cold within 5 minutes).
- Operate as specified after at least 2500 hours of steady state operation on propellant-grade methane and oxygen.
- Are cooled by way of conduction through the stack to a radiator exposed to space.

Advanced Solid Oxide Electrolyzers: Their high temperature heat rejection and operation, along with high efficiency, make solid oxide electrolyzers attractive as the final step of producing oxygen from Lunar regolith by way of hydrogen or carbothermal reduction. They are also attractive components for Sabatier reactors producing methane from the Martian atmosphere. Research directed towards improving the durability, efficiency, and reliability of solid oxide electrolyzers is desired.

Solid oxide electrolysis systems of interest:

- Require power inputs in the 1 to 3 kW range.
- Operate as specified after 10,000 hours of operation fed by water with mild contamination
- Operate as specified after 100 start-up cycles (from cold to operating temperature within 5 minutes) and 100 shut-down cycles (from operating temperature to cold within 5 minutes).
- Offer thermodynamic efficiencies of at least 70% (DC-input to Lower Heating Value H_2 output) when operating at the current feed corresponding to rated power.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X8.02 Advanced Space-Rated Batteries
Lead Center: GRC
Participating Center(s): JPL, JSC

Advanced battery systems are sought for future NASA Exploration missions to address requirements for safe, human-rated, high specific energy, high energy density, high efficiency power systems. Possible customers include extravehicular activities, landers, and rovers. Areas of emphasis include advanced cell chemistries and cell designs with aggressive weight and volume performance improvements and safety advancements over state-of-the-art lithium-based systems. Rechargeable batteries with advanced non-toxic anode and cathode materials and nonflammable electrolytes are of particular interest.

The focus of this solicitation is on advanced concepts that provide weight and volume improvements and safety advancements that contribute to the following cell level metric goals:

- Specific energy >300 Wh/kg at C/2 (Fully charged or discharged in 2 hours) and 0°C
- Energy density > 600 Wh/l at C/2 and 0°C
- Operating Temperature Range - 50°C to 60°C
- Radiation tolerant to survive the harmful effects of radiation in LEO and beyond
- Tolerance to abuse such as overcharge and over temperature
- Calendar life >5 years; Cycle life >250 cycles at 100% depth of discharge

Systems that combine all of the above characteristics and demonstrate a high degree of safety and radiation tolerance are desired. Cell safety devices such as shutdown separators, current limiting devices that inhibit thermal runaway, venting, and eliminate flame or fire; autonomous safety features that include safe, non-flammable, non-hazardous operation especially for human-rated applications are of particular interest.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X8.03 Space Nuclear Power Systems
Lead Center: GRC
Participating Center(s): JPL, JSC, MSFC

NASA is interested in the development of highly advanced systems, subsystems and components for use with space nuclear power systems for space electric propulsion and surface power systems in support of human missions in accordance with transformative technology development and flagship technology demonstrations to pursue new approaches to space exploration, high-efficiency space power systems.

Nuclear systems are anticipated to enable effective long surface stay crew habitation and operations, long-range surface mobility and planetary cargo transfer. Initial planetary outpost power levels are anticipated to be between 30-50 kWe with anticipated growth to 100's kWe. Additionally, space nuclear electric propulsion will require technologies capable of effective and efficient multi-hundred kilowatt systems. Technology performance goals include; reducing overall system mass, volume, radiator area with reduced cost and increased safety and reliability.

High specific power, high efficiency, radioisotope power systems (RPS) in the 1-3 kWe range are also of interest.

Specific technology topics of interest are:

- High efficiency (> 20%) power conversion at 900-1100 K;
- Electrical power management, control and distribution (400-2000 V);
- High temperature, low mass (< 6 kg/m^2) radiators, heat exchangers (> 90% effectiveness) and electromagnetic pumps (> 20% efficiency);
- Deployment systems/mechanisms for large radiators;
- High temperature heat source/heater head (~ 900 K) materials or coatings compatible with both space and planetary surface environments;
- Systems/technologies to mitigate planetary surface environments including dust accumulation, wind, planetary atmospheres, corrosive soils, etc.;
- System designs to provide autonomous control for 10-year operation, including sensor and control technologies;
- Radiation tolerant systems and materials enabling robust, long life operation.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X8.04 Advanced Photovoltaic Systems
Lead Center: GRC
Participating Center(s): JPL, JSC

NASA is interested in the development of advanced photovoltaic (PV) cell technology and PV power generation systems to improve efficiency and reliability of PV power generation for space exploration missions. Advanced PV systems are anticipated to require a wide range of power levels, depending on mission requirements, that are from 100s of Watts to 100s of kWe. Performance goals include higher efficiency PV cells, reduced cost, reduced overall system mass and volume, and reliability under various operating conditions. These advanced PV systems must enable or enhance the ability to provide low cost, low mass and greater reliability and efficiency for a wide variety of deep space exploration missions.

PV technology areas of interest are:

- Solar cell, blanket component and advanced solar array technology with high operating efficiency (>30%), low mass (>200W/kg), and low stowed volume;
- PV technology capable of long-term, reliable of planterary surface operation under dust, temperature extreme (high and low), radiation, and other space enviromental conditions;
- Advanced concepts for array packaging, autonomous deployment, retraction and redeployment;
- Modular, high power (10s to 100s kWe) concepts with lifetimes greater than 10 years;
- High voltage (>200 Volts) array designs capable of reliable operation under space environmental conditions.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. A major focus will be on the demonstration of dual-use technologies for clean and renewable energy for terrestrial applications.

X8.05 Advanced Power Conversion, Management, and Distribution (PMAD) for High Power Space Exploration Applications
Lead Center: GRC

Advanced power conversion technologies are sought for improvements in efficiency and reliability of power conversion for space exploration missions. Power levels for applications are expected to be in the range of 10s to 100s of kWe. System and component technologies are sought that can deliver efficiency and reliability improvements in this power range in the space environment.

In addition, advanced Power Management and Distribution (PMAD) technologies are required for the electrical components and systems on future high power platforms to address size, mass, efficiency, capacity, durability, and reliability improvements Of importance are improvements in energy density, speed, efficiency, and wide temperature (-125ºC to over 450ºC) with a number of thermal cycles.

Power conversion and PMAD technologies must enable or enhance the ability to provide low-cost, abundant power for deep space missions, with requirements from 10s to 100s of kWe and months to years of mission duration.

Examples of Power Conversion technology areas:

- High conversion efficiency for Brayton, Stirling or Rankine power convertors;
- High efficiency solar dynamic deployable solar concentrators and collectors;
- Research into advanced Power Conversion system concepts.

Examples of PMAD technology areas:

- Highly reliable devices and components;
- Radiation tolerance;
- Advanced power bus solutions;
- Technologies for high pulse power applications such as advanced energy storage devices;
- Efficient wireless power transmission.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. A major focus will be on the demonstration of dual-use technologies for clean and renewable energy for terrestrial applications.

TOPIC: X9 Entry, Descent, and Landing (EDL) Technology

The Thermal Protection System (TPS) protects a spacecraft from the severe heating encountered during hypersonic flight through a planetary atmosphere. In general, there are two classes of TPS: reusable and ablative. Typically, reusable TPS applications are limited to relatively mild entry environments like that of Space Shuttle. No change in the mass or properties of the TPS material results from entry with a significant amount of energy being re-radiated from the heated surface and the remainder conducted into the TPS material. Typically, a surface coating with high emissivity (to maximize the amount of energy re-radiated) and with low surface catalycity (to minimize convective heating by suppressing surface recombination of dissociated boundary layer species) is employed. The primary insulation has low thermal conductivity to minimize the mass of material required to insulate the primary structure. Ablative TPS materials, in contrast, accommodate high heating rates and heat loads through phase change and mass loss. All NASA planetary entry probes to date have used ablative TPS. Most ablative TPS materials are reinforced composites employing organic resins as binders. When heated, the resin pyrolyzes producing gaseous products that are heated as they percolate toward the surface thus transferring some energy from the solid to the gas. Additionally, the injection of the pyrolysis gases into the boundary layer alters the boundary layer properties resulting in reduced convective heating. However, the gases may undergo chemical reactions with the boundary layer gases that could return heat to the surface. Furthermore, chemical reactions between the surface material and boundary layer species can result in consumption of the surface material leading to surface recession. Those reactions can be endothermic (vaporization, sublimation) or exothermic (oxidation) and will have an important impact on net energy to the surface. Clearly, in comparison to reusable TPS materials, the interaction of ablative TPS materials with the surrounding gas environment is much more complex as there are many more mechanisms to accommodate the entry heating. NASA has successfully tackled the complexity of thermal protection systems for numerous missions to inner and outer planets in our solar system in the past; the knowledge gained has been invaluable but incomplete. Future missions will be more demanding. Better performing ablative TPS than currently available is needed to satisfy requirements of the most severe missions, e.g., Mars Landing with 8 km/s entry and Mars Sample Return with 12-15 km/s Earth entry. Beyond the improvement needed in ablative TPS materials, more demanding future missions such as large payload missions to Mars will require novel entry system designs that consider different vehicle shapes, deployable or inflatable configurations and integrated approaches of TPS materials with the entry system sub-structure.

X9.01 Ablative Thermal Protection Systems
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, LaRC

The technologies described below support the goal of developing higher performance ablative TPS materials for future Exploration missions.

- Developments are sought for ablative TPS materials and heat shield systems that exhibit maximum robustness, reliability and survivability while maintaining minimum mass requirements, and capable of enduring severe combined convective and radiative heating, including: development of acreage(main body, non-leading edge) materials, adhesives, joints, penetrations, and seals. Three classes of materials will be required.
    - One class of materials, for Mars aerocapture and entry for a rigid mid L/D (lift to drag ratio) shaped vehicle, will need to survive a dual heating exposure, with the first at heat fluxes of 400-500 W/cm^2 (primarily convective) and integrated heat loads of up to 55 kJ/cm^2, and the second at heat fluxes of 100-200 W/cm^2 and integrated heat loads of up to 25 kJ/cm^2. These materials or material systems must improve on the current state-of-the-art recession rates of 0.25 mm/s at heating rates of 200 W/cm^2 and pressures of 0.3 atm and improve on the state-of-the-art areal mass of 1.0 g/cm^2 required to maintain a bondline temperature below 250ºC
    - The second class of materials, for Mars aerocapture and entry for a hypersonic deployable aerodynamic decelerator, will need to survive a dual heating exposure, with the first at heat fluxes of 100-200 W/cm^2 (primarily convective) and integrated heat loads of 10 kJ/cm^2 and the second at heat fluxes of 30-50 W/cm^2 and heat loads of 5 kJ/cm^2. These materials may be either flexible or deployable.
    - The third class of materials, for Mars return, will need to survive heat fluxes of 1500-2500 W/cm^2, with radiation contributing up to 75% of that flux, and integrated heat loads from 75-150 kJ/cm^2. These materials, or material systems must improve on the current state-of-the-art recession rates of 1.00 mm/s at heating rates of 200 W/cm^2 and pressures of 0.3 atm and improve on the state-of-the-art areal mass of 4.0 g/cm^2, required to maintain a bondline temperature below 250ºC.

- In-situ heat flux sensors and surface recession diagnostics tools are needed for flight systems to provide better traceability from the modeling and design tools to actual performance. The resultant data will lead to higher fidelity design tools, risk reduction, decreased heat shield mass and increases in direct payload. The heat flux sensors should be accurate within 20%, surface recession diagnostic sensors should be accurate within 10%, and any temperature sensors should be accurate within 5% of actual values.
- Non Destructive Evaluation (NDE) tools are sought to verify design requirements are met during manufacturing and assembly of the heat shield, e.g. verifying that anisotropic materials have been installed in their proper orientation, that the bondline as well as the TPS materials have the proper integrity and are free of voids or defects. Void and/or defect detection requirements will depend upon the materials being inspected. Typical internal void detection requirements are on the order of 6-mm, and bondline defect detection requirements are on the order of 25.4-mm by 25.4-mm by the thickness of the adhesive.
- Advances are sought in ablation modeling, including radiation, convection, gas surface interactions, pyrolysis, coking, and charring. There is a specific need for improved models for low and mid density as well as multi-layered charring ablators (with different chemical composition in each layer). Consideration of the non-equilibrium states of the pyrolysis gases and the surface thermochemistry, as well as the potential to couple the resulting models to a computational fluid dynamics solver, should be included in the modeling efforts.

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

X9.02 Advanced Integrated Hypersonic Entry Systems
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, LaRC

The technologies below support the goal of developing advanced integrated hypersonic entry systems that meet the longer-term goals of realizing larger payload masses for future Exploration missions.

- Advanced integrated thermal protection systems are sought that address: (1) thermal performance efficiency (i.e. ablation vs. conduction), (2) in-depth thermal insulation performance (i.e. material thermal conductivity and heat capacity vs. areal density), (3) systems thermal-structural performance, and (4) system integration and integrity. Such integrated systems would not necessarily separate the ablative TPS material system from the underlying sub-structure, as is the case for most current NASA heat shield solutions. Instead, such integrated solutions may show benefits of technologies such as hot structures and/or multi-layer systems to improve the overall robustness of the integrated heat shield while reducing its overall mass. The primary performance metrics for concepts in this class are increased reliability, reduced areal mass, and/or reduced life cycle costs over the current state of the art.
- Advanced multi-purpose TPS solutions are sought that not only serve to protect the entry vehicle during primary planetary entry, but also show significant added benefits to protect from other natural or induced environments including: MMOD, solar radiation, cosmic radiation, passive thermal insulation, dual pulse heating (e.g., aero capture followed by entry). Such multi-purpose materials or systems must show significant additional secondary benefits relative to current TPS materials and systems while maintaining the primary thermal protection efficiencies of current materials/systems. The primary performance metrics for concepts in this class are reduced areal mass for the combined functions over the current state of the art.
- Integrated entry vehicle conceptual development is sought that allow for very high mass (> 20 mT) payloads for Earth and Mars entry applications. Such concepts will require an integrated solution approach that considers: TPS, structures, aerodynamic performance (e.g. L/D), controllability, deployment, packaging efficiency, system robustness/reliability, and practical constraints (e.g., launch shroud limits, ballistic coefficients, EDL sequence requirements, mass efficiency). Such novel system designs may include slender or winged bodies, deployable or inflatable entry systems as well as dual use strategies (e.g., combined launch shroud and entry vehicle). New concepts are enabling for this class of vehicle. Key peromance metrics for the overall design are system mass, reliability, complexity, and life cycle cost.

- Advances in Multidisciplinary Design Optimization (MDO) are sought specifically in application to address combined aerothermal environments, material response, vehicle thermal-structural performance, vehicle shape, vehicle size, aerodynamic stability, mass, vehicle entry trajectory/GN&C (Guidance, Navigation and Control), and cross-range, characterizing the entry vehicle design problem.

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

TOPIC: X10 Cryogenic Propellant Storage and Transfer

The Exploration Systems architecture presents cryogenic storage, distribution, and fluid handling challenges that require new technologies to be developed. Reliable knowledge of low-gravity cryogenic fluid management behavior is lacking and yet is critical for future manned and robotic exploration in the areas of storage, distribution, and low-gravity propellant management. Additionally, Earth-based and planetary surface missions will require success in storing and transferring liquid and gas commodities in applications. Some of the technology challenges are for long-term space use cryogenic propellant storage and distribution; cryogenic fluid ground processing and fluid conditioning; liquid hydrogen and liquid oxygen liquefaction processes on the lunar surface. Furthermore, specific technologies are required in valves, regulators, instrumentation, modeling, mass gauging, cryocoolers, and passive and active thermal control techniques. The technical focus for component technologies are for accuracy, reduced mass, minimal heat leak, minimal leakage, and minimal power consumption. The anticipated technologies proposed are expected to increase safety, reliability, economic efficiency over current state-of-the-art cryogenic system performance, and are capable of being made flight qualified and/or certified for the flight systems and dates to meet Exploration Systems mission requirements.

X10.01 Cryogenic Fluid Management Technologies
Lead Center: GRC
Participating Center(s): ARC, JPL, JSC, KSC, MSFC, SSC

This topic solicits technologies related to cryogenic propellant (i.e., Lox, CH_4, LH_2) storage, transfer, and instrumentation to support NASA's exploration goals. Proposed technologies should feature enhanced safety, reliability, long-term space use, economic efficiency over current state-of-the-art, or an enabling technologies to allow NASA to meet future space exploration goals. This includes a wide range of applications, scales, and environments on ground, in orbit, and on the lunar/planetary surfaces. Specifically:

- Innovative concepts for cryogenic fluid instrumentation are solicited to enable accurate measurement of propellant mass in low-gravity storage tanks, sensors to detect in-space and on-pad leaks from the storage system, minimally invasive cryogenic liquid mass flow measurement sensors, including cryogenic two-phase flow.
- Passive thermal control for Zero Boil-Off (ZBO) storage of cryogens for both long term (>200 days) and short term (~14 days) on ground, in orbit, and on the lunar/planetary surfaces, including in-space propellant depot concepts. Insulation for both ground and flight. Insulation systems that can also serve as Micrometeoroid/orbital debris (MMOD) protection and are self-healing are also desired.
- Active thermal control for long term ZBO storage for space applications. Technologies include 20K cryocoolers for Mars missions and in-space propellant depots, cryocooler integration techniques, heat exchangers, distributed cooling, and circulators. Scavenging of residual propellants for both orbit depots and on lunar/planetary surfaces.
- Zero gravity cryogenic control devices including thermodynamic vent systems, spray bars and mixers, and liquid acquisition devices.
- Advanced spacecraft valve actuators using piezoelectric ceramics. Actuators that can reduce the size and power while minimizing heat leak and increasing reliability.
- Propellant conditioning and densification technologies for launch vehicles and on orbit propellant depot applications. Destratification technologies and recirculation systems for homogeneous tank loads.

Reliability and operability upgrades over past densification systems. Specific component technologies include compact, efficient and economical cryogenic compressors, pumps, Joule-Thompson orifices and heat exchangers.
- Liquefaction of oxygen on Lunar/planetary surfaces, including passive cooling with radiators, cryocooler liquefaction, or open cycle systems that work with HP electrolysis. Efficiency, mass savings, and reliability upgrades are needed. Heat pumps, switches, and heat pipes to control energy flow at low temperatures. Deployable radiators and radiation shields.
- Efficient small to medium scale hydrogen liquefaction technologies (1-10k gal/day) including domestically produced wet cryogenic turboexpanders.

TOPIC: X11 Exploration Crew Health Capabilities

Human space flight is associated with losses in muscle strength, bone mineral density and aerobic capacity. Crewmembers returning from the International Space Station (ISS) can lose as much as 10-20% of their strength in weight bearing and postural muscles. Likewise, bone mineral density is decreased at a rate of ~1% per month. During future exploration missions such physiological decrements represent the potential for a significant loss of human performance which could lead to mission failure and/or a threat to crewmember health and safety. The ability to perform motion capture and kinematic analysis on-orbit to understand the similarities and differences of exercising in microgravity, estimate the physical cost of exploration tasks, monitor crew health and fitness, and to provide effective hardware for exercise countermeasures use will be valuable in supporting safe and successful space exploration. In this solicitation, Exercise Systems is seeking technologies to enable 3-D kinematic analysis of exercise sessions in-flight, and analyzed by research teams on the ground. Visit the following for additional information: http://hacd.jsc.nasa.gov/projects/ecp.cfm, http://hacd.jsc.nasa.gov/projects/eva.cfm.

X11.01 Crew Exercise System
Lead Center: GRC
Participating Center(s): JSC

Novel technologies to capture 3-D motion with a single video camera.

The Exercise Countermeasures Project is seeking technologies that can utilize single video camera systems aboard the International Space Station and allow 3-D kinematic analysis of exercise sessions post flight by research teams on the ground. These technologies may be software-driven or utilize dedicated hardware that requires minimal up-mass (e.g., novel lenses that may be fitted to standard 2-D camera systems, etc.). The objective is to obtain 3-D position coordinate data from a single camera and multiple markers in a manner that reduces the need for complex calibration and is simple for the crew to operate. The processing of the data could occur at a time later than actual data collection, but should not be overly labor intensive. Finally, automated digitization is highly desirable.

Phase I Requirements: a fully developed concept complete with feasibility analyses and top-level drawings or computational methodology as applicable. A breadboard or prototype system is highly desired.

TOPIC: X12 Exploration Medical Capability

Further human exploration of the solar system will present significant new challenges to crew health including hazards created by traversing the terrain of lunar or planetary surfaces and the effects of variable gravity environments. The limited communications with ground-based personnel for diagnosis and consultation of medical events creates additional challenges. Providing health care capabilities for the moon and mars will require the definition of new medical requirements and development of technologies to ensure the safety and success of

Exploration missions, pre-, in-, and post-flight. This SBIR Topic addresses some key medical technology and gaps that NASA will need to solve in order to proceed with exploration missions.

X12.01 Spaceflight Auscultation Capability
Lead Center: JSC

Analysis of body sounds for abnormalities is standard medical practice for diagnosing a medical condition. This call is for technology that can isolate internal body sounds (heart beating, breathing, etc.) in a potentially noisy ambient environment (up to 70 dBA) and capture the auscultation data to be managed and transmitted digitally to the appropriate destination for analysis.

Current commercially available systems have two main issues. Some systems pick up all sounds without filtering out the sounds of interest. Other systems use technology (e.g. doppler) that produce sounds that are not readily familiar to clinicians—thereby necessitating retraining.

Phase I Deliverable: Technical Feasibility Report; Draft Requirements Document
Phase II Deliverable: Prototype Hardware

X12.02 Quantifying Bone Degradation with High Resolution Ultrasound
Lead Center: GRC

Loss of bone strength, mass and density are known medical complications of space flight, where the static load of gravity is no longer present. The process of bone demineralization begins almost immediately upon an astronaut's arrival into a microgravity environment and appears to continue unabated. The losses occur particularly in weight bearing bone regions of the lower spine, hip and legs. NASA will eventually require diagnostics techniques that can perform in vivo quantitative evaluations of bone mineral density (BMD) and trabecular micro-architecture (i.e., porosity, trabecular size and geometry) during manned Exploration class missions. As an incremental step toward this end, a high-resolution diagnostic or imaging device is required for performing the quantitative evaluations identified above ex vivo with a technology that shows significant promise for adaptability to long duration human space flight. The device should be capable of resolving the trabecular micro-structure for analysis. The device should also demonstrate sufficient penetration depth in the body to eventually adapt the technology for in vivo evaluations of the calcaneus and lumbar spine, at a minimum. Efforts should be made to minimize the volume, mass, electromagnetic emissions and power draw of the device and its associated peripheral equipment. The use of ionizing radiation is not restricted, but its use is considered highly undesirable in a manned space flight environment and should, therefore, be minimized. This technology is desired for possible demonstration on ISS and for targeted deployment on future Exploration class vehicles supporting long duration missions.

X12.03 Lab to Marketplace: Commercializing Spaceflight Biomedical and Behavioral Research Tools
Lead Center: JSC

NASA and SBIR invest a significant amount of funds in the development of new technologies to study human physiology and behavior during spaceflight. This investment has produced a large number of technologies that include hardware (e.g., instruments, devices, etc.) and software (e.g., computational models, informatics tools, data analytic methods, etc.) While these technologies are put to good use by their developers, such non-commercial developers devote little attention to making their tools robust and easy to use by the broad research or clinical communities. Consequently, the promise of these advanced technologies is often realized only by the tool's developers and their close associates. Moreover, ongoing support to maintain and update technologies in non-commercial settings is difficult to obtain.

In contrast, tools that are commercially available need to be sturdy and easy to use, and commercial success often provides the means for continued maintenance and improvements of the underlying technology. This call is intended to formulate business plans that will move useful technologies from non-commercial laboratories into the commercial marketplace by inviting SBIR grant applications for further development of such technologies that are relevant to the missions of the NASA's Human Research Program. The supported research and development will likely include making the tools more robust and easy to use, advancing the Technology Readiness Levels (TRLs) from TRL 3-4 to TRL 6-7 and will likely require close collaboration between the original developers of these technologies and commercial partners.

Biomedical devices currently being developed that this will be focused on are: assisted medical procedure viewer, physiological and medical models, minimally invasive laboratory analysis capabilities, medical imaging techniques and procedures.

Phase I Deliverables: 5 business plans for current NASA/SBIR technology projects. These should include: market analysis; gap analyses reports between current state of 5 NASA biomedical technologies and what would be needed for commercialization/venture capital funding.

Phase II Deliverables: Updated business plans to include the following strategies: FDA regulatory; reimbursement; product adoption; competitive analysis; manufacturing costs; sales; use of proceeds; marketing; clinical trials.

X12.04 Batteries for Oxygen Concentrators
Lead Center: GRC

Advanced high energy battery systems are sought for use in Exploration Medical Capabilities mission applications such as power for mobile oxygen concentrators. There are only a few battery chemistries with a reasonable chance of achieving the target specific energies. Metal/air battery systems are the most likely candidates. The most common type of commercial metal/air battery utilizes zinc/air chemistry and has a practical specific energy of ~370 Wh/kg. While this battery chemistry has a theoretical specific energy of 1350 Wh/kg, it is not possible for this chemistry to meet the specific energy goals for these applications (>2000 Wh/kg). In addition to zinc/air batteries, aluminum/air batteries are also available in the commercial market, although only in a limited fashion. Aluminum/air batteries have a much greater theoretical specific energy (8140 Wh/kg) and although they currently have a practical specific energy of ~350 Wh/kg, the potential for significant near-term improvement exists. The highest theoretical specific energy for a metal/air battery chemistry is lithium/air at 11,500 Wh/kg giving it and aluminum/air batteries the best potential to realize the high specific energy values needed for Exploration Medical Capabilities mission applications.

The focus of this solicitation is on the development of a high specific energy battery that can meet the following goals:

- Specific energy (battery level) >2000 Wh/kg;
- Operating Temperature Range from 0°C to 35°C;
- Shelf life >2 years.

All classes of metal-air batteries (aqueous, non-aqueous, and solid state) as well as other battery chemistries will be considered if they fall within the guidelines of performance. Additionally, the battery system will be used inside a crewed space vehicle and must meet the requisite safety guidelines stated in [3]Crewed Space Vehicle Battery Safety Requirements[2] [JSC-20793 Rev. B].

Phase I research should be conducted to demonstrate technical feasibility and deliver multiple cell-level demonstration units at the conclusion of the contract. Additionally, a path toward a Phase II hardware demonstration should be shown which leads to the delivery of multiple module-level demonstration units mid-way through the phase II contract and multiple TRL 4 battery-level demonstration units for TRL 5/6 validation and verification testing at the end of the phase II contract.

TOPIC: X13 Behavioral Health and Performance

The Behavioral Health and Performance topic is interested in developing strategies, tools, and technologies to mitigate Behavioral Health and Performance risks. The Behavioral Health and Performance topic is seeking tools and technologies to prevent performance degradation, human errors, or failures during critical operations resulting from: fatigue or work overload; deterioration of morale and motivation; interpersonal conflicts or lack of team cohesion, coordination, and communication; team and individual decision-making; performance readiness factors (fatigue, cognition, and emotional readiness); and behavioral health disorders. For 2010, the Behavioral Health and Performance topic is interested in the following technologies: Unobtrusive behavioral health monitoring tools: specifically a tool(s) which would monitor physiological markers of stress and emotional states. Proposals should respond in this area: http://humanresearch.jsc.nasa.gov/elements/bhp.asp,
http://www.nsbri.org/Research/Psycho.html.

X13.01 Behavioral Health Monitoring Tools
Lead Center: JSC

The NASA Behavioral Health and Performance Program Element (BHP) identifies and characterizes the behavioral health and performance risks associated with training, living and working in Space, and return to Earth. BHP develops strategies, tools, and technologies to mitigate these risks. Currently, BHP has the need for behavioral health monitoring tools specific to the long duration Exploration Mission environment. The aim of the current task is to provide a non-invasive technology that would unobtrusively monitor and detect physiological markers of chronic stress that could lead to behavioral or performance decrements. Factors may include the changes in Central Nervous System, Autonomic Nervous System, emotional state, environment, gestures, and speech. The stress monitoring system would automatically generate meaningful feedback for the user regarding their individual behavioral health status based on measures of physiological, psychological and emotional state.

<u>Requirements</u>: The stress assessment tool shall:

- Be unobtrusive;
- Require minimal crew time or effort;
- Monitor physiological markers of stress and emotional state;
- Provide meaningful feedback to user regarding individual behavioral health status;
- If decrements are detected, the measure shall provide meaningful feedback to user regarding recommended course of action or treatment.

Phase I Deliverables: A final report summarizing current accepted methods and measures of physiological markers of stress as they relate to performance, the current state of technologies, recommendations regarding enhancements to current technology or the development of a new technology with the technology enhancement or development concept fully described. A draft requirements document for the recommended technology.

TOPIC: X14 Space Human Factors and Food Systems

The emphasis on developing new, innovative technologies to enable future Space Exploration encompasses a need for new approaches in the areas of Space Human Factors and Food Systems. Operations in confined, isolated, and foreign environments can lead to impairments of human performance. Research and development activities in this topic address challenges that are fundamental to design, development, and operation of the next generation crewed space vehicles. These challenges include: (1) technologies to unobtrusively and non-invasively measure crew task performance in real time, and (2) a need to develop, evaluate, and deliver food technologies for human spacecraft that allow for food processing or preparation in a reduced gravity and reduced pressure environment to support

crews on missions beyond low earth orbit, and efficiently balance vehicle resources such as mass, volume, water, air, waste, power, and crew time.
http://humanresearch.jsc.nasa.gov/elements/smo/docs/shfh_evidence_report_summary.pdf,
http://hefd.jsc.nasa.gov/aft.htm

X14.01 Technologies for Non-Invasive Measurement and Analysis of Human Task Performance
Lead Center: ARC
Participating Center(s): JSC

To support understanding human factors and performance risks during exploration missions, NASA needs technologies to unobtrusively and non-invasively measure the task performance of the crew in an operational research environment such as the ISS. To minimize impacts on the tasks themselves and self-reporting biases, task performance must be conducted in real time. Task performance includes a large array of activities (e.g., payload handling, experimental protocol, large physical motion).

The technologies should require minimal involvement of human operations. Potential technologies include keystroke analysis, communication protocols and voice analysis. Ideally, the technologies will maximize the use of existing ISS hardware and telemetry because of constraints of weight, power and volume.

Deliverables: Validated software and hardware tools that non-invasively measure task performance.

X14.02 Advanced Food Technologies
Lead Center: JSC

The purpose of the Advanced Food Technology Project is to develop, evaluate and deliver food technologies for human centered spacecraft that will support crews on missions beyond low earth orbit. A safe, nutritious, acceptable, and varied food system will be required to support the crew during future exploration missions. Concurrently, the food system must efficiently balance appropriate vehicle resources such as mass, volume, water, air, waste, power, and crew time. For example, it would require approximately 10,000 kg of packaged food with a 5-year shelf life for a 6-crew, 1000 day mission to Mars.

It has been proposed to use a food system which incorporates processing of raw ingredients into edible ingredients and uses these edible ingredients in recipes in the galley to produce meals. This type of food system will require technologies that will allow these raw ingredients to maintain their functionality and nutrition for 5-years. This food system would also require food processing and food preparation equipment. The equipment should be miniaturized, multipurpose and efficiently use vehicle resources such as mass, volume, water, and power.

There are some unique parameters that need to be considered when developing the technologies. The Moon's gravity is 1/6 of Earth's gravity, and that of Mars is 3/8 of Earth’s. In addition, it is proposed that the habitat will have an atmospheric pressure of 8 psia, equivalent to being on a 16,000 foot mountain top. These two factors will affect heat and mass transfer during food processing and food preparation.

The response to this subtopic should include a plan to develop a technology that will enable safe and timely food processing and food preparation in reduced pressure and reduced gravity. Phase I should concentrate on the scientific, technical, and commercial merit and feasibility of the proposed innovation resulting in a feasibility report and concept, complete with analyses and top-level drawings.

Deliverables: Conceptual designs for food preparation or food processing equipment that can be used in partial gravity while efficiently balancing appropriate vehicle resources such as mass, volume, waste, and crew time.

TOPIC: X15 Space Radiation

The goal of the NASA Space Radiation Research Program is to assure that we can safely live and work in the space radiation environment, anywhere, any time. Space radiation is different from forms of radiation encountered on Earth. Radiation in space consists of high-energy protons, heavy ions and secondary products created when the protons and heavy ions interact with matter such as a spacecraft, surface of a planet, moon or asteroid. NASA requires instruments that can reliably measure these radiations. For exploration class missions, there is extraordinary premium on compact and reliable active radiation detection systems to meet very stringent size and power requirements. NASA needs compact, low power, active monitors that can measure charged particle spectrum and flux separately from neutrons and other radiations. NASA also needs compact active neutron spectrometers that can measure the neutron component of the dose separate from the charged particles. Advanced technologies up to technology readiness level (TRL) 4 are requested in the following areas: Charged particle spectrometer that is capable of measuring charge and energy spectra of ions with energies, linear energy transfer (LET) characteristics, and dose-rate parameters specified here. Neutron spectrometer that is capable of measuring neutrons with energies, dose rates, and other performance parameters specified here.

X15.01 Active Charged Particle and Neutron Measurement
Lead Center: ARC

For exploration class missions, there is extraordinary premium on compact and reliable active radiation detection systems to meet very stringent size and power requirements. NASA needs compact, low power, active monitors that can measure charged particle spectrum and flux separately from neutrons and other radiations. NASA also needs compact active neutron spectrometers that can measure the neutron component of the dose separate from the charged particles. Advanced technologies up to technology readiness level (TRL) 4 are requested in the following areas:

Charged Particle Spectrometer
Measure charge and energy spectra of protons and other ions ($Z = 2$ to 26) and be sensitive to charged particles with linear energy transfer (LET) of 0.2 to 1000 keV/micrometer. For Z less than 3, the spectrometer should detect energies in the range 30 MeV/n to 400 MeV/n. For $Z = 3$ to 26, the spectrometer should detect energies in the range 50 MeV/n to 1 GeV/n. Design goals for mass should be 2 kg and for volume, 3000 cm^3. The spectrometer should be able to measure charged particles at both ambient conditions in space (0.01 mGy/hr) and during a large solar particle event (100 mGy/hr). The time resolution should be less than or equal to 1 minute. The spectrometer shall be able to perform data reduction internally and provide processed data.

Neutron Spectrometer
Measure neutron energy spectra in the range of 0.5 MeV to 150 MeV. Measure neutrons at ambient conditions such that proton/ion veto capability should be approaching 100% at solar minimum GCR rates; measure ambient dose equivalent of 0.02 mSv in a 1 hour measurement period, using ICRP 74 (1997) conversion factors; store all necessary science data for post measurement data evaluation. Design goals for mass and volume should be 5 kg and 6000 cm^3.

TOPIC: X16 Inflight Biological Sample Preservation and Analysis

Flight resources such as the International Space Station are essential assets for the Human Research Program goals of quantifying the human health and performance risks for crews during exploration missions. However, the resources for carrying supplies and returning biological samples to/from these assets are limited. Thus, the Human Research Program must identify the means for inflight sample analysis or unique sample processing techniques that minimize the need to return conditioned human samples for analysis. The Inflight Biological Sample Preservation and Analysis topic is seeking innovative technologies or techniques to: provide On Orbit Ambient Biological Sample Preservation Techniques and On Orbit Biologic Sample Analysis capabilities.

X16.01 Alternative Methods for Ambient Preservation of Human Biological Samples During Extended Spaceflight and Planetary Operations
Lead Center: JSC
Participating Center(s): ARC

Measurement of blood, plasma, and urine analytes is a common clinical medicine practice used for differential disease diagnosis and determination of the therapeutic response to treatment. Accurate biochemical results depend on maintaining the integrity of blood and urine samples until analyses can be completed. Improper sample collection, handling, or preservation may lead to critical errors in diagnostic interpretation of analytical results. Traditional methods have been developed that include the use of sample component separation by means of centrifugation, refrigeration, freezing or the addition of preservatives to maintain the integrity of biological samples. While such techniques are easily achieved in a routine clinical setting, the spaceflight environment presents unique challenges to sample processing and stowage. Thus, novel on-orbit methods for the ambient preservation of biological samples are critical for scientific research, monitoring of crew health and evaluation of countermeasure efficacy. The development of alternative innovative techniques with advantages over currently used methods for processing and preserving biological samples at ambient temperatures during spaceflight that provide a high level of reliability in maintaining a wide array of both blood and urine analytes over a long period of ambient stowage is highly desirable.

Phase I expectations include at a minimum a fully developed concept with feasibility analyses. A prototype is highly desirable.

9.1.3 SCIENCE

NASA leads the nation on a great journey of discovery, seeking new knowledge and understanding of our planet Earth, our Sun and solar system, and the universe out to its farthest reaches and back to its earliest moments of existence. NASA's Science Mission Directorate 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://nasascience.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 (http://nasascience.nasa.gov/astrophysics), Earth Science (http://nasascience.nasa.gov/earth-science), Heliophysics (http://nasascience.nasa.gov/heliophysics), and Planetary Science (http://nasascience.nasa.gov/planetary-science). A major objective of SMD instrument development programs is to implement science measurement capabilities with smaller or more affordable spacecraft so development programs can meet multiple mission needs and therefore make the best use of limited resources. The rapid development of small, low-cost remote sensing and in situ instruments is essential to achieving this objective. For Earth Science needs, in particular, the subtopics reflect a focus on instrument development for airborne and Unmanned Aerial Vehicle (UAV) platforms. Astrophysics has a critical need for sensitive detector arrays with imaging, spectroscopy, and polarimetric capabilities which can be demonstrated on ground, airborne, balloon, or suborbital rocket instruments. Heliophysics, which focuses on measurements of the sun and its interaction with the Earth and the other planets in the solar system, needs a significant reduction in the size, mass, power, and cost for instruments to fly on smaller spacecraft. Planetary Science has a critical need for miniaturized instruments with in situ sensors that can be deployed on surface landers, rovers, and airborne platforms. For the 2010 program year, we are actively encouraging proposal submissions for subtopic S1.10 that solicits technology for geodetic instruments and instruments to enable global navigation and very long baseline interferometry. A key objective of this SBIR topic is to develop and demonstrate instrument component and subsystem technologies that reduce the risk, cost, size, and development time of SMD observing instruments and to enable new measurements. Proposals are sought for development components that can be used in planned missions or a current technology program. Research should be conducted to demonstrate feasibility during Phase I and show a path towards a Phase II prototype demonstration. The following subtopics are concomitant with these objectives and are organized by technology.

S1.01 Lidar and Laser System Components
Lead Center: LaRC
Participating Center(s): GSFC, JPL

Accurate measurements of atmospheric parameters with high spatial resolution from ground, airborne, and space-based platforms require advances in the state-of-the-art lidar technology with emphasis on compactness, efficiency, reliability, lifetime, and high performance. Innovative lidar component technologies that directly address the measurements of the atmosphere and surface topography of the Earth, Mars, the Moon, and other planetary bodies will be considered under this subtopic. Frequency-stabilized lasers for a number of lidar applications such as CO_2 concentration measurements as well as for highly accurate measurements of the distance between spacecraft for gravitational wave astronomy and gravitational field planetary science are among technologies of interest. Innovative technologies that can expand current measurement capabilities to spaceborne or Unmanned Aerial Vehicle (UAV) platforms are particularly desirable. Development of components that can be used in planned missions or current technology programs is highly encouraged. Examples of planned missions and technology programs are: Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI), Laser Interferometer Space Antenna (LISA), Doppler Wind Lidar, Lidar for Surface Topography (LIST), or Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS).

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II prototype demonstration. For the PY10 SBIR Program, we are soliciting only the specific component technologies described below.

- Highly efficient solid state laser transmitter operating in the 1.0 µm – 1.7 µm range with wall-plug efficiency of greater than 25%. The proposed laser must show path in maturing to space applications. The laser transmitter must be capable of single frequency with narrow spectral width capable of generating transform-limited pulses, and M2 beam quality < 1.3. We are interested in two different regimes of repetition rate and output energy: in one case, repetition rate from 5 to 20 kHz with pulse energy from 2 - 10 mJ, and in the second case, repetition rate 100 Hz to 4 kHz with pulse energy from 30 - 300 mJ. In addition, development of non-traditional optical amplifier architectures that yield optical efficiency of >70% are of interest. Although amplifiers such as planar waveguide or grazing incidence have been shown to generate optical efficiencies >50%, much higher efficiency is needed for space applications. Proposed solutions should incorporate electronics packages suitable for use in aircraft demonstration (i.e., small, well packaged, low power).

- Efficient and compact single mode solid state or fiber lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for direct detection DIAL and coherent lidar applications. These lasers must meet the following general requirements: pulse energy 0.5 mJ to 50 mJ, repetition rate 10 Hz to 1 kHz, and pulse duration of either 10 nsec or 200 nsec regimes.
- Single frequency semiconductor or fiber laser generating CW power greater than 50 mW in 1.5 or 2.0 micron wavelength regions with less than 10 kHz linewidth tunable over several nanometers. Frequency modulation with about 5 GHz bandwidth over 1 msec period is highly desirable.
- Novel compact solid-state UV laser for Ozone DIAL measurements operating within the 300 nm - 320 nm wavelength range generating laser pulses of up to 1 KHz rate and average output power greater than 1 Watt. Operation at two distinct wavelengths separated by 10 nm to 15 nm is required for the Ozone measurements. Scalability of the laser design to power levels greater than 10 W for space deployment is important.
- Novel scanning telescope capable of scanning over 360 degrees in azimuth with nadir angle fixed in the range of 30 to 45 degrees. Clear apertures scalable to 1 m, good optical performance (although diffraction limited performance is not necessary), and high optical efficiency are desired, as is ability to operate at multiple wavelengths from 1064 nm to 355 nm. Optical materials (e.g. substrates and coatings) and components should be space qualifiable. Phase II should result in a prototype unit capable of demonstration in a high-altitude aircraft environment, with aperture on the order 8 inches. Due to issues with spacecraft momentum compensation and previous investments, concepts for large articulating telescopes will not be considered responsive to this request, nor will holographic substrates.
- High quantum efficiency, low-noise detectors operating at 355, 532, and 1064 nm suitable for space applications. Detectors must have an active area diameter greater than 0.5 mm and be capable of temporal resolutions less than 0.67 microsecond. Detectors must be linear over 4 orders of magnitude in dynamic range and suitable for analog detection schemes. Associated electronics including amplifiers and filters with matching impedance are desired.
- Flash Lidar Receiver for planetary landing application with at least 128X128 pixels capable of generating 3-dimensional images and detection of hazardous terrain features, such a as rocks, craters and steep slopes from at least 1 km distance. The receiver must include real-time image processing capability with 30 Hz frame rate. Embedded image enhancement and classification algorithms are highly desirable. Proposals for low noise Avalanche Photodiode (APD) arrays with 256x256 pixels format suitable for use in Flash Lidar receiver will be also considered. The detector array must operate in the 1.06 to 1.57 micron region and be able to detect laser pulses with 6 nsec in duration. The array needs to achieve greater than 90% fill factor with a pitch size of 50 to 100 microns with provisions for hybridization with an Integrated Readout Circuit (ROIC).

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

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

NASA employs active sensors (radars) for a wide range of remote sensing applications (for example, see: http://www.nap.edu/catalog/11820.html). These sensors include low frequency (less than 10 MHz) sounders to G-band (160 GHz) radars for measuring precipitation and clouds and for planetary landing. We are seeking proposals for the development of innovative technologies to support future radar missions and applications. The areas of interest for this call are listed below:

- **High -density low- loss millimeter-wave packaging and interconnects** for Advanced Cloud and Precipitation Radars and Mars Landing Radars. These packing and interconnect technologies are critical to achieving the density and RF signal performance required for scanning millimeter-wave array radars.
  - Frequency: 35 - 160 GHz
  - Interconnect loss: <0.05 dB @35 GHz
  - Line loss: <0.1 dB/cm @35 GHz

- **High -speed, low- power analog -to -digital converters (ADCs) and digital -to –analog Converters (DACs)** for Advanced SAR, Advanced Interferometer for Surface monitoring, ice topography, and hydrology. Digital beam forming (DBF) systems require an array of ADCs. The power consumption of current ADC chips prohibits implementation of large DBF arrays. Furthermore, large arrays require true time delays, which can be implemented using low- power high speed ADCs and DACs. Ideal ADCs are modeled with perfectly linear input-output transfer functions. In addition to seeking novel devices, we are seeking innovative methods to correct for both differential and integral nonlinearities (DNL and INL) in ADCs to increase ADC ENOB. Proposed methods should be adaptable to a wide range of sampling rates, input frequencies, and device types; furthermore, they should be amenable to realtime operation on an FPGA.
  - Bandwidth: 1.5 GHz
  - Sampling rate: 500 MS/s
  - ENOB: 12 bits
  - Power consumption: 100 mW

- **Compact True-Time Delay Beamformers** for Advanced Cloud and Precipitation Radars, Mars Landing Radars, and Advanced SAR. Large, wideband scanned arrays require true-time-delay beamforming to avoid beam squint over operating frequency range.
  - Center Frequencies: 35, 94, 160 GHz
  - Inputs: 128
  - Loss: <6dB
  - Mass: < 250g

- **Dual frequency Millimeter-wave transmit/receive MMICs** for Advanced SAR, Advanced Interferometer for surface monitoring, ice topography, hydrology, Advanced Cloud and Precipitation Radars, and Mars Landing Radars. Monolithic integration of TR function is required to meet space constraints for high-density arrays and to reduce assembly costs.
  - Frequencies: 35/94 GHz
  - Transmit Power: 5W@35GHz, 1W@94 GHz
  - TX PAE: >25%
  - TX Gain >20 dB
  - TX/RX Switch Isolation: 40 dB
  - RX NF: <3 dB
  - RX Gain: > 20 dB
  - Phase Shifter: 360 deg, 6-bits

- **Ultra - high efficiency P-band and L - band power amplifiers** for Advanced SAR / Interferometers, Geosynchronous SAR for earthquake monitoring, and Mars subsurface sounding. Using lower efficiency amplifiers in large arrays leads to much higher power system requirements and thermal management challenges.
  - Frequency: 400-500 MHz, 1.2-1.3 GHz
  - Efficiency: >85%

- **High Efficiency Ka-band and W-band Vacuum Device Amplifiers** for Advanced Cloud and Precipitation Radars, Advanced SAR, Telecommunications. Using lower efficiency amplifiers leads to much higher power system requirements and thermal management challenges.
    - Center Frequencies: 35, 94 GHz
    - Power output: 1-5 kW (for pulsed operation); 25 W (for CW operation)
    - Efficiency: >50%

- **Frequency selective surface at Ka and W-band** for Clouds and Precipitation, ACE Decadal Survey Mission. A Ka/W frequency selective surface will enable the development of compact dual frequency radar using a shared single aperture antenna, significantly reducing the dual radar beam pointing error, and radar development cost.
    - High reflection at Ka-band (35GHz) and high pass (low loss) at W-band (94 GHz).
    - Power handling requirement: 2 kW (peak), 100 W (average)

- **FPGA based Radar Pulse Compression Technology and techniques** for Clouds and Precipitation, and ACE Decadal Survey Mission. Cloud and precipitation radars require very high system sensitivity that can be achieved using pulse compression. However, conventional pulse compression techniques cannot be used in downward-looking spaceborne and airborne radar applications due to poor range sidelobe performance.
    - Achieves low range side lobe levels (<-70dB), and low SNR loss. Must include methods to compensate for all sources of noise, distortion and drift in radar transmitter and receiver.

- **Radar Receiver Protector** for Clouds and Precipitation and ACE Decadal Survey Mission. Spaceborne and airborne cloud/precipitation radars require medium to high peak power transmitters in order to achieve the desired system sensitivity. High speed, low loss receiver protector is necessary to prevent RF damage of the receiver components.
    - W-band (94 GHz), Ka-band (35GHz), low loss (< 0.5 dB), high speed (transition time < 500 ns) switching radar receiver protector.

- **Technologies and techniques for noise assisted data analysis of I-Q ensemble detection** for Clouds and Precipitation, ACE Decadal Survey. Radar receiver technologies that mix in-phase and quadrature components of radar returns with calibrated-correlated noise references and noise assisted data analysis algorithms are sought to reduce the effects of platform motion on Doppler measurement and retrieval of hydrometeor drop size distribution. Pulse pair and spectral processing drive the need for a large aperture to reduce the effect of platform motion on Doppler estimates.

- **Multi-frequency compact, light weight electronically tunable antennas and radar systems** for Ice sheet sounding, subsurface exploration of planetary and near-Earth objects. Low, multi-frequency active radars are often used for ice sounding and subsurface exploration of planets, moons and near-Earth objects/bodies. The large size and narrow bandwidth of HF/VHF antennas and radars make them unsuitable for many applications. Compact, light weight electronically tunable antennas and radar systems will enable a range of missions.
    - Compact, light weight, electronically tunable antennas, and radars units to make up basic building blocks of transmission-reflection tomography radars.
    - Tunable Frequency Ranges:
    - 3-30 MHz, 25-100 MHz
    - VSWR: <2:1
    - Length: <6m, conformable to aircraft or spacecraft
    - Gain: >0 dBi
    - Power handling: >200W

S1.03 Passive Microwave Technologies
Lead Center: GSFC
Participating Center(s): JPL

NASA employs passive microwave and millimeter-wave instruments for a wide range of remote sensing applications from measurements of the Earth's surface and atmosphere (http://www.nap.edu/catalog.php?record_id=11820) to cosmic background emission. Proposals are sought for the development of innovative technology to support future science and exploration missions employing 450 MHz to 5 THz sensors. Technology innovations should either enhance measurement capabilities (e.g., improve spatial, temporal, or spectral resolution, or improve calibration accuracy) or ease implementation in spaceborne missions (e.g., reduce size, weight, or power, improve reliability, or lower cost). While other concepts will be entertained, specific technology innovations of interest are listed below for missions including decadal survey missions (http://www.nap.edu/catalog/11820.html) such as PATH, SCLP, and GACM and the Beyond Einstein Inflation Probe (Inflation Probe - cosmic microwave background, http://science.gsfc.nasa.gov/660/research/)

- RF (GHz to THz) MEMS switches with low insertion loss (< 0.5 dB), high isolation (>18 dB), capable of switching with speeds of >100 Hz at cryogenic temperatures (below 5 K) for 10^8 or more cycles. Technology applies to Beyond Einstein Probe.
- MEMs variable delay line up to 40 GHz with 180 degree of phase variation at room temperature. The delay line's phase increment should be linear or with at least 16 discrete steps. Applies to: Venture class airborne instruments, SCLP.
- MMIC Low Noise Amplifiers (LNA). Room temperature LNAs for 165 to 193 GHz with low 1/f noise, and a noise figure of 6.0 dB or better; and cryogenic LNAs for 180 to 270 GHz with noise temperatures of less than 150K. Earth Science Decadal Survey missions that apply: PATH and GACM.
- Enabling technology for ultra-stable microwave noise references (three or more) embedded in switched network with reference stability (after temperature correction) to within 0.01K/year. Applies to: PATH, SCLP, GACM, SWOT.
- High emissivity (>40 dB return loss) surfaces/structures for use as onboard calibration targets that will reduce the weight of aluminum core targets, while reliably improving the uniformity and knowledge of the calibration target temperature. Earth Science Decadal survey missions which apply: SCLP and PATH.
- Broad band 180 - 270 GHz radomes for aircraft borne submillimeter remote sensing instruments.
- Multi-Frequency and/or multi-Beam Focal Plane Arrays (FPA) as a primary feed for reflector antennas. PATH, SCLP, SWOT.
- Low power >200 Mb/s 1-bit A/D converters and cross-correlators for microwave interferometers. Earth Science Decadal survey missions which apply: PATH, SCLP.
- Automated assembly of 180 GHz direct conversion I-Q receiver modules. This technology applies to both the Beyond Einstein Inflation probe and the Decadal Survey PATH concept.
- Low DC power spectrometer (channelizer) covering >500 MHz with 125 kHz resolution for planetary radiometer missions and covering 4 GHz with 1 MHz resolution for Earth observing missions. Also RFI mitigation approaches employing channelizers for broad band radiometers. Earth Science Decadal Survey mission which applies: GACM

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

S1.04 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter
Lead Center: JPL
Participating Center(s): ARC, GSFC, KSC, LaRC

NASA is seeking new technologies or improvements to existing technologies to meet the detector needs of future missions, as described in the most recent decadal surveys for Earth science (http://www.nap.edu/catalog/11820.html), planetary science (http://www.nap.edu/catalog/10432.html), and astronomy and astrophysics(http://www.nap.edu/books/0309070317/html/).

The following technologies are of interest for the Scanning Microwave Limb Sounder (http://mls.jpl.nasa.gov/index-cameo.php) on the Global Atmospheric Composition Mission, Single Aperture Far Infrared (SAFIR) Observatory (http://safir.jpl.nasa.gov/technologies.shtml), the SOFIA (Stratospheric Observatory for Infrared Astronomy) airborne observatory (http://www.sofia.usra.edu/), and Inflation Probe (cosmic microwave background, http://science.gsfc.nasa.gov/660/research/):

- Radiation tolerant digital polyphase filterbank back ends for sideband separating microwave spectrometers. Requirements are >5GHz instantaneous bandwidth per sideband, 2 MHz resolution, low power (<5 W/GHz), and 4 bits or higher digitization.
- Improved submillimeter mixers for frequencies >2 THz are needed for heterodyne receivers to fly on SOFIA. Minimum noise temperatures for cyrogenic operation and instantaneous bandwidths >5 GHz are key parameters.
- Large format (megapixel) broadband detector arrays in the 30 to 300 micron wavelength range are needed for SAFIR. These should offer background limited operation with cooled (5 K) telescope optics, and have minimal power dissipation at low temperatures. Low power frequency multiplexers are also of interest for readout of submm bolometer arrays for SAFIR and Inflation Probe.

High performance sensors and detectors that can operate with low noise under the severe radiation environment (high energy electrons, ≥1 megarad total dose) anticipated during the Europa Jupiter System Mission (EJSM) are of interest (see the Jupiter Europa Orbiter Mission Study 2008: Final Report, http://opfm.jpl.nasa.gov/library/). Notional instruments include visible and infrared cameras and spectrometers, a thermal imager and laser altimeter. Devices can be radiation hardened by design and/or process:

- Hardened visible imaging arrays with low dark currents even in harsh radiation environments, line or framing arrays suitable for use in pushbroom and framing cameras. Detectors include CCDs (n or p-channel), CMOS imagers, PIN photodiode hybrids, etc.
- Hardened infrared imaging arrays with a spectral range of 400 to 5000 nm with high quantum efficiency and low dark current, as well as compatible radiation hardened CMOS readouts. These devices could include substrate removed HgCdTe hybrid focal plane arrays responsive from 400 to 2500 nm and IR only focal plane arrays responsive from 2500 nm to 5000 nm.
- High speed radiation hardened avalanche photodiodes that respond to a 1.06 micron laser beam suitable for use in time of flight laser rangefinders. Devices should have high and stable gain with lower dark current in harsh radiation environments.
- Radiation hardened detectors suitable for use in uncooled thermal imagers that respond to spectral bands ranging from 8 to 100 microns. Detectors could include thermopile or microbolometer small line arrays.

Technologies are needed for active and passive wave front and amplitude control, and relevant missions include Extra solar Planetary Imaging Coronagraph (EPIC), and other coronagraphic missions such as Terrestrial Planet Finder (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) and Stellar Imager (http://hires.gsfc.nasa.gov/si/):

- Spatial Filter Array (SFA) consisting of a monolithic array of up to 1200 coherent, polarization preserving, single mode fibers, or custom waveguides, that operate with minimal coupling losses over a large fraction of the spectral range from 0.4 - 1.0 microns. The SFA should have input and output lenslet with each pair mapped to a single fiber or waveguide and such that the lenslets maintain path length uniformity to < 100 nm. Uniformity of both output intensity and wave front phase, and high throughput is desired and fiber-to-fiber placement accuracies of < 1.0 microns are required with < 0.5 microns desired.
- MEMS based segmented deformable mirrors consisting of arrays of up to 1200 hexagonal packed segments with strokes over the range of 0 to 1.0 microns, quantized with 16-bit electronics with segment level

stabilities of 0.015 nm rms (1-bit) over 1 hour intervals. Segments should be flat to 2 nm rms or better and the substrate flat to 125 nm or better and high uniformity of coatings (1% rms).

S1.05 Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments
Lead Center: GSFC
Participating Center(s): JPL, MSFC

This subtopic covers detector requirements for a broad range of wavelengths from UV through to gamma ray for applications in Astrophysics, Earth science, Heliophysics, and Planetary science. Requirements across the board are for greater numbers of readout pixels, lower power, faster readout rates, greater quantum efficiency, and enhanced energy resolution.

The proposed efforts must be directly linked to a requirement for a NASA mission. These include Explorers, Discovery, Cosmic Origins, Physics of the Cosmos, Vision Missions, and Earth Science Decadel 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:
EXIST: http://exist.gsfc.nasa.gov/,
IXO: http://htxs.gsfc.nasa.gov/index.html,
Future Planetery Programs: http://nasascience.nasa.gov/planetary-science/mission_list,
Earth Science Decadel Missions: http://www.nap.edu/catalog/11820.html
Helio Probes: http://nasascience.nasa.gov/heliophysics/mission_list

Specific technology areas are listed below:

- Significant improvement in wide band gap semiconductor materials, individual detectors, and detector arrays for operation at room temperature or higher for missions such as EXIST, Geo-CAPE 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 Council Decadal Survey (NRC, 2007): Future Missions include EXIST, GEOCape, HyspIRI, GACM, future GOES and SOHO programs and planetary science composition measurements.
- Large format UV and X-ray focal plane detector arrays: micro-channel plates, CCDs, and active pixel sensors (>50% QE, 100 Megapixels, <0.1 W/Megapixel, 30 Hz). Improved micro-channel plate detectors, including improvements to the plates themselves (smaller pores, greater lifetimes, alternative fabrication technologies, e.g., silicon), as well as improvements to the associated electronic readout systems (spatial resolution, signal-to-noise capability, and dynamic range), and in sealed tube fabrication yield. Possible future mission applications are the International X-ray Observatory, Advanced Technology Large Aperture Space Telescope (ATLAST) and Black Hole Imager.
- Advanced Charged Couple Device (CCD) detectors, including improvements in UV quantum efficiency and read noise, to increase the limiting sensitivity in long exposures and improved radiation tolerance. Electron-bombarded CCD detectors, including improvements in efficiency, resolution, and global and local count rate capability. In the X-ray, we seek to extend the response to lower energies in some CCDs, and to higher, perhaps up to 50 keV, in others. Possible missions are future GOES missions and International X-ray Observatory.
- Wide band gap semiconductor, radiation hard, visible and solar blind large format imagers for next generation hyperspectral Earth remote sensing experiments. Need larger formats (>1Kx1K), much higher resolution (<18μm pixel size), high fill factor and low read noise (<60 electrons). See needs of National Council Decadal Survey (NRC, 2007): Future missions include GEOCape, HyspIRI, GACM.

- Solar blind, compact, low-noise, radiation hard, EUV and soft X-ray detectors are required. Both single pixels (up to 1cm x 1cm) and large format 1D and 2D arrays are required to span the 0.05nm to 150nm spectral wavelength range. Future GOES missions post-GOES R and T.
- Visible-blind SiC APDs for EUV photon counting are required. The APDs must show a linear mode gain >1E6 at a breakdown reverse voltage between 80 and 100V. The APD's must demonstrate detection capability of better than 6 photons/pixel/s at near 135nm spectral wavelength. See needs of National Council Decadal Survey (NRC, 2007): Tropospheric ozone.
- Imaging from low-Earth orbit of air fluorescence, UV light generated by giant airshowers by ultra-high energy (E >10E19 eV) cosmic rays require the development of high sensitivity and efficiency detection of 300-400 nm UV photons to measure signals at the few photon (single photo-electron) level. A secondary goal minimizes the sensitivity to photons with a wavelength greater than 400 nm. High electronic gain (~106), low noise, fast time response (<10 ns), minimal dead time (<5% dead time at 10 ns response time), high segmentation with low dead area (<20% nominal, <5% goal), and the ability to tailor pixel size to match that dictated by the imaging optics. Optical designs under consideration dictate a pixel size ranging from approximately 2 x 2 mm^2 to 10 x 10 mm^2. Focal plane mass must be minimized (2 g/cm^2 goal). Individual pixel readout is required. The entire focal plane detector can be formed from smaller, individual sub-arrays.
- Large area (3 m**2) photon counting near-UV detectors with 3 mm pixels and able to count at 10 MHz. Array with high active area fraction (>85%), 0.5 Megapixels and readout less than 1 mW/channel. Future instruments are JEM-EUSO and OWL.
- Large area (m**2) X-ray detectors with <1mm pixels and high active area fraction (>85%).

Future instrument is a Phased-Fresnel X-ray Imager.

S1.06 Particles and Field Sensors and Instrument Enabling Technologies
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC, MSFC

Advanced sensors and instrument enabling technologies for the measurement of the physical properties of space plasmas and energetic charged particles, mesospheric – thermospheric neutral species, energetic neutral atoms created at high altitudes by charge exchange, and electric and magnetic fields in space are needed to achieve NASA's transformational science advancements in Heliophysics. The Heliophysics discipline (http://nasascience.nasa.gov/heliophysics) has as its primary strategic goal the understanding of the physical coupling between the sun's outer corona, the solar wind, the trapped radiation in Earth's and other planetary magnetic fields, and the upper atmospheres of the planets and their moons. This understanding is of national importance not only because of its intrinsic scientific worth, but also because it is the necessary first step toward developing the ability to measure and forecast the "space weather" that affects all human crewed and robotic space assets. Improvements in particles and fields sensors and associated instrument technologies will enable further scientific advancement for upcoming NASA missions such as Solar Probe Plus (SPP) (http://nasascience.nasa.gov/missions/solar-probe), Origins of Near Earth Plasma (ONEP), Solar Energetic Particle Acceleration and Transport (SEPAT), Ion-Neutral Coupling in the Atmosphere (INCA), Climate Impacts of Space Radiation (CISR), Dynamic Geospace Coupling (DGC) (http://sec.gsfc.nasa.gov/sec_roadmap.htm) and planetary exploration missions. Technology developments that result in expanded measurement capabilities and a reduction in size, mass, power, and cost are necessary in order for some of these missions to proceed. Of special interest are fast high voltage stepping power supplies for charged particle analyzers, electric field booms, self calibrating vector magnetometers, and other supporting sensor electronics.

Specific areas of interest include:

- Low cost, low power, low current, high voltage power supplies which allow ultra-fast stepping (t < 100-µs) over the full voltage range (0 < V < 5-15 kV).

- Strong, lightweight, thin, compactly-stowed electric field booms possibly using composite materials that deploy sensors to distances of 10m or more and/or long wire boom (> 50 m) deployment systems for the deployment of very lightweight tethers or antennae on spinning spacecraft.
- Self-calibrating scalar-vector magnetometer for future Earth and space science missions. Performance goals are dynamic range: +/-100,000 nT, accuracy with self-calibration: 1 nT, sensitivity: 5 pT / sqrtHz,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".
- Low-power cathode for detection of neutral atoms and molecules ionosphere-thermosphere and planetary investigations. Performance goals are thermionic cathodes capable of emitting 1 mA electron current with heater power less than 0.1 W. The largest dimension of the electron emitter surface should not exceed 1 mm; the entire cathode assembly should be small enough so it may be mounted in a shallow channel shaped to match the largest cathode dimension. The assembly should include robust connection leads for heater and cathode surface. Uniformity across the electron beam is not critical.

S1.07 Cryogenic Systems for Sensors and Detectors
Lead Center: GSFC
Participating Center(s): ARC, JPL, MSFC

Cryogenic cooling systems often serve as enabling technologies for detectors and sensors flown on scientific instruments as well as advanced telescopes and observatories. As such, technological improvements to cryogenic systems (as well as components) further advance the mission goals of NASA through enabling performance (and ultimately science gathering) capabilities of flight detectors and sensors. Presently, there are six potential investment areas that NASA is seeking to expand state of the art capabilities in for possible use on future programs such as IXO (http://ixo.gsfc.nasa.gov/), Safir (http://safir.jpl.nasa.gov/), Spirit and Specs, Planetary and Europa science missions (Jupiter Europa Orbiter (JEO), Jupiter Ganymede Orbiter (JGO), Titan Saturn System mission (TSSM)). The topic areas are as follows:

Extremely Low Vibration Cooling Systems
Examples of such systems include joule thomson coolers, pulse tube coolers and turbo brayton cycles. Desired cooling capabilities sought are on the order of 40 mW at 4K or 1W at 50K. Present state of the art capabilities display < 100 mN vibration at operational frequencies of 30-70 Hz. Proposed systems should either satisfy or improve upon this benchmark.

Advanced Magnetic Cooler Components
Continuous ADRs can operate at 50 mK or lower, with heat sinks up to 5 K. Refrigerators with larger operating temperature range (lower cold temperature, higher heat sink temperature), having lower mass, lower (or zero) fringing magnetic fields, and/or more efficient operation are sought. In addition, technologies that improve system performance (e.g., HTS leads) are also sought. Examples of specific components include:

- Low current superconducting magnets
- Active/Passive magnetic shielding (3-4 Tesla magnets)
- Single or polycrystalline magnetocaloric materials (< 1 cm^3)
- Superconducting leads (10K - 90K) capable of 10 amp operation with 1 mW conduction
- 10 mK scale thermometry.

Continuous Flow Distributed Cooling Systems
Distributed cooling provides increased lifetime of cryogen fluids for applications on both the ground and spaceborne platforms. This has impacts on payload mass and volume for flight systems which translate into costs (either on the ground, during launch or in flight). Cooling systems that provide continuous distributed flow are a cost effective alternative to present techniques/methodologies. Cooling systems that can be used with large loads and/or deployable structures are presently being sought after.

Heat Switches
More robust heat switches (e.g., operating ranges and conductance performance) are currently needed that are easy to operate and applicable to spaceflight activities. Performance capabilities include heat switches for operating ranges < 0.2K and 0.2K-10+K, switches with On/Off conductance (i.e., switching) ratios of 10^5 or greater, low off conductance and simple manufacturing/operational capability.

Highly Efficient Magnetic and Dilution Cooling Technologies < 1K
These systems are currently limited to continuous ADR performance capabilities. Alternative technologies that provide sub-Kelvin cooling are sought.

Low Input Power/Low Temperature Cooling Systems
Cooling systems providing cooling capacities upwards of 0.3W at 35K with heat rejection capability to temperature sinks as low as 150K are of interest. Presently there are no cooling systems operating at this heat rejection temperature. Input powers should be limited to no greater than 20W.

S1.08 In Situ Airborne, Surface, and Submersible Instruments for Earth Science
Lead Center: GSFC
Participating Center(s): ARC, JPL, KSC, LaRC, MSFC, SSC

New, innovative, high risk/high payoff approaches to miniaturized and low cost instrument systems are needed to enhance Earth science research capabilities. Sensor systems for a variety of platforms are desired, including those designed for remotely operated robotic aircraft, surface craft, submersible vehicles, balloon-based systems (tethered or free), and kites. Global deployment of numerous sensors is an important objective, therefore cost and platform adaptability are key factors.

Novel methods to minimize the operational labor requirements and improve reliability are desired. Long endurance (days/weeks/months) autonomous/unattended instruments with self/remote diagnostics, self/remote maintenance, capable of maintaining calibration for long periods, and remote control are important. Use of data systems that collect geospatial, inertial, temporal information, and synchronize multiple sensor platforms are also of interest.

Priorities include:

- Atmospheric measurements in the troposphere and lower stratosphere: Aerosol Optical and Microphysical Properties, Cloud Properties and Particles, Water, Chemical Composition, i.e.; Carbon Dioxide ($12CO_2$ and $13CO_2$), Carbon Monoxide, Methane, Nitrogen Dioxide, Hydrogen Peroxide, Formaldehyde, Bromine Oxides, Ozone, and Three-dimensional Winds and Turbulence.
- Oceanic, coastal, and fresh water measurements including inherent and apparent optical properties, temperature, salinity, currents, chemical and particle composition, sediment, and biological components such as nutrient distribution, phytoplankton, harmful algal blooms, fish or aquatic plants.
- Instrument systems for hazardous environments such as volcanoes and severe storms, including measurements Sulfur Dioxide, Particles, and Precipitation.
- Land Surface characterization geopotential field sensors, such as gravity, geomagnetic, electric, and electromagnetic.
- Miniaturized instrument systems for submersible vehicles and tethered sub-surface observation systems for difficult to access water bodies associated with glaciers, including sub-glacial lakes, melt-water channels, and sub-ice shelf environments. Systems may be put down boreholes or placed on small submersibles and are required to map all aspects of cavity shape; determine sediment depth, composition, and spatial variability by acoustic or other methods; and measure water currents, temperature, thermal structure, and composition.

Instrument systems to support satellite measurement calibration and validation observations, as well as field studies of fundamental processes are of interest. A priority is applicability to NASA's research activities such as the

Atmospheric Composition and Radiation Sciences programs, including Airborne Science support thereof, as well as the Applied Sciences, and Ocean Biology and Biogeochemistry programs. Support of the Integrated Ocean Observing System (IOOS) and regional coastal research is also desired.

S1.09 In Situ Sensors and Sensor Systems for Planetary Science
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC, KSC, LaRC, MSFC

This subtopic solicits development of advanced instrument technologies and components suitable for deployment on planetary missions which access the widely diverse bodies in our solar system. These instruments 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 scientific measurements are solicited. For example missions, see http://science.hq.nasa.gov/missions/solar system.html. For details of the specific requirements see the Planetary Science Decadal Survey white papers on NASA Assessment Groups websites (OPAG, MEPAG, VEXAG, SBAG) or the National Academy of Science site http://www8.nationalacademies.org/ssbsurvey/publicview.aspx.

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 in situ measurements of elemental, mineralogical, and organic composition of planetary materials. 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.).
- Europa: Technologies, 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 are sought.
- Titan: Methods and technologies to achieve much higher resolution and sensitivity orbital instruments with significant improvements over those flown on Cassini. 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) for use on Titan’s surface. Mechanical and electrical components and subsystems that work in cryogenic (95K) environments are particularly sought after. 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 particularly solicited. Balloon instruments, such as IR spectrometers, imagers, meteorological instruments, radar sounders, air sampling mechanisms for mass analyzers, and aerosol detectors are also required.
- 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, improved determination of atmospheric and isotopic composition, and external sample acquisition into a pressure vessel are particularly desired. Sample acquisition and processing system for multiple samples that could operate under Venus surface conditions are sought.

- Small Bodies: Technologies that can enable sampling from asteroids and from depth in a comet nucleus, improved in situ analysis of comets.
- Planetary Probes: Technologies are sought for components, sample acquisition and instrument systems that can withstand the high temperature/pressure of Saturn and Neptune atmospheric probes during entry.

Proposers are strongly encouraged to relate their proposed development to (a) NASA's future planetary exploration goals, and (b) 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.

Proposers should show an understanding of relevant space science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S1.10 Space Geodetic Observatory Components
Lead Center: GSFC
Participating Center(s): JPL

NASA is working with the international community to develop the next generation of geodetic instruments and networks to determine the terrestrial reference frame with accuracy better than one part per billion. These instruments include Global Navigation Satellite System (GNSS) receivers, Very Long Baseline Interferometry (VLBI) systems, and Next Generation Satellite Laser Ranging (SLR) stations. The development of these instruments and the needed integrating technology will require contributions from a broad variety of optical, microwave, antenna and survey engineering suppliers. These needs include but are not limited to:

- Broadband feeds capable of receiving GNSS signals, Ka-band feeds integrated with broadband feeds, and matching antennas that meet or exceed the slewing and duty cycle requirements of the IVS VLBI2010 specifications.
- VLBI system components including > 4 Gbps recorders, phase/cable calibrators, frequency standards / distribution systems and cluster or GPU-enhanced correlators that meet or exceed the requirements of the IVS VLBI2010 specifications.
- Cost-effective data transmission for e-VLBI from a global network of 30 VLBI stations operating up to 8 Gbps.
- Compact, low mass, space-qualified for MEO, SLR retroreflector arrays with greater than 100 million square meter lidar cross section, with a design that assures the ability to determine the array center to the center of mass of the spacecraft to a millimeter.
- A very high quantum efficiency (>50% at 532nm), low instrument noise, multi-pixilated detector for SLR use in the automated tracking.
- Wide band GNSS antenna and RF front-end technologies accommodating all expected GNSS signals in the next decade, and offering at least an order of magnitude improvements over COTS devices in terms of multipath rejection, and stability of output relative to temperature.
- Continuous, reliable co-location monitoring and control system for the relative 3-D displacement of geodetic instruments within a geodetic observatory to better than 1 mm.
- Single chip RF processors with selectable bandpasses from 1.1GHz to 2.2GHz. Greater than 50dB of gain and IF bandwidths from 10 to 60 MHz. Space-capable technology covering -40C to +85C and greater than 50 kRad TID.
- Space qualified GNSS array covering 1.15 to 1.61 GHz. Deployable from a compact, stowed position to a collector area of 1 - 2 meters, >40% efficiency. Array elements independently fed or phase combined; multiple polarizations available.

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

S1.11 Lunar Science Instruments and Technology
Lead Center: MSFC
Participating Center(s): ARC, GSFC, JPL, JSC, KSC

NASA lunar robotic science missions support the high-priority goals identified in the 2007 National Research Council report, The Scientific Context for Exploration of the Moon: Final Report (http://www.nap.edu/catalog.php?record_id=11954) Space-qualified instruments perform remote and in situ lunar science investigations, to include measurements of micrometeoroid and lunar secondary ejecta environment, lunar dust composition, reactivity and transport, searching for water ice, assessing the radiation environment, gathering long period measurements of the lunar exosphere, and conducting surface and subsurface geophysical measurements. Improving science return and/or reducing mass, power, volume, or data rates is desired.

In support of these requirements, this subtopic seeks advancements in the following areas:

Geophysical Measurements
Systems, subsystems, and components 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 compared to the Apollo Lunar Surface Experiments Package (ALSEP) instruments (http://www.hq.nasa.gov/alsj/frame.html). Instrument deployment options include robotic deployment from soft Landers, as well as emplacement by hard landers or penetrators. Also of interest are portable surface ground penetrating radars with antenna frequencies of 250-MHz, 500-MHz, and 1000-MHz to characterize the thickness of the lunar regolith. Also of interest are accurate, low mass, thermally stable hollow cubes and retroreflector array assemblies for lunar surface laser ranging.

In Situ Lunar Surface Measurements
Light-weight and power efficient instruments that enable elemental and/or mineralogy analysis using techniques 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 (TDL) sensors for in situ isotopic and elemental analysis of evolved volatiles, calorimetry, Laser-Raman Spectroscopy, Imaging Spectroscopy, and Laser Induced Breakdown Spectroscopy (LIBS). Instruments shall have the potential to provide isotope ratio measurements and/or hydrogen distributions to ±10 ppm locally. Characterizing the meteoroid and subsequent eject flux environment and measurements of surface and deep dielectric charging on the lunar surface should be considered. Also, self-calibrating instruments to measure surface and deep dielectric charging on a variety of materials encompassing conductors, semi-conductors, and insulators are another area. Instrument deployment options include robotic deployment from soft Landers, as well as emplacement by hard Landers or penetrators.

Lunar Atmosphere and Dust Environment Measurements
Low-mass and low-power instruments that measure the local lunar surface environment which includes but is not limited to the characterization of: micrometeoroid and lunar secondary ejecta environment, the plasma environment, surface electric field, secondary radiation at the lunar surface, and dust concentrations and its diurnal dynamics. Instrument deployment options include robotic deployment from soft Landers, as well as emplacement by hard Landers or penetrators.

Lunar Regolith Particle Analysis
A substantial portion of the particles in the Lunar Regolith are smaller than the integration volume of e-beam analytical equipment, making automated quantitative analysis extremely difficult using available approaches. Other techniques for obtaining particle analysis are desired. Example techniques include 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. The said software would then use standard image processing tools to resample to common

scales, perform appropriate discriminant analysis using the high resolution data, mixed pixel inversion, image segmentation to extract particles, and correlate chemistry with products of the discriminant analysis.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

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-degrees Kelvin. This topic will consider technologies necessary to enable future telescopes and observatories collecting electromagnetic bands, ranging from UV to millimeter waves, and also include gravity waves. The subtopics will consider all technologies associated with the collection and combination of observable signals. Earth science requires modest apertures in the 2 to 4 meter size category that are cost effective. New technologies in innovative mirror materials, such as silicon, silicon carbide and nanolaminates, innovative structures, including nanotechnology, and wavefront sensing and control are needed to build telescope for Earth science that have the potential to cost between $50 to $150M.

S2.01 Precision Spacecraft Formations for Telescope Systems
Lead Center: JPL
Participating Center(s): GSFC

This subtopic seeks hardware and software technologies necessary to establish, maintain, and operate precision spacecraft formations to a level that enables cost effective large aperture and separated spacecraft optical telescopes and interferometers (e.g., http://planetquest.jpl.nasa.gov/TPF/, http://instrument.jpl.nasa.gov/steller/). Also sought are technologies (analysis, algorithms, and testbeds) to enable detailed analysis, synthesis, modeling, and visualization of such distributed systems.

Formation flight can synthesize large effective telescope apertures through, multiple, collaborative, smaller telescopes in a precision formation. Large effective apertures can also be achieved by tiling curved segments to form an aperture larger than can be achieved in a single launch, for deep-space high resolution imaging of faint astrophysical sources. These formations require the capability for autonomous precision alignment and synchronized maneuvers, reconfigurations, and collision avoidance. The spacecraft also require onboard capability for optimal path planning and time optimal maneuver design and execution.

Innovations are solicited for: (a) sensor systems for inertial alignment of multiple vehicles with separations of tens of meters to thousands of kilometers to accuracy of 1 - 50 milli-arcseconds (b) development of nanometer to sub-nanometer metrology for measuring inter-spacecraft range and/or bearing for space telescopes and interferometers (c) control approaches to maintain line-of-sight between two vehicles in inertial space near Sun-Earth L2 to milli-arcsecond levels accuracy (d) development of combined cm-to-nanometer-level precision formation flying control of numerous spacecraft and their optics to enable large baseline, sparse aperture UV/optical and X-ray telescopes and interferometers for ultra-high angular resolution imagery. Proposals addressing staged-control experiments, which combine coarse formation control with fine-level wavefront sensing based control are encouraged.

Innovations are also solicited for distributed spacecraft systems in the following areas:

- Distributed, multi-timing, high fidelity simulations;
- Formation modeling techniques;
- Precision guidance and control architectures and design methodologies;
- Centralized and decentralized formation estimation;
- Distributed sensor fusion;
- RF and optical precision metrology systems;
- Formation sensors;
- Precision microthrusters/actuators;
- Autonomous reconfigurable formation techniques;
- Optimal, synchronized, maneuver design methodologies;
- Collision avoidance mechanisms;
- Formation management and station keeping.

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

S2.02 Proximity Glare Suppression for Astronomical Coronagraphy
Lead Center: JPL
Participating Center(s): ARC, GSFC

This subtopic addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources and innovative advanced wavefront sensing and control for cost-effective space telescopes. 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 infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission. Much of the scientific instrumentation used in future NASA observatories for the astrophysical sciences will require control of unwanted radiation (thermal and scattered) across a modest field of view. The performance and observing efficiency of astrophysics instruments, however, must be greatly enhanced. The instrument components are expected to offer much higher optical throughput, larger fields of view, and better detector performance. The wavelengths of primary interest extend from the visible to the thermal infrared. Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development, and innovative instrument design, as well as in the fabrication of subsystem devices to include, but not limited to, the following areas:

Starlight Suppression Technologies

- Advanced starlight canceling coronagraphic instrument concepts;
- Advanced aperture apodization and aperture shaping techniques;
- Advanced apodization mask or occulting spot fabrication technology controlling smooth density gradients to 10-4 with spatial resolutions ~1 µm, low dispersion, and low dependence of phase on optical density;
- Metrology for detailed evaluation of compact, deep density apodizing masks, Lyot stops, and other types of graded and binary mask elements. Development of a system to measure spatial optical density, phase inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of masks and stops is needed;

- Interferometric starlight cancellation instruments and techniques to include aperture synthesis and single input beam combination strategies;
- Pupil remapping technologies to achieve beam apodization;
- Techniques to characterize highly aspheric optics;
- Methods to distinguish the coherent and incoherent scatter in a broad band speckle field;
- Methods of polarization control and polarization apodization; and
- Components and methods to insure amplitude uniformity in both coronagraphs and interferometers, specifically materials, processes, and metrology to insure coating uniformity.
- Coherent fiber bundles consisting of up to 10^4 fibers with lenslets on both input and output side, such that both spatial and temporal coherence is maintained across the fiber bundle for possible wavefront/amplitude control through the fiber bundle.

Wavefront Control Technologies

- Development of small stroke, high precision, deformable mirrors and associated driving electronics scalable to 104 or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple deformable mirror technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices;
- Development of instruments to perform broad-band sensing of wavefronts and distinguish amplitude and phase in the wavefront;
- Adaptive optics actuators, integrated mirror/actuator programmable deformable mirror;
- Reliability and qualification of actuators and structures in deformable mirrors to eliminate or mitigate single actuator failures;
- Multiplexer development for electrical connection to deformable mirrors that has ultra-low power dissipation; and
- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance.

Optical Coating and Measurement Technologies

- Instruments capable of measuring polarization cross-talk and birefringence to parts per million;
- Highly reflecting broadband coatings for large (> 1 m diameter) optics
- Polarization-insensitive coatings for large optics

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

S2.03 Precision Deployable Optical Structures and Metrology
Lead Center: JPL
Participating Center(s): GSFC, LaRC

Planned future NASA Missions in astrophysics, such as: Single Aperture Far-IR (SAFIR) telescope; Terrestrial Planet Finder (TPF); Coronagraph, External Occulter and Interferometer, Advanced Technology Large-Aperture Space Telescope (ATLAST); Life Finder; and Submillimeter Probe of the Evolution of Cosmic Structure (SPECS); and the UV Optical Imager (UVOIR) 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. The desired areal density is 1 - 10 kg/m^2. 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 L2.

This subtopic solicits proposals to develop enabling, cost effective component and subsystem technology for these telescopes. Research areas of particular interest include:

- Precision deployable structures and metrology (i.e., innovative active or passive deployable primary or secondary support structures);
- Innovative concepts for packaging fully integrated (i.e., including power distribution, sensing, and control components);
- Distributed and localized actuation systems;
- Deployment packaging and mechanisms;
- Active opto-mechanical control distributed on or within the structure;
- Actuator systems for alignment of reflector panels (order of cm stroke actuators, lightweight, nanometer stability);
- Innovative architectures, materials, packaging and deployment of large sunshields and external occulters;
- Mechanical, inflatable, or other deployable technologies;
- New thermally-stable materials (CTE < 1ppm) for deployables;
- Innovative ground testing and verification methodologies; and
- New approaches for achieving packagable depth in primary mirror support structures.

Also of interest are:

- Innovative metrology systems for direct measurement of the optical elements or their supporting structure;
- Requirements for micron level absolute and subnanometer relative metrology for multiple locations on the primary mirror;
- Measurement of the metering truss;
- Innovative systems, which minimize complexity, mass, power and cost.

The goal for this effort is to mature technologies that can be used to fabricate 10 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. A successful proposal shows a path toward a Phase II delivery of demonstration hardware scalable to 3 m for characterization.

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

S2.04 Advanced Optical Component Systems
Lead Center: MSFC
Participating Center(s): GSFC, JPL

Future heavy lift launch systems will enable extremely large and/or extremely massive 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 IXO and GenX) require 1 to 2 meter long grazing incidence segments with angular resolution < 5 arc-sec down to 0.1 arc-sec and surface micro-roughness < 0.5 nm rms. Additionally, missions such as EUSO and OWL need 2 to 9 meter diameter UV-transparent refractive, double-sided Fresnel or diffractive lens.

In view of the very large total mirror or lens collecting aperture required, affordability or areal cost (cost per square meter of collecting aperture) rather than areal density is probably the single most important system characteristic of an advanced optical system. For example, both x-ray and normal incidence space mirrors currently cost \$3 million to \$4 million per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 20 to 100 times, to less than \$100K/m^2.

The primary purpose of this subtopic is to develop and demonstrate technologies to manufacture ultra-low-cost precision optical systems for very large x-ray, UV/optical or infrared telescopes. Potential solutions include but are not limited to new mirror materials such as Silicon carbide or nanolaminates or carbon-fiber reinforced polymer; or new fabrication processes such as direct precision machining, rapid optical fabrication, slumping or replication technologies to manufacture 1 to 2 meter (or larger) precision quality mirror or lens segments (either normal incidence for UV/optical/infrared or grazing incidence for x-ray).

Another key enabling technology is optical coatings. UV/optical telescopes require broadband (from 100 nm to 2500 nm) high-reflectivity mirror coating with extremely uniform amplitude and polarization properties which can be deposited on 1 to 3 meter class mirror. EUSO requires anti-reflection coatings which can be deposited onto 2.5 meter diameter PMMA Fresnel lenses. In both cases, ability to demonstrate optical performance on 2.5 meter class optical surfaces is important.

Successful proposals will demonstrate prototype manufacturing of a precision mirror or lens system or precision replicating mandrel in the 0.25 to 0.5 meter class with a specific scale up roadmap to 1 to 2+ meter class space qualifiable flight optics systems. Material behavior, process control, optical performance, and mounting/deploying issues should be resolved and demonstrated. The potential for scale-up will need to be addressed from a processing and infrastructure point of view.

An ideal Phase I deliverable would be a near UV, visible or x-ray precision mirror, lens or replicating mandrel of at least 0.25 meters. The Phase II project would further advance the technology to produce a space-qualifiable precision mirror, lens or mandrel greater than 0.5 meters, with a TRL in the 4 to 5 range. Both deliverables would be accompanied by all necessary documentation, including the optical performance assessment and all data on processing and properties of its substrate materials. The Phase II would also include a mechanical and thermal stability analysis.

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

S2.05 Optics Manufacturing and Metrology for Telescope Optical Surfaces
Lead Center: GSFC
Participating Center(s): JPL, MSFC

This subtopic focuses primarily on manufacturing and metrology of optical surfaces, especially for very small or very large and/or thin optics. Missions of interest include:

JDEM concepts: http://jdem.gsfc.nasa.gov/,
IXO: http://ixo.gsfc.nasa.gov/,
LISA: http://lisa.gsfc.nasa.gov/,
ICESAT: http://icesat.gsfc.nasa.gov/, CLARREO, and ACE.
ATLAST: http://www.stsci.edu/institute/atlast/

Optical systems currently being researched for these missions are large area aspheres, requiring accurate figuring and polishing across six orders of magnitude in period. Technologies are sought that will enhance the figure quality of optics in any range as long as the process does not introduce artifacts in other ranges. For example, mm-period polishing should not introduce waviness errors at the 20 mm or 0.05 mm periods in the power spectral density. Also, novel metrological solutions that can measure figure errors over a large fraction of the PSD range are sought, especially techniques and instrumentation that can perform measurements while the optic is mounted to the figuring/polishing machine.

Of particular interest is the area of x-ray optics metrology, including the evaluation of the optical quality of x-ray mirrors and substrates; the general characterization of x-ray mirrors; and the development of new metrology measurement techniques and instrumentation for x-ray mirrors.

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 5 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:

- Interferometric nulling optics for very shallow conical optics used in x-ray telescopes.
- Segmented systems commonly span 60 degrees in azimuth and 200 mm axial length and cone angles vary from 0.1 to 1 degree.
- Low stress metrology mounts that can hold very thin optics without introducing mounting distortion.
- Low normal force figuring/polishing systems operating in the 1 mm to 50 mm period range with minimal impact at significantly smaller and larger period ranges.
- In-situ metrology systems that can measure optics and provide feedback to figuring/polishing instruments without removing the part from the spindle.
- Innovative mirror substrate materials or manufacturing methods that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods.
- Extreme aspheric and/or anamorphic optics for pupil intensity amplitude apodization (PIAA).

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 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 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. 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 2010 are sought in the areas of:

- Command and Data Handling, and Instrument Electronics
- Thermal Control Systems
- Power Generation and Conversion
- Propulsion Systems
- Power Management and Storage
- Guidance, Navigation and Control
- Planetary Ascent Vehicles (non-Earth)
- Unmanned Aircraft and Sounding Rocket Technologies
- Terrestrial and Planetary Balloons
- Earth Entry Vehicle Systems

Significant changes to the S3 Topic for 2010 are:

- Consolidation of spacecraft and platform related technologies from S4 Low-cost Small Spacecraft and Technologies into the applicable S3 Sub-topics for a more integrated approach to spacecraft and platform subsystems technology development spanning from small to large spacecraft.
- Merged the 2009 subtopics of S3.01 Command, Data Handling, and Electronics, S3.07 Sensor and Platform Data Processing and Control, O1.01 Coding, Modulation, and Compression, and related content from the S4 Topic into a single Command and Data Handling, and Instrument Electronics subtopic.
- Merged the 2009 subtopics of Terrestrial Balloons with Planetary Balloons (from S5) into a single subtopic for balloon technologies.
- Added a new Earth Entry Vehicle Systems subtopic.

The following references discuss some of NASA's science mission and technology needs:

- The Astrophysics Roadmap: http://nasascience.nasa.gov/about-us/science-strategy
- 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 2003 solar system exploration decadal survey titled a "New Frontiers in the Solar System: An Integrated Exploration Strategy." http://www.nap.edu/catalog.php?record_id=10432
- The 2009-2010 Planetary Science Decadal Survey is currently ongoing and due in 2011. This decadal survey is considering technology needs.
  http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412
- The 2006 Solar System Exploration Roadmap: http://nasascience.nasa.gov/about-us/science-strategy

S3.01 Command, Data Handling, and Electronics
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC, LaRC

NASA's space based observatories, fly by spacecraft, orbiters, landers, and robotic and sample return missions, require robust command and control capabilities. Advances in technologies relevant to command and data handling and instrument electronics are sought to support NASA's goals and several missions and projects under development.

http://science.nasa.gov/search/?q=missions+under+development
http://www.nap.edu/catalog.php?record_id=10432

The subtopic goals are to: (1) develop high-performance processors and memory architectures and reliable electronic systems, (2) develop an avionics architecture that is flexible, scalable, extensible, adaptable, and reusable, and (3) develop tools technologies that can enable rapid deployment of high-reliability, high-performance onboard processing applications and interface to external sensors on flight hardware. The subtopic objective is to elicit novel architectural concepts and component technologies that are realistic and operate effectively and credibly in environments consistent with the future NASA Science missions.

Successful proposal concepts should significantly advance the state-of-the-art. Proposals should clearly (1) state what the product is; (2) identify the needs it addresses; (3) identify the improvements over the current state of the art; (4) outline the feasibility of the technical and programmatic approach; and (5) present how it could be infused into a NASA program. Furthermore, proposals should indicate an understanding of the intended operating environment, including temperature and radiation. It should be noted that environmental requirements can vary significantly from mission to mission. For example, some low earth orbit missions have a total ionizing dose (TID) radiation requirement of less than 10 kRad, while some planetary missions can have requirements well in excess of 1MRad. For descriptions of radiation effects in electronics, the proposer may visit http://radhome.gsfc.nasa.gov/radhome/background.htm. If a Phase II proposal is awarded, the combined Phase I and Phase II developments should produce a prototype that can be characterized by NASA.

The technology priorities sought are listed below.

C&DH Architectures

- High performance hardware/software processor platform capable of implementing high-throughput numerically intensive real-time applications that entail autonomous landing and guidance and control. Sensor computations. Key performance metrics must achieve 40 GOPS, 20 GMACS, and 40,000 MIPS with EDAC-protected memory, comprising 256 (TBR) MB DDR volatile for flight software execution and 256 (TBR) MB non-volatile for image storage, respectively. Standard interfaces must include Gigbit Ethernet, RS232 UART serial ports, and control interfaces to Lidar/Camera with a maximum bandwidth of up to 1 Gbps. Platform should be in 6U form factor and consume no greater than 20 W. Processor trades should be conducted to balance size, weight, power against reliability, flexibility, and performance for future space missions. Radiation hardened by design best practices, rapid development tools, and a radiation-tolerant path to space qualification are appealing features. The platform should operate, at reduced capability, during high energy cosmic rays events. Principal capabilities will encompass command generation and handling, control of safe landing system, sensor data processing and storage, and on-board memory management, optimized for acceptable performance and reliability.
- Novel, miniaturized, low-power C&DH architectures tailored to small spacecraft. Solutions must perform functions of traditional C&DH systems at a fraction of the SWAP (Size, Weight, and Power). Proposed systems should be capable of supporting typical spacecraft C&DH functions and should be radiation tolerant, and should further be compatible with Space Plug and Play (SPA) architectures, including SPA-1.
- Development system design tools that (a) take full advantage of rapid prototyping hardware-in-the-loop (HIL) environments for hybrid processing platforms, and (b) automate/accelerate the deployment of data processing and sensor interface design on flight hardware.

Discrete Components for C&DH Subsystems

- Processors - General purpose (processor chips and radiation-hardened by design synthesizable IP cores) and special purpose single-chip components (DSPs), with sustainable processing performance and power efficiency (>40,000 MIPS at >1,000 MIPS/W for general purpose processing platforms, >20 GMACs at >5 GMACS/W for computationally-intensive processing platforms), and tolerance to total dose and single-

event radiation effects. Concepts must include tools required to support an integrated hardware/software development flow.
- Radiation-hardened non-volatile low power memories >100KRad.
- Radiation hardened DDR1, DDR2, and DDR3 high speed memories.

Onboard Network Architectures and Devices

- Radiation-hardened physical layer components for (copper/fiber-optic) onboard data busses (e.g., SpaceWire, Ethernet, Serial Rapid I/O, Ring Bus) speeds >1Gb/s.
- Power distribution through onboard data network technologies.
- Wireless data network architectures and components.
- Wireless RFID housekeeping sensors and interrogation hardware.

Tunable, Scalable, Reconfigurable, Adaptive Fault-Tolerant Onboard Processing Architectures

- Technologies Enabling Use of Commercial Devices for Spaceflight Applications, including Radiation Hardened By Software (RHBS) approaches.
- Highly adaptive reconfigurable computing platforms (including hybrid DSP/FPGA/CPU architectures).
- Tools and methodologies to accelerate development of highly reliable applications on reconfigurable computing platforms.

Technologies Enabling Custom Radiation-Hardened Component Development

- Radiation-Hardened-By-Design (RHBD) cell libraries.
- Radiation-hardened Programmable Logic Devices (PLDs) and structured ASIC devices (digital and/or mixed-signal).
- Intellectual Property (IP) cores allowing the implementation of highly reliable System-On-a-Chip (SOC) devices for spacecraft subsystems or instrument electronics. Functions of interest include processors, memory interfaces, and data bus interfaces.

Novel, Ruggedized Packaging/Interconnect

- High density packaging (enclosures, printed wiring boards) enabling miniaturization.
- Novel high density and low resistance cabling, including carbon nanotube (CNT) based wiring.

Data Compression

- Ground-based high-speed data compression decoder capable of decoding coded bit stream conforming to CCSDS 122.0-B-1 Image Data Compression standard (www.ccsds.org), providing over 40 M samples/sec for up to 16-bit image data coded in an embedded bit stream. Spaceflight hardware currently exists to perform the encoding function. The requested decoder would be used for ground processing of a downlinked encoded data stream. The decoder shall not consume more than 5 watts of power at the specified speed.

Power Conversion and Distribution

- Radiation-hardened high efficiency Point-Of-Load (POL) down convertor.
- Power distribution through onboard data network technologies.

S3.02 Thermal Control Systems
Lead Center: GSFC
Participating Center(s): ARC, GRC, JPL, 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:

- Optical systems, lasers (ICESAT 2), and detectors require tight temperature control, often to better than +/- 1°C. Some new missions such as LISA require thermal gradients held to even tighter micro-degree levels. Methods of precise temperature measurement and control to tight temperature levels are needed.
- New generations of electronics used on numerous missions have higher power densities than in the past. High conductivity, vacuum-compatible interface materials to minimize losses across make/break interfaces are needed to reduce interface temperature gradients and facilitate heat removal.
- Detectors and optical systems at infrared wavelengths require efficient cooling methods to low temperatures. Advanced thermoelectric devices with higher Coefficients of Performance (COP) are required.
- More sensitive instruments are resulting in increased requirements for high electrical conductivity on spacecraft instruments and surfaces. This has increased the need for advanced thermal control coatings, particular with low absorptance, high emmittance, and good electrical conductivity.
- Phase change systems are needed for Mars or Lunar applications. Reusable phase change systems are desired which can be employed to absorb transient heat dissipations during instrument operations. Technology is sought for phase change systems, typically near room temperature, which can then either store this energy or provide an exothermic process, which would provide heat for instrument power-on after the dormant phase.
- Future high-powered missions, some possibly nuclear powered, may require active cooling systems to efficiently transport large amounts of heat. These include single and two-phase mechanically pumped fluid loop systems which accommodate multiple heat sources and sinks; and long life, lightweight pumps which are capable of generating a high pressure head. It also includes efficient, lightweight, oil-less, high lift vapor compression systems or novel new technologies for high performance cooling up to 2 KW.
- Exploration science missions beyond earth orbit present engineering challenges requiring systems, which can withstand extreme temperatures ranging from high temperatures on Venus to the cryogenic temperatures of the outer planets. High performance insulation systems, which are more easily fabricated than traditional multi-layer (MLI) systems, are required for both hot and cold environments. Potential applications include traditional vacuum environments, low-pressure carbon dioxide atmospheres on Mars, and high-pressure atmospheres found on Venus.
- Low-Cost Variable Conductance Heat Pipes for Terrestrial Balloons – Please see sub-topic S3.07 Terrestrial and Planetary Balloons to respond to this requirement.
- Thermal Control Systems for S3.10 Earth Entry Systems. Low mass/cost/power/complexity payload thermal control systems are needed, which can maintain the sample temperature in-flight, through impact, and post landing. Candidate thermal control systems must be able to maintain a payload up to 10 kg at temperature levels ranging from cryogenic up to -20C (depending on specific mission requirements) for up to 1 day after landing/impact, and cannot exceed 20kg in total mass.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration. Phase II should deliver a demonstration unit for NASA testing at the completion of the Phase II contract.

Note to Proposer: Subtopic X3.04 Thermal Control Systems for Human Spacecraft, under the Exploration Mission Directorate, also addresses thermal control technologies. Proposals more aligned with exploration mission requirements should be proposed in X3.04.

S3.03 Power Generation and Conversion
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC, MSFC

Future NASA science missions will employ Earth orbiting spacecraft, planetary spacecraft, balloons, aircraft, surface assets, and marine craft as observation platforms. Proposals are solicited to develop advanced power generation and conversion technologies to enable or enhance the capabilities of future science missions. Requirements for these missions are varied and include long life, high reliability, significantly lower mass and volume, higher mass specific power, and improved efficiency over the state of practice for components and systems. Other desired capabilities are high radiation tolerance and the ability to operate in extreme environments (high and low temperatures and over wide temperature ranges).

While power generation technology affects a wide range of NASA missions and operational environments, technologies that provide substantial benefits for key mission applications/capabilities are being sought in the following areas.

Radioisotope Power Conversion
Radioisotope technology enables a wide range of mission opportunities, both near and far from the Sun and hostile planetary environments including high energy radiation, both high and low temperature and diverse atmospheric chemistries. Technology innovations capable of advancing lifetimes, improving efficiency, highly tolerant to hostile environments are desired for all thermal to electric conversion technologies considered here. Specific systems of interest for this solicitation are listed below.

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

- System specific mass greater than 10 We/kg
- Highly reliable autonomous control
- Low EMI
- High temperature, high performance materials, 850-1200 C
- Radiation tolerant sensors, materials and electronics

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

- High temperature, high efficiency conversion greater than 10%
- Long life, minimal degradation
- Higher power density

Cubesat and Nanosat On-orbit Power Generation
NASA desires to build smaller spacecraft types carrying smaller instrument packages. However, power requirements to accommodate these instruments and spacecraft systems will not necessarily scale down in a similar fashion as spacecraft size. Therefore, power generation and power management technologies are sought that are compatible with small spacecraft geometries and sizes, especially in cubesat and nanosat form factors.

Photovoltaic Energy Conversion
Photovoltaic cell, blanket, and array technologies that lead to significant improvements in overall solar array performance (i.e. conversion efficiency >30%, array mass specific power >300watts/kilogram, decreased stowed volume, reduced initial and recurring cost, long-term operation in high radiation environments, high power arrays, and a wide range of space environmental operating conditions) are solicited. Technologies specifically addressing the following mission needs are highly sought:

- Photovoltaic cell and blanket technologies capable of low intensity, low-temperature operation applicable to outer planetary (low solar intensity) missions
- Photovoltaic cell, blanket and array technologies capable of enhancing solar array operation in a high intensity, high-temperature environment (i.e. inner planetary and solar probe-type missions)
- Lightweight solar array technologies applicable to solar electric propulsion missions. Current missions being studied require solar arrays that provide 1 to 20 kilowatts of power at 1 AU, are greater than 300 watts/kilogram specific power, can operate in the range of 0.7 to 3 AU, provide operational array voltages up to 150 volts and have a low stowed volume.

Thermophotovoltaic conversion is currently focused on follow-on technology for the International Lunar Network (ILN) and for the outer planets mission. Advances sought, but not limited to, include:

- Low-bandgap cells having high efficiency and high reliability
- High temperature selective emitters
- Low absorptance optical band-pass filters
- Efficient multi-foil insulation

Note to Proposer: Topic X8 under the Exploration Mission Directorate also addresses power technologies (X8.03 Space Nuclear Power Systems, and X8.04 Advanced Photovoltaic Systems). Proposals more aligned with exploration mission requirements should be proposed in X8.

S3.04 Propulsion Systems
Lead Center: GRC
Participating Center(s): JPL

The Science Mission Directorate (SMD) needs spacecraft with more demanding propulsive performance and flexibility for more ambitious missions requiring high duty cycles, more challenging environmental conditions, and extended operation. Planetary spacecraft need the ability to rendezvous with, orbit, and conduct in situ exploration of planets, moons, and other small bodies in the solar system (http://www.nap.edu/catalog.php?record_id=10432). Future spacecraft and constellations of spacecraft will have high-precision propulsion requirements, usually in volume- and power-limited envelopes.

This subtopic seeks innovations to meet SMD propulsion requirements, which are reflected in the goals of NASA's In-Space Propulsion Technology program to reduce the travel time, mass, and cost of SMD spacecraft. Advancements in chemical and electric propulsion systems related to sample return missions to Mars, small bodies (like asteroids, comets, and Near-Earth Objects), outer planet moons, and Venus are desired. Additional electric propulsion technology innovations are also sought to enable low cost systems for Discovery class missions, and eventually to enable radioisotope electric propulsion (REP) type missions.

The focus of this solicitation is for next generation propulsion systems and components, including high-pressure chemical rocket technologies and low cost/low mass electric propulsion technologies. Specific sample return propulsion technologies of interest include higher-pressure chemical propulsion system components, lightweight propulsion components, and Earth-return vehicle propulsion systems. Propulsion technologies related specifically to planetary ascent vehicles will be sought under S3.08 Planetary Ascent Vehicle.

Chemical Propulsion Systems
Technology needs include:

- Improved materials and manufacturing processes to produce Iridium/Rhenium apogee class thruster chambers with improved mechanical properties targeting a yield stress of 40ksi and an elongation of 10%;
- Advanced nontoxic mono-propellant rockets for in-space applications.

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

- Efficient thrusters with up to 1 kW of input power that provide thrust up to 20 mN with a specific impulse between 1600 to 3500 seconds;
- A throttleable dual mode thruster that is capable of operating in both high thrust and high specific impulse modes for a fixed power;
- High power electric propulsion thrusters (>20 kW) and components including cathodes, ion optics, and low sputtering materials with long life (>1x108 N-s).

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.

Note to Proposer: Topic X2 under the Exploration Mission Directorate also addresses advanced propulsion. Proposals more aligned with exploration mission requirements should be proposed in X2.

S3.05 Power Management and Storage
Lead Center: GRC
Participating Center(s): ARC, JPL, JSC

Future NASA science objectives will include missions such as Earth Orbiting, Venus, Europa, Titan, 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 long life, high reliability, low mass/volume, radiation tolerance, and wide temperature operation.

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°C to 500°C for Venus missions, and a span of -230°C to +120°C for Lunar Quest. 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 (>200 Wh/kg for secondary battery systems) and energy density, along with radiation tolerance are of interest.

In addition to batteries, other advanced energy storage/load leveling technologies designed to the above mission requirements, such as flywheels, supercapacitors or magnetic energy storage, are of interest. These technologies have the potential to minimize the size and mass of future power systems.

Power Management and Distribution (PMAD)
The "New Frontiers in the Solar System: An Integrated Exploration Strategy" (http://www.nap.edu/catalog.php?record_id=10432), the 2006 Solar System Exploration Roadmap (http://nasascience.nasa.gov/about-us/science-strategy) and the Science Plan for NASA's Science Mission Directorate (http://nasascience.nasa.gov/about-us/science-strategy) all describe the need for radioisotope power systems (RPS) for planetary exploration. In conjunction with the RPS, intelligent, fault-tolerant PMAD technologies are needed to efficiently manage the system power for these deep space missions. 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. 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. Advancements are sought for power electronic devices, components and packaging for Venus type missions with power ranges of a few watts for minimum missions up to a few kilowatts for large missions.

For the lower power applications (up to 20 watts), NASA desires to build smaller spacecraft types carrying smaller instrument packages. However, power requirements to accommodate these instruments and spacecraft systems will not necessarily shrink in a similar fashion as spacecraft size. Therefore, power management technologies are sought that are compatible with small spacecraft geometries and sizes. These Electrical Power Systems should be compatible with Space Plug and Play (SPA) architectures.

Overall technologies of interest include:

- Intelligent, fault-tolerant electrical components and PMAD systems
- High temperature devices and components (up to 450°C)
- Advanced electronic packaging for thermal control and electromagnetic shielding
- Plug and Play compatibility for low power applications

Power Conversion and Distribution relevant to Command, Data Handling, and Electronics, will be covered under subtopic S3.01.

Power Storage for Terrestrial Balloons will be covered under sub-topic S3.07 Terrestrial and Planetary Balloons.

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.

Other subtopics, which could potentially benefit from these technology developments include O5 – Low-Cost and Reliable Access to Space (LCRATS), S5.05 – Extreme Environments Technology, and S5.01 – Planetary Entry, Descent and Landing Technology. Battery development could also be beneficial to X8.02 – Advanced Space-rated Batteries, which is investigating some similar technologies in the secondary battery area but with very different operational requirements. Power Management and Distribution could be beneficial to X8.05 - Advanced Power Conversion Systems AND Management and Distribution (PMAD), which is investigating similar technologies, but with very different power levels.

S3.06 Guidance, Navigation and Control
Lead Center: GSFC
Participating Center(s): ARC, JPL

Advances in the following areas of guidance, navigation and control are sought.

Navigation systems (including multiple sensors and algorithms/estimators, possibly based on existing component technologies) that work collectively on multiple vehicles to enable inertial alignment of the formation of vehicles (i.e., pointing of the line-of-sight defined by fixed points on the vehicles) on the level of milli-arcseconds relative to the background star field.

Light-weight sensors (gyroscopic or other approach) to enable milli-arcsecond class pointing measurement for individual large telescopes and low cost small spacecraft.

Isolated pointing and tracking platforms (pointing 0.5 arcseconds, jitter to 5 milli-arcsecond), targeted to placing a scientific instrument on GEO communication satellites that can track the sun for > 3 hours/day.

Working prototypes of GN&C actuators (e.g., reaction or momentum wheels) that advance mass and technology improvements for small spacecraft use. Such technologies may include such non-contact approaches such as magnetic or gas. Superconducting materials, driven by temperature conditioning may also be appropriate provided that the net power used to drive and condition the "frictionless" wheels is comparable to traditional approaches.

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

S3.07 Terrestrial and Planetary Balloons
Lead Center: GSFC
Participating Center(s): JPL

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

Terrestrial Scientific 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 three key areas to monitor and advance the performance of this new vehicle.

(1) Power Storage: Devices or methods to store electrical energy onboard the balloon with lower mass than current techniques are needed. Long duration balloon flights at mid-latitudes will experience up to 12 hours of darkness, during which electrical power is needed for experiments and NASA support systems. Typically, solar panels are flown to generate power during the daylight hours, and excess power is readily available. This excess power needs to be stored for use during the night. Current power storage techniques consist of rechargeable batteries which range from lead-acid to lithium-ion chemistries. Innovative alternatives to these batteries, either advanced chemistries or alternate power storage techniques such as capacitors or flywheels, which result in overall mass savings are needed. Nominal voltage levels for balloon systems are 28 volts DC, and nominal power levels can vary from 100 watts to 1000 watts. Therefore, power storage requirements range from 1000 watt-hours to 12,000-watt hours or more. Alternative power systems, which do not rely on solar panels, may also be proposed. These alternative systems may use energy storage techniques such as fuel cells or flywheels, which are prepared or charged on the ground prior to flight, and then would provide continuous power throughout the flight at the power levels specified above. Spacecraft power storage requirements are found under subtopic S3.05 Power Management and Storage.

(2) Balloon Instrumentation: Devices or methods are desired to accurately measure ambient air temperature, helium gas temperature, balloon film temperatures, film strain, and tendon load are desired. These measurements are needed to accurately model the balloon performance during a typical flight at altitudes of approximately 36 kilometers. The measurements must compensate for the effects of direct solar radiation through shielding or calculation. Minimal mass and volume are highly desired. Remote sensing of the parameters and non-invasive and non-contact approaches are also desired. The non-invasive and non-contact approaches are highly desired for the thin polyethylene film measurements used as the balloon envelope, with film thickness ranging from 0.8 to 1.5 mil. Strain measurements of these thin films via in-flight photogrammetric techniques would be beneficial. Devices or methods to accurately measure axially loaded tendons on an array of ~50 or up to 300 separate tendons during flight are of interest. Tendons are typically captured at the end fittings via individual pins with loading levels ranging from ~20 N to ~8,000 N per tendon, and can be exposed to temperatures from room temperature to the troposphere temperatures of -90 degrees Celsius or colder. The measurement devices must be compatible with existing NASA balloon packaging, inflation, and launch methods. These instruments must also be able to interface with existing NASA balloon flight support systems or alternatively, a definition of a data acquisition solution be provided.

Support telemetry systems are not part of the this initiative; however, data from any sensors (devices) that are selected from this initiative must be able to be stored on board and/or telemetered in-flight using single-channel (two-wire) interface into existing NASA balloon flight support systems. The devices of interest shall be easily integrated and shall have minimal impact on the overall mass of the balloon system.

(3) Low-Cost Variable Conductance Heat Pipes for Balloon Payloads: With the ever-increasing complexity of both scientific instruments and NASA mission support equipment, advanced thermal control techniques are needed. The type of advanced thermal control techniques desired are similar to those utilized on large-budget orbital and deep space payloads (variable conductance heat pipes, diode heat pipes, loop heat pipes, capillary pumped loops, heat switches, louvers) are far more expensive to implement on balloon payloads that their limited budgets can afford. Innovative solutions are sought that would allow these more advanced thermal control measures to be utilized with reduced expense. Spacecraft thermal control requirements are found under subtopic S3.02 Thermal Control Systems.

Though not considered "cutting-edge technology", commercial quality, constant conductance, copper-methanol heat pipes have begun to be utilized on balloon payloads to effectively move heat significant distances. The problem with these devices is that the conductance cannot effectively be reduced under cold operating or cold survival environment conditions without expending significant energy in an active heater to maintain the condenser section warm. It is desirable to develop a cost-effective method of conducting the heat in this manner and allowing the flow to be reduced/eliminated when conditions warrant. Therefore, innovative thermal control techniques and devices developed must be inexpensive to implement. They must function reliably at balloon altitudes of 30-40km and temperature ranges from -90C to +40C. They should require little or no energy consumption and provide the capability of moderating heat flow autonomously or by remote control under certain thermal conditions.

Planetary 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 and airships 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:

(1) Titan Montgolfiere Balloons: Recent NASA mission studies have recommended the use of radioisotope-heated Montgolfiere balloons for future in situ Titan exploration. Proposals are sought for the design, fabrication and Earth atmosphere flight testing of prototypes that can support an eventual Titan Montgolfiere balloon mission. Particular importance is attached to the acquisition of test data that can help validate thermodynamic and fluid mechanic models that will ultimately be used to design the Titan flight balloon. The size of balloon required for Titan will be approximately 10 m in diameter and will require 2 kW of thermal energy to float the balloon at an expected Titan temperature of 85 to 95 K. Any proposed Earth-test prototype will require an alternate heat source that nevertheless adequately mimics the effects of using radioisotope energy at Titan.

(2) Gas Management Systems for Titan Aerobots: Hydrogen-filled aerobots at Titan must contend with the problem of gas leakage over long duration (1 year or more) flights. Proposals are sought for the development and testing of two kinds of prototype devices that can be carried on the aerobot to compensate for these gas leakage problems: one device is to produce make-up hydrogen gas from atmospheric methane; the other device is to remove atmospheric gas (mostly nitrogen) that leaks from the ballonets into the hydrogen-filled blimp. Both kinds of devices will need to operate on no more than 15 W of electrical power each while compensating for a leakage rate of at least 40 g/week of hydrogen or 500 g/week of nitrogen.

(3) Metal Balloons for High Temperature Venus Exploration: Balloons made of metals are a potential solution to the problem of enabling long duration flight in the hot lower atmosphere of Venus. Proposals are sought for metal balloon concepts and prototypes that provide 1-5 m3 of fully inflated volume, areal densities of 1 kg/m^2 or less, sulfuric acid compatibility at 85% concentration, and operation at 460 °C for a period of up to 1 year.

S3.08 Planetary Ascent Vehicles
Lead Center: GRC
Participating Center(s): DFRC, JPL, MSFC

NASA aims to design, build and test vehicles that will be launched from the surface of other planets and small bodies and place a payload, Orbiting Sample (OS), into orbit. We are seeking proposals for the development of innovative technologies to support future planetary ascent vehicles. Immediate focus is the Mars ascent vehicle. Technology innovations should either enhance vehicle capabilities (e.g., launch success probability, mission success, improved performance or margins, and improved environmental robustness) or ease implementation in space borne missions (e.g., reduce size, mass, power, and thermal requirements, improve reliability and ability to withstand the ~20 g lateral g-loading, or lower cost). The areas of interest for this call are listed below.

Alternate propellants, thrusters and propulsion system technologies for the planetary ascent vehicles:

- Higher performing monopropellants with specific impulse >240 secs;
- "Green" propellants;
- High chamber pressure thrusters > 500 psia;
- Pressurization component technologies to reduce system mass (filters, solenoid valves, latch valves, tanks, fill and drain and check valves);
- Small lightweight pump technologies to operate at >500 psi output pressure especially non-electrically driven;
- Non-pyrotechnic isolation valves.

Advanced solid propellant engine system technologies:

- Solid propellant technology with specific impulse performance potential higher than HTPB and CTPB;
- Propellant blend with high performance low storage impacts, and operating capability down to 150 K;
- Low temperature seals and components;
- Light weight and reliable thrust vector control;
- Other lightweight system and component technologies.

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.

Launch vehicle technologies relevant to Earth are not sought under this sub-topic. For launch vehicle technologies related to Earth, see X2.01 Earth-to-Orbit Propulsion. Proposals more aligned with exploration mission requirements should be proposed in X2.01.

S3.09 Unmanned Aircraft and Sounding Rocket Technologies
Lead Center: GSFC
Participating Center(s): ARC, DFRC, GRC, JPL, LaRC

Sounding Rockets
The NASA Sounding Rocket Program (NSRP) provides low-cost, sub-orbital access to space in support of space and earth sciences research and technology development sponsored by NASA and other users by providing payload development, launch vehicles, and mission support services. NASA utilizes a variety of vehicle systems comprised of military surplus and commercially available rocket motors, capable of lofting scientific payloads, up to 1300lbs, to altitudes from 100km to 1500km. NASA launches sounding rocket vehicles worldwide, from both land-based and water-based ranges, based on the science needs to study phenomenon in specific locations.

NASA is seeking innovations to enhance capabilities and operations in the following areas:

- Autonomous vehicle environmental diagnostics system capable of monitoring flight loading (thermal, acceleration, stress/strain) for solid rocket vehicle systems.
- Location determination systems to provide over-the-horizon position of buoyant payloads to facilitate expedient location and retrieval from the ocean.
- Flotation systems, ranging from tethered flotation devices to self-encapsulation systems, for augmenting buoyancy of seal payload systems launched from water-based launch ranges.
- High-glide parachute designs capable of deploying at altitudes above 25,000 ft to facilitate mid-air retrieval and/or fly-back/fly-to-point precision landing.

Unmanned Aircraft Systems
Unmanned Aircraft Systems (UAS) offer significant potential for Suborbital Scientific Earth Exploration Missions over a very large range of payload complexities, mission durations, altitudes, and extreme environmental conditions. To more fully realize the potential improvement in capabilities for atmospheric sampling and remote sensing, new technologies are needed .Scientific observation and documentation of environmental phenomena on both global and localized scales that will advance climate research and monitoring; e.g., U.S. Global Change Research Program as well as Arctic and Antarctic research activities (Ice Bridge, etc.).

NASA is increasing scientific participation to understand impacts associated with worldwide environmental changes. Capability for suborbital unmanned flight operations in either the North or South Polar Regions are limited because of technology gaps for extremely remote telemetry capabilities and precision flight path control requirements. It is also highly desirable to have UAS ability to perform atmospheric and surface sampling.

(1) Telemetry, Tracking and Control: Low cost over-the-horizon global networks are needed to enable unmanned collaborative multi-platform earth observation missions that are more efficient and cost effective.

(2) Avionics and Flight Control:

- Precision Flight Path Control solutions in smooth atmospheric conditions.
- Aircraft control in violent atmospheric conditions.
- Low cost (<$20k), High precision inertial navigation systems (greater than 1/10th degree accuracy and knowledge)

Precise/repeatable flight path control capabilities are needed to enable repeat path observations for earth monitoring on seasonal and multi-year cycles. In addition, long endurance atmospheric sampling in extreme inclement weather conditions (hurricanes) and volcanic plumes can provide high fidelity time and spatial resolution data

(3) UA Integrated Vehicle Health Management:

- Fuel Heat/Anti-freezing
- Unmanned platform icing detection and minimization

(4) Guided Dropsondes: NASA Earth Science Research activities could utilize more capable dropsondes than are currently available as market items. Specifically, dropsondes that could effectively be guided through atmospheric regions of interest such as volcanic plumes could enable unprecedented observations of important phenomena. Capabilities of interest include:

- Compatibility with existing drop-sonde dispensing systems deployed on the NASA/NOAA P-3 and planned for the NASA Global Hawk
- Guidance schemes, autonomous or active control
- Cross-range performance and flight path accuracy
- Operational considerations including airspace utilization and conflicting traffic

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

S3.10 Earth Entry Vehicle Systems
Lead Center: LaRC
Participating Center(s): ARC

This subtopic seeks innovations to meet Science Mission Directorate (SMD) requirements for Earth Entry Vehicles (EEV). Advancements in materials, structures, and systems related to sample return missions to the Moon, planetary bodies (e.g., Mars and Venus), small bodies (e.g., asteroids, comets, and Near-Earth Objects) and outer planet bodies are desired.

EEVs provide several challenges to current material and structural designs in several areas. New classes of structure and impact materials are needed which are lightweight and versatile, remaining stiff during impact with soft surfaces while providing low impact loads when crushing with impact to hard surfaces. Lightweight structures that are suitable for thermal protection system (TPS) substructures, including serving as a thermal barrier or sink, are also desired. Current EEV concepts are blunt-body vehicles (60-degree sphere cones) that are 0.5 to 2.0 meters in diameter, entering Earth¹s atmosphere at 11-16 km/s.

This subtopic also seeks proposals that explore new technologies in several key vehicle systems that include:

- Low mass/cost/complexity, high reliability impact attenuation systems capable of keeping peak impact loads below 1500 g's under nominal conditions, or 2500 g's under off-nominal conditions (i.e. impact with a rock or hard man-made surface, e.g. concrete road). Payload stroke resulting from compression of candidate impact foam must not exceed 2.5% of the vehicle overall diameter.
- Lightweight structures that are suitable for TPS substructures (i.e., lightweight, stiff, good insulator).
- Mid-density robust ablator systems that can be tailored to entry heating for a range of missions from high speed to low speed, and are easy to manufacture across the range of possible vehicle scales.
- Adhesives that are compatible with lightweight structures and TPS.
- Passive (or nearly passive), self-contained methods of determining whether a micrometeoroid strike (of the TPS) has occurred.
- Low mass, low power, reliable self-contained beacon for EEV retrieval.
- Candidate beacon mass must not exceed 100g (including power and activation) and must provide a reliable signal for up to 2 days after landing/impact.
- Low mass, low power, reliable, self-contained GPS with broadcast system and the antenna to beam the trajectory and landing location information to IRIDIUM or other easily accessible commercial global communication systems as an aid to locating the landed EEV.
- Thermal control system technologies for EEVs will be covered under sub-topic S3.02 Thermal Control Systems.
- EEV closing and locking mechanism(s) that are reliable and easily verifiable.

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.

Other subtopics that could be soliciting entry, descent, and landing related technology developments include S5.01 Entry, Descent and Landing Technologies, X9.01 Ablative Thermal Protection Systems, and X9.02 Advanced Integrated Hypersonic Entry Systems. Proposals more aligned with exploration mission requirements should be proposed in X9.

TOPIC: S4 Low-Cost Small Spacecraft and Technologies

This subtopic is targeted at the development of technologies and systems, which can enable the realization of small spacecraft science missions. While small spacecraft have the benefit of reduced launch costs by virtue of their lower mass, they may be currently limited in performance and their capacity to provide on-orbit resources to payload and instrument systems. With the incorporation of smaller bus technologies, launch costs, as well as total life cycle costs, can continue to be reduced, while still achieving and expanding NASA's mission objectives.

The Low-Cost Small Spacecraft and Technologies category is focused on the identification and development of specific key spacecraft technologies primarily in the areas of integrated avionics, attitude determination and control including de-orbit technologies, and spacecraft power generation and management. The primary thrust of this topic is directed at reducing the footprint and resources that these bus subsystems require (size, weight, and power), allowing more of these critical resources to be shifted to payload and instrument systems, and to further reduce the overall launch mass and volume requirements for small spacecraft.

Note that related topics of interest to S4 Low-cost Small Spacecraft and Technologies may be found in other areas of the solicitation: S3.01 Command, Data Handling and Electronics; S3.03 Power Generation and Conversion; and S3.05 Power Management and Storage.

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

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and/or software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

S4.01 De-orbit Devices/Technologies for Small Spacecraft
Lead Center: ARC
Participating Center(s): GRC, KSC

NASA intends to place small spacecraft (<100kg) and very small spacecraft (<15kg) into a variety of altitudes ranging from low LEO (350km circular) to high and/or elliptical (700km) orbits. Methods and technologies are needed to intentionally de-orbit these spacecraft at end of mission, or upon loss of control and function. These devices and approaches should require a minimum of on-orbit resources (size, weight and power) and should provide a reasonable amount of positive control to the timing of the de-orbit event. There is also specific interest for these technologies compatible with cubesat (<6kg) and nanosatellite (<15kg) spacecraft form factors.

S4.02 Miniature Integrated Payload Suites
Lead Center: ARC
Participating Center(s): GSFC

In order to fully realize the economy, launch frequency, and science utility benefits that small spacecraft represent, a new generation of MEMS-based sensor suites are desired. These sensors could be the result of miniaturization and repacking of existing sensors, or consist of novel devices and technologies that can accomplish similar measurements of larger systems in a fraction of the current size, weight and power. In addition, these suites would contain the necessary data processing and power conditioning systems to support routine operation. Compatibility with Space Plug and Play (SPA) or similar architectures that streamline system integration processes is also desired.

TOPIC: S5 Robotic Exploration Technologies

NASA is pursuing technologies to enable robotic exploration of the Solar System including its planets, their moons, and small bodies. NASA has a development program that includes technologies for the atmospheric entry, descent, and landing, mobility systems, extreme environments technology, sample acquisition and preparation for in situ experiments, and in situ planetary science instruments. Robotic exploration missions that are planned include a Europa Jupiter System mission, Titan Saturn System mission, Venus In Situ Explorer, sample return from Comet or Asteroid and lunar south polar basin and continued Mars exploration missions launching every 26 months including a network lander mission, an Astrobiology Field Laboratory, a Mars Sample Return mission and other rover missions. Numerous new technologies will be required to enable such ambitious missions. The solicitation for in situ planetary instruments can be found in the in situ instruments section of this solicitation. See URL: http://solarsystem.nasa.gov/missions/index.cfm for mission information. See URL: http://marsprogram.jpl.nasa.gov/ for additional information on Mars Exploration technologies.

S5.01 Planetary Entry, Descent and Landing Technology
Lead Center: JPL
Participating Center(s): ARC, JSC, LaRC

NASA seeks innovative sensor technologies to enhance success for entry, descent and landing (EDL) operations on missions to Mars. Sensing technologies are desired which determine the entry point of the spacecraft in the Mars atmosphere; provide inputs to systems that control spacecraft trajectory, speed, and orientation to the surface; locate the spacecraft relative to the Martian surface; evaluate potential hazards at the landing site; and determine when the spacecraft has touched down. Appropriate sensing technologies for this topic should provide measurements of physical forces or properties that support some aspect of EDL operations. NASA also seeks to use measurements made during EDL to better characterize the Martian atmosphere, providing data for improving atmospheric modeling for future landers. Proposals are invited for innovative sensor technologies that improve the reliability of EDL operations.

Products or technologies are sought that can be made compatible with the environmental conditions of spaceflight and the rigors of landing on the Martian surface. Successful candidate sensor technologies can address this call by:

- Providing critical measurements during the entry phase (e.g., pressure and/or temperature sensors embedded into the aeroshell);
- Improving the accuracy on measurements needed for guidance decisions (e.g., surface relative velocities < 10cm/s error, altitudes < 10cm error, orientation < 0.1 milliradian error, localization < 10m terrain relative error);
- Extending the range over which such measurements are collected (e.g., providing a method of imaging through the aeroshell, or terrain-relative navigation that does not require imaging through the aeroshell);
- Enhancing the situational awareness during landing by identifying hazards (rocks > 20cm height, slopes > 0.05 radians, craters > 1m diameter) and distinguishing between favorable and unfavorable landing materials (e.g., differentiate bowls of dust from solid rock)
- Substantially reducing the amount of external processing needed to calculate the measurements or provide high performance flight qualified processing with low mass and power (e.g., 1 GFLOPS processing in < 10W;
- Decoupling spacecraft attitude from instrument pointing through the development of fast gimbals that are low mass and power (2rad/s^2 accelerations, 2 rad/s rates with mass < 5kg and power less than < 50W);
- Improving landing site map accuracy and resolution while also providing a means for validating the generated map (10cm resolution elevation with 5cm height errors and map tie errors < 10m);
- Providing modular and low mass spacecraft to spacecraft navigation systems that work through all of EDL (e.g. orbiter to lander during entry or lander to surface rover).

- Monitoring local environmental (weather) conditions on the surface to facilitate forecasting of wind velocities up to ~10km altitude above the surface in preparation for landing (for missions targeted to land near previously landed assets)
- Significantly reducing the impact of incorporating such sensors on the spacecraft in terms of volume, mass, placement, or cost.

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.

Other subtopics that could be soliciting entry, descent, and landing related technology developments include S1.01 Laser and Lidar System Components, S3.10 Earth Entry Vehicle Systems, X9.01 Ablative Thermal Protection Systems, and X9.02 Advanced Integrated Hypersonic Entry Systems. Proposals more aligned with exploration mission requirements should be proposed in X9.

S5.02 Sample Collection, Processing, and Handling
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC

Robust systems for sample acquisition, handling and processing are critical to the next generation of robotic explorers for investigation of planetary bodies (http://books.nap.edu/openbook.php?record_id=10432&page=R1). Limited spacecraft resources (power, volume, mass, computational capabilities, and telemetry bandwidth) demand innovative, integrated sampling systems that can survive and operate in challenging environments (extremes in temperature, pressure, gravity, vibration and thermal cycling). Special interest lies in sampling systems and components (actuators, gearboxes, etc.) that are suitable for use in the extremely hot high-pressure environment at the Venusian surface (460ºC, 93 bar). Relevant systems could be integrated on multiple platforms, however of primary interest are samplers that could be mounted on a mobile platform, such as a rover. For reference, current Mars-relevant rovers range in mass from 200 - 800 kg.

Sample Acquisition
Research should be conducted to develop compact, low-power, lightweight subsurface sampling systems that can obtain 1 cm diameter cores of consolidated material (e.g., rock, icy regolith) up to 10 cm below the surface. Systems should be capable of autonomously acquiring and ejecting samples reliably. Also of interest are methods of autonomously exposing rock interiors from below weathered rind layers. Other sample types of interest are unconsolidated regolith, dust, and atmospheric gas.

Sample Manipulation (core management, sub-sampling/sorting, powder transport)
Sample manipulation technologies are needed to enable handling and transfer of structured and unstructured samples from a sampling device to instruments and sample processing systems. Core, cuttings, and regolith samples may be variable in size and composition, so a sample manipulation system needs to be flexible enough to handle the sample variability. Core samples will be on the order of 1 cm diameter and up to 10 cm long. Soil and rock fragment samples will be of similar volumes.

Sample Integrity (encapsulation and contamination)
For a sample return mission, it is critical to find solutions for maintaining physical integrity of the sample during the surface mission (rover driving loads, diurnal temperature fluctuations) as well as the return to Earth (cruise, atmospheric entry and impact). Technologies are needed for characterizing state of sample in situ - physical integrity (e.g., cracked, crushed), sample volume, mass or temperature, as well as retention of volatiles in solid (core, regolith) samples, and retention of atmospheric gas samples.

Also of particular need are means of acquiring subsurface rock and regolith samples with minimum contamination. This contamination may include contaminants in the sampling tool itself, material from one location contaminating samples collected at another location (sample cross-contamination), or Earth-source microorganisms brought to the

Martian surface prior to drilling ('clean' sampling from a 'dirty' surface). Consideration should be given to use of materials and processes compatible with 110 - 125°C dry heat sterilization. In situ sterilization may be explored, as well as innovative mechanical or system solutions - e.g., single-use sample "sleeves," or fully-integrated sample acquisition and encapsulation systems.

For a sample return mission, sample transfer of a payload into a planetary ascent vehicle: Automated payload transfer mechanisms; and Orbiting Sample (OS) sealing techniques.

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

S5.03 Surface and Subsurface Robotic Exploration
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC, LaRC

Technologies are needed to enable access, mobility, and sample acquisition at surface and subsurface sampling sites of scientific interest on Mars, Venus, small planetary bodies, and the moons of the Earth, Mars, Jovian and Saturnian systems. Many scientifically valuable sites are accessible only via terrain that is too difficult for state-of-the-art planetary rovers to traverse in terms of ground slope, rock obstacle size, plateaus, and non-cohesive soils types. Sites include crater walls, canyons, gullies, sand dunes, and high rock density regions. Tethered systems, non-wheeled systems, and marsupial systems are examples of mobility technologies that are of interest. These technologies could enable new approaches for deployment, retrieval, access, and mobility.

A variety of mobility system architectures can be considered. Single vehicle systems might utilize a 200 kg class rover and dual vehicle systems might utilize a 500 - 800 kg primary vehicle that provides long traverse to the vicinity of a challenging site and then deployment of a smaller 20 - 50 kg vehicle with steep mobility capability for access and sampling at the site.

For surface and subsurface sampling, advanced manipulation technologies are needed to deploy instruments and tools from landers and rovers. Technologies to enable acquisition of subsurface samples are also needed. For Mars and Venus, technologies are needed to acquire core samples in the shallow subsurface to about 10cm and to enable subsurface sampling in multiple holes at least 1 - 3 meters deep through rock, regolith, or ice compositions. Shallow subsurface sampling systems need to be low mass and deeper subsurface sampling solutions need to be integratable onto 500 - 800 kg stationary landers and mobile platforms. For Europa, penetrators and tools to allow deep drilling are needed to sample and bore the outer water-ice layer and through 10 to 30km to a potential liquid ocean below Consideration should be given for potential failure scenarios, such as platform slip and borehole misalignment for integrated systems, and the challenges of dry drilling into mixed media including icy mixtures of rock and regolith. Systems should ensure minimal contamination of samples from Earth-source contaminants and cross-contamination from samples at different locations or depths.

Innovative component technologies for low mass, low power, and modular systems tolerant to the in-situ environment are of particular interest. For Europa, the radiation environment is estimated at 2.9 Mrad total ionizing dose (TID) behind 100 mil thick aluminum. Technical feasibility should be demonstrated during Phase I and a full capability unit of at least TRL level 4 should be delivered in Phase II. Specific areas of interest include the following:

- Tether play-out and retrieval systems including tension and length sensing;
- Low-mass tether cables with power and communication;
- Steep terrain adherence for vertical and horizontal mobility;
- Modular actuators with 1000:1 scale gear ratios;
- Electro-mechanical couplers to enable change out of instruments on an arm end-effector;

- Drill, core, penetrator, and boring systems for subsurface sampling to 10cm , 1 m, 3 m, and deep subsurface;
- Shared intelligence allowing systems to collaborate and adapt exploration scenarios to new conditions.

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

S5.04 Rendezvous and Docking Technologies for Orbiting Sample Capture
Lead Center: JPL
Participating Center(s): GSFC, JSC

NASA seeks an innovative suite of products or technologies that will enable and enhance the successful tracking and capture of a sample canister in Mars orbit in anticipation of the start of a Mars Sample Return (MSR) mission in the next decade.

The principal means of detection and tracking of the Orbiting Sample Canister (OSC) is optically with visual-band cameras. The challenging technology of long-range optical sensors for detection and distant tracking is not part of this call, however, short-range optical (or other) sensors and an on-sample radio-metric-based back-up detection and tracking method is desired, including a low-power, low-mass illuminator for short-range imaging of up to 0.5km.

Sample capture mechanisms are sought, of very low mass and volume, and of low complexity and extremely high reliability, including detection of contact with the capture mechanism. Appropriate on-sample radio-beacons are sought that are compatible with NASA's radio systems, in particular, the Electra onboard programmable radio system; requirements for these beacons are for long life, and independent initiation of on-orbit operation. Solutions are sought that are either battery powered or via solar cells that do not reduce the overall OSC outer shell visual albdeo below 0.5. Sample capture mechanisms should include close-proximity/contact sensors, including immediate-field imaging.

Methods are sought to provide a practice mechanism for testing rendezvous and proximity operations with a test sample canister in Earth or Mars orbit. The test carrier and release mechanism must be of very low mass and volume, and the test sample canister(s) should carry a radio beacon. Test OSC canisters should be of limited life after release, ceasing broadcast, and degrading in surface reflectance in approximately one month after release to avoid confusion with the actual canister. The test articles may be deployed and used on a previous mission to MSR, or on the actual MSR mission for operational readiness testing.

Products or technologies are sought that can be made compatible with the environmental conditions of interplanetary spaceflight and the rigors normal Mars orbits. Proposals should show an understanding of proposals and plans for previous NASA-supported Mars Sample Return relevant missions and mission concepts, and present a feasible plan to fully develop a technology and infuse it into a NASA program. Successful candidate products or technologies can address this call by providing one or more of the following functions, and giving estimated expected performance capabilities of the approach, including, but not limited to, accuracies, ranges, limits of operation, references to previous or related flight experience:

- Autonomously actuated mechanisms for orbiting sample capture of the OSC
  - Mechanical capture mechanisms
  - Transfer mechanisms from capture device to containment transfer mechanism

- Optical and contact sensors
  - Near field imagers (optical or other) (e.g. 10m to 1km)
  - Immediate field imagers (optical) (0.25 to 10m)
  - Detection of OSC for triggering capture mechanism
  - Near field illuminator

- Coherent Radio Doppler and range beacon (high-performance)
    - Low power, low mass and long life beacon for detection aid
    - 2-way communication for activation, ranging and coherency via NASA's Electra radio interface
    - Programmable intermittent transmission for power saving and very long dormancy period
    - Battery or solar powered, preserving 0.5 visual albedo of OSC

- Simple Radio beacon (low-performance)
    - Simple 1-way beacon, for long-range detection and 1-way Electra Doppler extraction
    - Timer activated, multi-year dormant life, and long active life battery, or solar powered – preserving 0.5 visual albedo of OSC

- Low-mass, low-cost sample OSC for proximity operations operational readiness tests
    - A simple, low-cost, low-mass practice sample canister that could be deployed in Earth or Mars orbit and provide low-risk practice runs, either for a precursor mission, or with the actual MSR.
    - The readiness test exercise would not necessarily capture the test article in the capture mechanism for the actual MSR flight, but only perform the rendezvous and proximity ops operations sufficient to demonstrate very high likelihood of actual OSC capture.

S5.05 Extreme Environments Technology
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC, MSFC

High Temperature, High Pressure, and Chemically Corrosive Environments
NASA is interested in expanding its ability to explore the deep atmosphere and surface of Venus through the use of long-lived (days or weeks) balloons and landers. Survivability in extreme high temperatures and high pressures is also required for deep atmospheric probes to giant planets. Proposals are sought for technologies that enable the in situ exploration of the surface and deep atmosphere of Venus and the deep atmospheres of Jupiter or Saturn for future NASA missions. Venus features a dense, CO_2 atmosphere completely covered by sulfuric acid clouds at about 55 km above the surface, a surface temperature of about 486 degrees Centigrade and a surface pressure of about 90 bars. Technologies of interest include high temperature and acid resistant high strength-to-weight textile materials for landing systems (balloons, parachutes, tethers, bridles, airbags), high temperature electronics components, high temperature energy storage systems, light mass refrigeration systems, high-temperature motors and actuators for robotic arms and other mechanisms, high temperature drills, phase change materials for short term thermal maintenance, low conductivity and high-compressive strength insulation materials, high temperature optical window systems (that are transparent in IR, visible and UV wavelengths) and advanced materials with high specific heat capacity and strength for pressure vessel construction, and pressure vessel components compatible with materials such as steal, titanium and beryllium such as low leak rate wide temperature (-50 degrees Centigrade C to 500 degrees Centigrade) seals capable of operating between 0 and 90 bars.

Low Temperature Environments
Low temperature survivability is required for surface missions to Titan (-180 degrees Centigrade), Europa surface (-220 degrees Centigrade), Ganymede (-200 degrees Centigrade) and comets. Also the Earth's Moon equatorial regions experience wide temperature swings from -180 degrees Centigrade to +130 degrees Centigrade during the lunar day/night cycle, and the sustained temperature at the shadowed regions of lunar poles can be as low as -230 degrees Centigrade. Mars diurnal temperature changes from about -120 degrees Centigrade to +20 degrees Centigrade. Also for the baseline concept for Europa Jupiter System Mission (EJSM), with a mission life of 10 years, the radiation environment is estimated at 2.9 Mega-rad total ionizing dose (TID) behind 100 mil thick aluminum. Proposals are sought for technologies that enable NASA's long duration missions to low temperature and wide temperature environments. Technologies of interests include low-temperature resistant high strength-weight textiles for landing systems (parachutes, air bags), low power radiation-tolerant /radiation hardened RF electronics, radiation-tolerant / radiation hardened mixed signal electronics, radiation-tolerant / radiation hardened power

electronics, radiation-tolerant/ radiation hardened high speed fiber optic transceivers, radiation-tolerant/ radiation hardened electronic packaging (including, shielding, passives, connectors, wiring harness and materials used in advanced electronics assembly), actuators and energy storage sources capable of operating across an ultra-wide temperature range from -230 degrees Centigrade to 200 degrees Centigrade and Computer Aided Design (CAD) tools for modeling and predicting the electrical performance, reliability, and life cycle for low-temperature electronic systems and components.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware/software demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

S5.06 Planetary Protection
Lead Center: JPL
Participating Center(s): LaRC

NASA seeks innovative technologies to facilitate meeting Back Planetary Protection objectives for a potential Mars Sample Return mission and to facilitate Forward Planetary Protection implementation for a potential mission to Europa.

Back Planetary Protection deals with the possibility that Mars material may pose a biological threat to the Earth's biosphere. This leads to a constraint that returned samples of Mars material be contained with extraordinary robustness until they can be tested and proved harmless or be sterilized by an accepted method. Achieving this containment goal will require new technology for several functions. Containment assurance requires "breaking the chain of contact" with Mars: the exterior of the sample container must not be contaminated with Mars material. Also, the integrity of the containment must be verified, the sample container and its seals must survive the worst-case Earth impact corresponding to the candidate mission profile, and the Earth entry vehicle (EEV) must withstand the thermal and structural rigors of Earth atmosphere entry - all with an unprecedented degree of confidence.

Back Planetary Protection technologies for the following MSR functions are included in this call:

- Container Design, Sealing, and Verification: Options for sealing the sample container include brazing, explosive welding, and various types of soft seals, with sealing performed either on the Mars surface or in orbit. Confirmation of sealing can be provided by observation of sealing system parameters and by leak detection after sealing. Wireless data and power transmission may be needed for leak detection. Additional containment using a flexible liner within the EEV that is sealed while in Mars orbit has also been considered. Further validation prior to Earth entry may also be needed.
- Breaking-the-Chain and Dust Mitigation: Several paths have been identified that would result in Mars material contaminating the outside of the sealed sample container and/or the Earth return vehicle (ERV). Technology options for mitigation include ejection of containment layers during ascent and orbit and/or capturing a contaminated "Orbiting Sample" into a clean container on the ERV and then ejecting the capture device.
- Meteoroid Protection and Breach Detection: Protection is required for both the sample container and the EEV heat shield, with the later appearing to be the more challenging technology requirement. New lightweight shielding techniques are needed. Even with these the shield may be excessively heavy leading to a requirement for technology to detect a breach of the shield or damage to the EEV.
- Entry, Descent, and Landing: The EEV should be aerodynamically self-righting and should provide shock attenuation for the sample container consistent with the planned no-parachute descent.
- PRA and Reliability Analysis: Obtaining approval to proceed with an MSR mission is likely to involve quantitative assessment of the probability of containment loss. This will benefit from advances in the state of the art of probabilistic risk assessment for complex space systems and of reliability analysis of the spacecraft components involved.

Technologies are desired for the Europa mission that allow sterilization of previously non-sterilizable flight hardware by either i) dry heat processing or ii) gamma irradiation. NASA also seeks to use iii) hydrogen peroxide vapor processes for re-sterilization of assembled flight hardware elements. Proposals are invited for innovative approaches to sterilization of flight hardware in the pre-flight environment using this technology. Note: this call is not for novel sterilization processes.

For Europa, products and technologies are sought that can be demonstrated to be compatible with the three identified sterilization processes, as well as the environmental conditions of spaceflight and the Jovian system. Candidate technologies for the following functions and capabilities are included in this call:

- Sterilization Process Compatibility: Options for proving compatibility of novel product elements (materials, parts) with recognized spacecraft sterilization process parameters are desired.
- Redesign for Sterilization: Development of alternative solutions for spacecraft hardware is needed where there are known sterilization process incompatibilities, for example for heat tolerant sensors, seals (battery, valve), optical coating applications.
- Biobarrier Technology: Demonstration of novel biobarrier and recontamination prevention approaches for spacecraft hardware is needed when applying one or more of these three sterilization processes.

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

TOPIC: S6 Information Technologies

NASA Missions and Programs create a wealth of science data and information that are essential to understanding our earth, our solar system and the universe. Advancements in information technology will allow many people within and beyond the Agency to more effectively analyze and apply this data to create knowledge. In particular, modeling and simulation are being used more pervasively throughout NASA, for both engineering and science pursuits, than ever before. These are tools that allow high fidelity simulations of systems in environments that are difficult or impossible to create on Earth, allow removal of humans from experiments in dangerous situations, and provide visualizations of datasets that are extremely large and complicated. In many of these situations, assimilation of real data into a highly sophisticated physics model is needed. Information technology is also being used to allow better access to science data, more effective and robust tools for analyzing and manipulating data, and better methods for collaboration between scientists or other interested parties. The desired end result is to see that NASA science information be used to generate the maximum possible impact to the nation: to advance scientific knowledge and technological capabilities, to inspire and motivate the nation's students and teachers, and to engage and educate the public.

S6.01 Technologies for Large-Scale Numerical Simulation
Lead Center: ARC
Participating Center(s): GSFC

NASA scientists and engineers are increasingly turning to large-scale numerical simulation on supercomputers to advance understanding of complex Earth and astrophysical systems, and to conduct high-fidelity aerospace engineering analyses. The goal of this subtopic is to increase the mission impact of NASA’s investments in supercomputing systems and associated operations and services. Specific objectives are to:

- Decrease the barriers to entry for prospective supercomputing users;
- Minimize the supercomputer user’s total time-to-solution (e.g., time to discover, understand, predict, or design);

- Increase the achievable scale and complexity of computational analysis, data ingest, and data communications;
- Reduce the cost of providing a given level of supercomputing performance on NASA applications; and
- 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 (http://www.hec.nasa.gov/): the High End Computing Capability project at Ames and the Scientific Computing project at Goddard. To assure maximum relevance to NASA, funded SBIR contracts under this subtopic should engage in direct interactions with one or both HEC projects, and with key HEC users where appropriate. Research should be conducted to demonstrate technical feasibility and NASA relevance during Phase I and show a path toward a Phase II prototype demonstration.

Offerors should demonstrate awareness of the state-of-the-art of their proposed technology, and should leverage existing commercial capabilities and research efforts where appropriate. Open source software and open standards are strongly preferred. Note that the NASA supercomputing environment is characterized by: HEC systems operating behind a firewall to meet strict IT security requirements, communication-intensive applications, massive computations requiring high concurrency, complex computational workflows and immense datasets, and the need to support hundreds of complex application codes – many of which are frequently updated by the user/developer. As a result, solutions that involve the following must clearly explain how they would work in the NASA environment: Grid computing, web services, client-server models, embarrassingly parallel computations, and technologies that require significant application re-engineering. Projects need not benefit all NASA HEC users or application codes, but demonstrating applicability to an important NASA discipline, or even a key NASA application code, could provide significant value.

Specific technology areas of interest include:

- **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, more capable storage/interconnect/visualization technologies, improved algorithms for key codes, and power-aware "Green" computing technologies and techniques.
- **Integrated Environments**: The user interface to a supercomputer is typically a command line in a text window. This subtopic element seeks more intuitive, intelligent, user-customizable, and integrated interfaces to supercomputing resources, enabling users to more completely leverage the power of HEC to increase their productivity. Such an interface could enhance many essential supercomputing tasks: accessing and managing resources, training, getting services, developing codes, running computations, managing files and data, analyzing and visualizing results, transmitting data, collaborating, etc.
- **Cloud Supercomputing**: Cloud computing has made tremendous promises, and demonstrated some success, for business computing: on-demand resource availability, resource virtualization, automated job migration, increased system availability, customized software environments, a web user interface, increased system reliability, and more. This subtopic element seeks technologies that enable Cloud computing to be used for efficient and effective supercomputing operations.

S6.02 Earth Science Applied Research and Decision Support
Lead Center: SSC
Participating Center(s): ARC, 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 natural disasters.

This subtopic seeks new, advanced information systems and decision environments that take full advantage of multiple data sources and platforms. Tailored distribution networks and timely products delivered to a broad range of users are needed to support applications in disaster management, resource management, energy and urban sustainability.

- Development of new integrated multiple user requirements knowledge databases and archival library tools to support researchers and promote infusion of successful technologies into existing processes.
- Development of new decision support strategies and presentation methodologies for applied earth science applications to reduce risk, cost, and time.

This subtopic is also soliciting proposals for utilities, plug-ins or enhancements to open source geobrowsers that improve their utility for earth science research and decision support. Examples of geobrowsers include NASA World Wind, World Wind Java (http://worldwindcentral.com/wiki/Main_page) and COAST (http://www.coastal.ssc.nasa.gov/coast/COAST.aspx). Special consideration will be given to tools for COAST. Examples of specific interest are:

- Tools and utilities to support creation or simplify the import and integration of new datasets;
- Tools and utilities to discover and integrate existing web-enabled sensor data (e.g., webcams, meteorology stations, beach monitors);
- Innovative output mechanisms for data layer sharing and collaboration;
- Enhancements to visualization of custom 3rd dimensional data;
- Enhancements to real time animation capabilities, or incorporation of existing animations into a geobrowser;
- Plug-ins that enable visualization of high resolution imagery in a COAST accessible data viewer;
- Utilities that enable regional estuarine or bay data compilations that are of interest to the major coastal ecosystem managers in those areas;
- Applications that subset, filter, merge, and reformat existing spatial data; provide links to attribute data; or visualize spatial or temporal analytic results in innovative value added fashion within the application.

Proposals should present a feasible plan to fully develop and apply the subject technology.

S6.03 Algorithms for Science Data Processing and Analysis
Lead Center: GSFC
Participating Center(s): ARC, JPL, LaRC, MSFC, SSC

This subtopic seeks technical innovation and unique approaches for the processing and the analysis of data from NASA science missions. Analysis of NASA science data enables insights into dynamic systems such as the sun, oceans, and earth's climate in addition to looking back in time to explore the origins of the universe. Complex algorithms and intensive data processing are needed to understand and utilize this data. Advances in such algorithms will support science data analysis and decision support systems related to current and future missions and mission concepts such as:

- Current operational missions listed at http://www.nasa.gov/missions/current/index.html
- All Earth Science Decadal Survey missions including HyspIRI (http://hyspiri.jpl.nasa.gov/) and DESDynI (http://desdyni.jpl.nasa.gov/)
- Landsat Data Continuity Mission (LDCM) (http://ldcm.nasa.gov/)
- NPOES Preparatory Project (NPP) (http://jointmission.gsfc.nasa.gov/)
- Lunar Reconnaissance Orbiter (LRO), (http://lunar.gsfc.nasa.gov/)
- Lunar Atmosphere and Dust Environment Explorer (LADEE) (http://nasascience.nasa.gov/missions/ladee)
- Moon Mineralogy Mapper (M3) on Chandrayaan (http://moonmineralogymapper.jpl.nasa.gov/)
- Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) (http://crism.jhuapl.edu)
- Visual Infrared Mapping Spectrometer (VIMS) on Cassini (http://saturn.jpl.nasa.gov/spacecraft/cassiniorbiterinstruments/instrumentscassinivims/)
- James Webb Space Telescope (JWST) (http://www.jwst.nasa.gov/)

Research proposed to this subtopic should demonstrate technical feasibility during Phase I, in partnership with scientists, and subsequently 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. Innovations are sought in data processing and analysis algorithms in the following areas:

- **Optimization of Algorithms and Computational Methods** that increase the utility of scientific research data for models, data assimilation, simulations, and visualizations. Of particular interest are innovative computational methods that will dramatically increase algorithm efficiency as well as the performance of scientific applications. Success will be measured by both speed improvements and output validation.
- **Improvement of Data Collection** by identifying data gaps in real-time, and/or derive information through synthesis of data from multiple sources. The ultimate goal is to increase the value of data collected in terms of scientific discovery and application; examples are long-term global and local models and decision support systems for national and humanitarian applications.
- **Frameworks and Related Tools for Processing, Analyzing and Fusing** image and vector data for the purpose of analyzing NASA's astrophysics, heliophysics, planetary and earth science mission data and therefore enable the advancement of NASA's scientific objectives. Of particular interest are open source frameworks or framework components that would enable sharing and validation of tools and algorithms.

Tools and products developed under this subtopic may be used for broad public dissemination or for use within a narrow scientific community. These tools can be plug-ins or enhancements to existing software or on-line data/computing services. They also can be new stand-alone applications or web services, provided that they are compatible with most widely used computer platforms and exchange information effectively (via standard protocols and file formats) with existing, standard or prevalent applications. To promote interoperability, tools shall use industry standard protocols, formats, and APIs (Application Programming Interfaces), including compliance with the FDGC (Federal Geographic Data Committee) and OGC (Open Geospatial Consortium) standards as appropriate.

S6.04 Science Data Discovery in Extremely Large Data Environments
Lead Center: GSFC
Participating Center(s): JPL, LaRC

This subtopic focuses on supporting science data discovery for extremely large data environments through developing innovative cloud and large cluster based science data discover applications, application development tools, and performance monitoring tools. Specific areas for which proposals are being sought:

- Science discovery applications: Applications for science data discovery, data mining, data search, and data sub setting that scale to extremely large data sets in cloud or large cluster computing environments.

- Application development tools: integrated ecosystem of tools for developing applications for high performance processing environments, including cloud computing, high performance cluster, and GPU processing environments, that support software development for science data discovery applications, including support for compilation, debugging, and parallelization.
- Performance monitoring tools: Integrated tools to collect, analyze, store, and present performance data for cloud computing and large scale cluster environments, including tools to collect data throughput of system hardware and software components such as node and network interconnects (GbE, 10 GbE, and Infiniband), storage area networks, and disk subsystems, and tools to capture data on a user configured basis, that allow extensibility for new metrics, and verification of the configuration and health of a system.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware/software demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

S6.05 Software Engineering Tools for Scientific Models
Lead Center: GSFC

This subtopic seeks to improve the productivity and quality of NASA's scientific modeling endeavors through customized tools, which enable and encourage improved software engineering practices. Because many of NASA's principal scientific models have evolved over decades to be hundreds of thousands of lines long with contributions from a wide variety of scientists, much of the software has become "brittle" in the sense that it has become difficult to extend, couple, and optimize. In other software communities (and other programming languages), access to modern software tools has enabled large gains in productivity by providing high-level tools for isolating software defects (bugs) as well as by automating common, albeit tedious, software processes. The goal is to extend these capabilities to support the Fortran programming language so that NASA's scientific models can extract similar benefits.

Target Programs, Missions and Mission Classes
Advances in developer productivity would be of significant benefit to several research and analysis programs within the Science Mission Directorate including:

- High-End Computing Program (http://hec.nasa.gov)
- Modeling, Analysis, and Prediction Program (http://map.nasa.gov)

Technology Areas
The objective is to create a suite of software tools, which directly ameliorate the most significant bottlenecks to productivity in the development of scientific models:

- Tools that assist in the construction of fine-grained unit-level software tests based upon existing functionality in a legacy Fortran application. Although tests written by developers are desirable, such tests are exceedingly difficult to create for legacy numerical software. Suites of these tests could provide a significant element of risk-reduction for maintenance and extension of these models, and would be incorporated into some sort of unit-testing framework.
- Tools that reduce cost and risk for maintaining and extending legacy scientific software. Desirable to be integrated within other common development tools.
- Tools that enable high-level source code transformations ("refactorings"). Although refactoring support for Fortran is improving rapidly (http://www.eclipse.org/photran/), substantial opportunities exist for new refactorings targeted at NASA's scientific computing needs.

Tools and products developed under this subtopic may be used for broad public dissemination or for use within a narrow scientific community. These tools can be plug-ins or enhancements to existing software or on-line data/computing services. They also can be new stand-alone applications or web services, provided that they are compatible with most widely used computer platforms and exchange information effectively (via standard protocols and file formats) with existing, standard or prevalent applications. To promote interoperability, tools shall use industry standard protocols, formats, and APIs (Application Programming Interfaces).

It is highly desirable that the proposed projects lead to software that is infused into NASA programs and projects.

9.1.4 SPACE OPERATIONS

The Space Operations Mission Directorate (SOMD) provides the foundation for NASA's space programs — space travel for human and robotic missions, in-space laboratories, processing and operations of space systems, and the means to return data to the Earth. The directorate provides the daily operational capabilities for the agency. These capabilities: Space Communications; Space Transportation; Processing and Operations; Navigation; and International Space Station (ISS) operations must continue to evolve synergistically as the directorate guides their development and enhancement. In addition, as other NASA programs develop new mission requirements and capabilities, SOMD's operational capability will evolve to include these new enhancements. In summary, the Space Operations Mission Directorate provides space access and operations for our customers with a high standard of safety, reliability, and affordability.

In support of NASA's mission, the Space Operations Mission Directorate will marshal its SBIR efforts around four key technology areas: (1) Space Communications; (2) Space Transportation; (3) Processing and Operations; and (4) Navigation. These technology areas will enable efficient and affordable technology development for: communications and navigation; human operation in space; science missions; space access services and cost reduction; ISS utilization; ISS Life Extension; and daily system operations. We go forward as explorers and as scientists to understand the universe in which we live.

http://www.nasa.gov/directorates/somd/home/index.html

TOPIC: O1 Space Communications

NASA's communications capability is based on the premise that communications shall enable and not constrain missions. Communications must be robust to support the numerous missions for space science, Earth science and exploration of the universe. Technologies such as optical communications, RF including antennas and ground based Earth stations, surface networks, access links, reprogrammable communications systems, advanced antenna technology, transmit array concepts and communications in support of launch services including space based assets are very important to the future of exploration and science activities of the Agency. Emphasis is placed on size, weight and power improvements. Even greater emphasis is placed on these attributes as small satellites (e.g., micro and nano satellite) technology matures. Innovative solutions centered on operational issues are needed in all of the aforementioned areas. Communication technologies enabling acquisition of range safety data from sensitive instruments is imperative. All technologies developed under this topic area to be aligned with the Architecture Definition Document and technical direction as established by the NASA Office of Space Communications and Navigation (SCaN). For more details, see:

https://www.spacecomm.nasa.gov/spacecomm/
https://www.spacecomm.nasa.gov/spacecomm/programs/default.cfm
https://www.spacecomm.nasa.gov/spacecomm/programs/technology/default.cfm
https://www.spacecomm.nasa.gov/spacecomm/programs/technology/sbir/default.cfm

A typical approach for flight hardware would include: Phase I – Research to identify and evaluate candidate telecommunications technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration.

Bench or lab-level demonstrations are desirable. Phase II – Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions. The proposal shall outline a path showing how the technology could be developed into space-worthy systems. The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract. Some of the subtopics in this topic could result in products that may be included in a future flight opportunity. Please see the following for more details:

- SMD Topic S4 for more details concerning requirements for Small Satellite flight opportunities.
- Facilitated Access to the Space Environment for Technology Development and Training (FAST): http://ipp.nasa.gov/ii_fast.htm
- International Space Station payload opportunities: http://www.nasa.gov/mission_pages/station/science/experiments/Discipline.html
- Terrestrial analogs (Desert Rats, Haughton Field): http://www.nasa.gov/exploration/analogs/desert_rats.html, http://ti.arc.nasa.gov/projects/haughton_field

Note: Communications technologies for space-based range must be highly integrated with required navigation components; hence, space-based range technologies are solicited in Space Transportation Subtopic O2.03 – Spaceport Enhancements and Improvements.

O1.01 Antenna Technology
Lead Center: GRC
Participating Center(s): DFRC, GSFC, JPL, JSC, LaRC

NASA seeks advanced antenna technologies in the following areas: phased array antennas; ground-based uplink antenna array designs; large aperture deployable antennas; novel materials for next generation antennas; smart, reconfigurable antennas; and antenna concepts for harsh environments.

Phased Array Antennas
High performance phased array antennas are needed for high-data rate communication at Ka-Band frequencies and above as well as for remote sensing applications. Communications applications include: planetary exploration, landers, probes, rovers, EVA, suborbital vehicles, sounding rockets, balloons, unmanned aerial vehicles (UAV's), TDRSS communication, and expendable launch vehicles (ELV's). Also of interest are multi-band phased array antennas (e.g., X- and Ka-band) and RF/optical shared aperture dual use antennas, which can dynamically reconfigure active elements in order to operate in either band as required in order to maximize flexibility, efficiency and minimize the mass of hardware delivered to space. Phased array antennas for space-based range applications to accommodate dynamic maneuvers are also of interest. The arrays are required to be aerodynamic or conformal in shape for sounding rockets, UAV's, and expendable platforms and must be able to withstand the launch environment. Potential remote sensing applications include: radiometers, passive radar interferometer platforms, and synthetic aperture radar (SAR) platforms for planetary science.

Ground-based Uplink Antenna Array Designs
NASA is considering arrays of ground-based antennas to increase capacity and system flexibility, to reduce reliance on large antennas and high operating costs, and eliminate single point of failure of large antennas. A large number of smaller antennas arrayed together results in a scalable, evolvable system, which enables a flexible schedule and support for more simultaneous missions. A significant challenge is the implementation of an array for transmitting (uplinking), which may or may not use the same antennas that are used for receiving. Arraying concepts that can enable a single network (i.e., DSN, NEN, and SN) at Ka-band frequencies and above are highly desired.

Large Aperture Deployable Antennas
Large aperture deployable antennas with surface root-mean-square (rms) quality better than $\lambda/40$ at Ka-Band frequencies and above, are desired. In addition, these antennas should significantly reduce stowage volume (packaging efficiencies as high as 50:1), provide high deployment reliability, and significantly reduced mass density (i.e., $\leq 1 kg/m^2$). These large Gossamer-like antennas are required to provide high-capacity communication links with low fabrication costs from deep space (Mars and beyond). Applicability to Ka-Band or higher frequencies is required. Concepts addressing antenna adaptive beam correction with pointing control are also of interest.

Novel Materials for Next Generation Antennas
NASA is interested in exploiting novel materials approaches for next generation antennas. For example, “smart” materials such as shape memory polymers or ionic polymer metal composites to permit active shape control or beam correction are of interest. Artificial electromagnetic media for phase velocity control and impedance tuning to improve the efficiency and bandwidth of electrically small antennas is of interest. Ferroelectric based technologies as well as multiferroics and spintronics concepts leading to new antenna designs are desirable.

Smart, Reconfigurable Antennas
Smart, reconfigurable antennas for applications in planetary operations are of interest. The characteristics to consider include the frequency, polarization, and the radiation pattern. Low-cost approaches are encouraged to reduce the number of antenna apertures needed to meet the requirements associated with rovers, pressurized surface vehicles, habitats, etc. for planetary surface exploration. Desirable features include multi-beam operation to support connectivity to different communication nodes on planetary surfaces, or in support of communication links for satellite relays around planetary orbits. Innovative receiver front-ends or technologies that allow for the DSP to move closer to the antenna terminal furthering the impact of the aforementioned, revolutionary “game-changing” antenna technology concepts are highly desirable.

Antenna Concepts for Harsh Environments
Novel, “Game Changing”, robust antenna concepts that can perform optimally and reliably in harsh environments such as those imposed by the Lunar regolith/dust and Martian dust are highly desirable.

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: A final report containing optimal design for the technology concept including feasibility of concept, and a detailed path towards Phase II hardware demonstration. The report shall also provide options for commercialization opportunities after Phase II.

Phase II Deliverables: A working proof-of-concept demonstrated and delivered to NASA for testing and verification. Exit TRL 5 is expected at the end of Phase II.

O1.02 Reconfigurable/Reprogrammable Communication Systems
Lead Center: GRC
Participating Center(s): DFRC, GSFC, JPL, JSC

This solicitation seeks advancements in reconfigurable transceiver and associated component technology. The goal of the subtopic is to provide flexible, reconfigurable communications capability while minimizing on-board resources and cost. Areas of interest to develop and/or demonstrate are as follows:

- Software/firmware for the management of waveform or functional reconfiguration. Simultaneous operation while reconfiguration takes place and an adherence to the Space Telecommunications Radio System (STRS) v 1.02.1 document is desired, which will soon be publicly available at https://www.spacecomm.nasa.gov/spacecomm/default.cfm
    - Goal: Simultaneous operation while reconfiguration takes place.
    - Goal: STRS compliance

- Methods and tools for the development of software/firmware components that are portable across multiple platforms. Standards-based approaches are preferred.
    - Goal: Tool chain and/or development processes that result in 80% portability between 2 standards-based SDR platforms.

- Dynamic/distributed on-board processing architectures that are scalable and are designed to operate in various space environments.
    - Goal: 10x processing capability increase for fixed SWaP.

- Component technology advancements in bandwidth capacity and reduced resource consumption.
    - Goal: 5x bandwidth processing increase, 2x decrease in resource consumption.

- Analog-to-digital converters or digital-to-analog converters to increase sampling and resolution capabilities.
    - Goal: 3x increase in sampling resolution capabilities.

- Novel techniques or processes to increase memory densities.
    - Goal: 5x increase in memory per unit volume.

- Novel approaches to mitigate device susceptibility to radiation effects.
    - Goal: Target payload class SEU and latch-up mitigation techniques to achieve requirements for various class payloads in the desired space environment at lowest SWaP cost.

NASA also seeks to populate a repository for STRS compliant waveforms. These waveforms may be field or ported to available STRS-compliant SDRs. The description of STRS-compliance is available in the STRS 1.02.1 document, soon to be publicly available at https://www.spacecomm.nasa.gov/spacecomm/default.cfm.

Note that NASA not only seeks reconfigurable/reprogrammable communication systems for flight applications, but also for the additional capabilities reconfigurable/reprogrammable systems may add to R&D and interoperability test labs. NASA centers have varying roles, capabilities, and R&D interests/priorities. Therefore, this year's call will also take into consideration how the products from O1.03 (Phase I, II, and III) will contribute to the current administration's vision for NASA and its commercial and international partners, and where these products may be relevant within our collection of terrestrial labs and/or flight systems.

The advancement of component technology for reconfigurable/reprogrammable communications systems is highly desirable for the insertion of these systems into space missions. Further adoption of reconfigurable/reprogrammable communications systems allow NASA science and human space flight missions to reduce risk and evolve as future requirements mature. These component technologies address either the reduction of size, weight, and power of these systems, or the costs associated with development.

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

Phase I Deliverables: The Phase I deliverable consists of a report detailing the technical feasibility of the innovation and it's contribution to the advancement of the state-of-the-art. The Phase I technology is expected to result in the component technology developed to TRL 2-3.

Phase II Deliverables: The Phase II deliverable consists of a demonstration of hardware and/or software prototype(s) with the intent of integration or testing in a relevant NASA laboratory, with a corresponding report detailing operating instructions for the component technology. The Phase II technology is expected to result in the component technology developed to TRL 5-6.

O1.03 Game Changing Technologies
Lead Center: GRC
Participating Center(s): ARC, JSC

NASA seeks revolutionary, highly innovative, game changing technologies that have the potential to enable order of magnitude performance improvements for space communications and navigation. Fundamental, strategic R&D is a critical element in developing innovative and superior technologies for space communication and navigation systems by addressing deficiencies in the current space communications network infrastructure to enhance performance, improve efficiency and reduce cost.

Research is geared towards emphasizing research and space technologies that are far-term focused in (but not limited to) the following areas:

- Low SWAP Transceivers: Develop novel techniques to reduce the size, weight, and power (SWAP) requirements for communications transceivers and software-defined radios for space missions. Address SWAP challenges by addressing digital processing and logic implementation tradeoffs, static vs. dynamic power, voltage and frequency scaling, hardware and software partitioning such that operational modes are effectively managed. Use of open, interoperable standards is encouraged.
- Ka-band RF Devices and Components: Investigate novel RF (especially Ka-band) communications technologies and innovative approaches for high bandwidth, Ka-band devices and components (transceivers, modulators, highly efficient amplifiers, etc.). Approaches to significantly reducing size, mass, and power requirements for these components are paramount as well.
- High Performance Ultra Low-Power ADCs and DACs: The high power consumption and lack of flexibility to reconfigure on-the-fly make off-the-shelf analog-to digital converters (ADCs) devices ill-suited for digital radio applications. To en-able next-generation radios and support the ever-increasing user demands

of high resolution (6 GSPS) and input bandwidths (2.5 GHz), breakthroughs in high-speed, low power ADCs are needed. Assume dynamically adjustable resolution up to 16 bits and on-board ultra-low jitter clock circuit to enhance spectral power distribution. A deep sleep mode feature is highly desirable to conserve power. Currently, state-of-the-art high rate digital-to-analog converters (DACs) are power prohibitive. To increase robustness, spectral efficiency, and compactness, NASA seeks to develop complementary DACs. For example, at a scant total power budget of 4 watts, ADCs and DACs will facilitate breakthroughs in S-band digital transceivers with fewer parts, smaller form factors, and greater design flexibility.

- Nanotechnology: High-performance, multi-functional, nano-structured materials for communications applications. Single wall carbon nano-tubes exhibit extraordinary mechanical, electrical, and thermal properties at the nano-scale level and possess exceptionally high surface area to volume ratio. The development of nano-scale communication devices and systems including nano-antennas, nano-transceivers, etc. are of interest for nano-spacecraft applications.
- Quantum Entanglement: Innovative breakthroughs in quantum information physics has sparked interest to specifically address this phenomenon and the critical unknowns relevant to revolutionary improvements in communicating data, information or knowledge. Methods or techniques that demonstrate extremely novel means of effectively packaging, storing, encrypting, and/or transferring information are sought.
- RF MEMS Integrated Components: RF micro-electromechanical systems (MEMS) offer exceptional RF performance and power characteristics that can lead to dramatic advantages for novel radio applications. Such as wireless filter banks, switching matrices, and instrumentation. Although low-power, high efficiency charge pumps can be integrated into advanced communication systems that employ novel MEMS devices (e.g. switches or varactors) or circuits (e.g. tunable filters or power amplifiers), there are some long-term challenges with power handling and non-linear behavior for power levels of 1 Watt. Because high-Q varactors and filters are not well understood, NASA seeks to advance revolutionary MEMS devices and architectures that are immune to bias noise.
- Trans-Horizon Communications: Innovative approaches to use of medium to high frequency (300 KHz-30MHz) bands for applications benefiting future surface landing missions. Concepts, studies, development of key technologies are needed to perform non-line-of-sight communication for potential use on the surfaces of celestial bodies. For example, the lunar exosphere may have the ability to support such communications, if fully understood. Modulation and coding techniques, antennas, solid-state amplifiers, digital baseband circuitry, etc. are required to be developed and/or validated to enable over the horizon communication and communications into craters for robotic and human missions. Range of communications on the order of 10-20 kilometers at a data rate of 128 kbps is envisioned to support many of these types of surface communications links.
- Navigation: In adopting any proposed game-changing technologies, the capability for provision of high-quality metric tracking observables for orbit determination and other tracking services must be considered. Proposers should recognize that NASA may not be able to adopt certain game-changers in communications and navigation technology if they do not support at least NASA's current needs for metric tracking data services. Proposals in this area should document any potential performance enhancements, and especially any foreseeable compatibility issues associated with metric tracking data services.
- Low-Power High Stability Reference Sources: Highly stable clocks and oscillators play a pivotal role in a myriad of space communications and navigation applications. Atomic (cesium) clocks used today have time measurement accuracies on the order of 2 nanoseconds per day. New research (optical, quantum) into improving time measurement accuracy, size, reliability for space communications and navigation are of interest. Highly stable clock sources for wireless communications devices can improve network synchronization and channel selection to enhance security and anti-jamming capabilities.

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

Phase I Deliverables: Deliverables expected at the end of Phase I include trade studies, conceptual designs, simulations, analyses, reports, etc. at TRL 1-2.

Phase II Deliverables: Demonstrate performance of technique or product through simulations and models, hardware or software prototypes. It is expected that at the end of the Phase II award period, the resulting deliverables/products will be at or above TRL 3.

O1.04 Long Range Optical Telecommunications
Lead Center: JPL
Participating Center(s): GRC, GSFC

This subtopic seeks innovative technologies for long range Optical Telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

Systems and technologies relating to acquisition, tracking and sub-micro-radian pointing of the optical communications beam under typical deep-space ranges (to 40 AU) and spacecraft micro-vibration environments, as follows:

- **Small lightweight two-axis gimbals:** Flight qualifiable, less than 2 kg in mass capable to actuating payload mass of approximately 3 kg at rates up to 5 degrees/second, less than 30 micro-radian jitter, 30 micro-radian rms error and blind-pointing accuracy of less than 35 micro-radian. Proposals should come up with innovative pragmatic designs that can be flown in space.
- **Photon counting Si, InGaAs, and HgCdTe detectors and arrays:** For the 1000 to 1600 nm wavelength range with single photon detection efficiencies greater than 60% and output jitters less than 20 pico-second, active area greater than 20 microns/pixel, and 1 dB saturation rates of at least 100 mega-photons (detected) per pixel and dark count rates of less than 1 MHz/square-mm.
- **Single-photon-sensitive, high-bandwidth, linear mode photo-detectors:** With high bandwidth (>1GHz), high gain (>1000), low-noise (<1kcps), large diameter (200 micron), HgCdTe avalanche photodiode and/or (small diameter) arrays for optical detection at 1060 nm or 1550 nm.
- **Uncooled photon counting imagers:** With >1024 x 1024 formats, ultra low dark count rates and visible to near-IR sensitivity.
- **Ultra-low fixed pattern non-uniformity NIR imagers:** With large format (1024x1024), non-uniformity of less than 0.1%, low noise (<1e- read, <1ke/pix/s dark) and high (>0.7) quantum efficiency.
- **Radiation hard photon counting detectors and arrays:** For the 1000 to 1600 nm wavelength range with single photon detection efficiencies greater than 40% and 1dB saturation rates of at least 30 mega-photons/pixel and operational temperatures above 220K and dark count rates of <10 MHz/mm. Radiation levels of at least 300 krad (unprotected).
- **Isolation platforms:** Compact, lightweight, low power, broad bandwidth (0.1 Hz -3 kHz) disturbance rejection.
- **Laser transmitters:** Space qualifiable, greater than 20% wall plug efficiency, lightweight, 20-500 pico-second pulse-width (10 to >100 MHz PRF), tunable (~0.2 nm) pulsed 1064-nm or 1550-nm laser transmitter fiber or planar-waveguide MOPA sources with greater than 1 kW of peak power per pulse (over the entire pulse-repetition rate), with Stimulated Brillouin Scattering suppression and >10 W of average power, near transform limited spectral width, and less than 10 pico-second pulse rise and fall times. Also of interest for the laser transmitter are: robust and compact packaging with radiation tolerant electronics inherent in the design, and high speed electrical interface to support output of pulse position modulation encoding of sub nanosecond pulses and inputs such as Spacewire, Firewire or Gigabit Ethernet. Detailed description of approaches to achieve the stated efficiency is a must.
- **Low-cost ground-based telescope assembly:** With diameter greater than 2-m, primary mirror with f–number of ~1.1 and Cassegrain focus to be used as optical communication receiver optics. Maximum RMS surface figure error of 1-wave at 1000 nm wavelength. Telescope shall be positioned with a two-axis

gimbal capable of 0.25mrad pointing. Combined telescope, gimbal and dome shall be manufacturable in quantity (tens) for ~$3 M each.

- **Daytime atmospheric compensation techniques:** Capable of removing all significant atmospheric turbulence distortions (tilt and higher-order components) on an uplink laser beam; and/or for a 2-m diameter downlink receiver telescope. Also of interest are technologies to actively compensate for the static and dynamic (gravity sag and thermal) aberrations of 2-m diameter telescopes with a surface figure of 10's of waves (down to less than 1-wave at 1000 nm).

Research should be conducted to convincingly prove technical feasibility during Phase I, with clear pathways to demonstrating and delivering functional hardware, meeting all objectives and specifications, in Phase II.

Phase I Deliverables:

- Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4)
- Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables:

- Working brassboard model of proposed product, along with full report of development and measurements, including populated verification matrix from phase II (TRL 5).
- Opportunities and plans should also be identified and summarized for potential commercialization.

O1.05 Long Range Space RF Telecommunications
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC

This solicitation seeks to develop innovative long-range RF telecommunications technologies supporting the needs of space missions. The ultimate objective is to maximize aggregate mission data return per unit mass, unit volume, unit cost and unit power consumed by the spacecraft telecommunications subsystem.

In the future, spacecraft with increasingly capable instruments producing large quantities of data will be visiting the moon and the planets. To support the communication needs of these missions and maximize the data return to Earth, innovative long-range telecommunications technologies that maximize power efficiency, transmitted power density and data rate, while minimizing size, mass and power are required.

The current state-of-the-art in long-range RF space telecommunications is 6 Mbps from Mars using microwave communications systems (X-Band and Ka-Band) with output power levels in the low tens of Watts and DC-to-RF efficiencies in the range of 10-25%.

This solicitation seeks proposals in the following areas:

- Ultra-small, light-weight, low-cost, low-power, modular deep-space transceivers, transponders and components, incorporating MMICs 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-efficiency (> 60%), low mass Solid-State Power Amplifiers (SSPAs), of both medium output power (10 W-50 W) and high-output power (150 W-1 KW), using power combining and/or wide band-gap semiconductors at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz);

- Utilization of nano-materials and/or other novel materials and techniques for improving the power efficiency or reducing the cost of reliable vacuum electronics amplifier components (e.g., TWTAs and Klystrons);
- Ultra low-noise amplifiers (MMICs or hybrid) for RF front-ends (< 50 K noise temperature);
- MEMS-based integrated RF subsystems that reduce the size and mass of space transceivers and transponders. Frequencies of interest include UHF, X- and Ka-Band. Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.
- Ultra low mass, high gain, high efficiency spacecraft antennas using advanced light materials and structures.
- Novel, hybrid spacecraft antenna designs that can act as efficient reflectors/concentrators of both RF (X- and Ka-Band) and optical (1550 nm) electromagnetic waves.

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

Phase I Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4). Verification matrix of measurements to be performed at the end of Phase II, along with specific quantitative pass-fail ranges for each quantity listed.

Phase II Deliverables: Working engineering model of proposed product, along with full report of development and measurements, including populated verification matrix from Phase II (TRL 5-6). Opportunities and plans should also be identified and summarized for potential commercialization.

O1.06 Space Networking
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

NASA's Space Communications and Navigation Program (SCaN) is integrating its current agency networks: Deep Space Network (DSN), Space Network (SN), TDRSS spacecraft, Near Earth Network (NEN), and future Exploration Destination networks into a single Integrated Architecture circa 2018. Technologies must be adaptable to a variety of network operating environments ranging from the long-latency limited bandwidths of deep space communications to near Earth environments with traffic flow over global partner assets and the future internet. It is also important to note that NASA systems include ground-to-ground segments in addition to space-to-ground links. Solutions must keep in mind the "big picture" and be capable of seamlessly integrating with future ground systems.

Emerging space communications environments are expected to be shaped in various ways: small mobile mission clusters; traditional large spacecraft and launch vehicles; complexities of commercial and international partnering on the network and user sides; increasing threats to US space communications and navigation assets; and NASA's need for 40% reduction in network operating costs.

NASA seeks space-networking technologies, which add network intelligence and learning capabilities to increase network efficiency; provide tailored user services; reduce network operating costs through automation; and increase security and resiliency.

Several technologies with promise to meet some of these challenges are listed below with their purpose current state-of--art, and performance metrics desired. Proposals should focus on one or two of these technologies, or for the more complex topics, single implementation aspects.

- Dynamic traffic prioritization provides a means to quickly isolate different types of traffic schemes across the space network. Current technologies allow for such features in the ground environment and the study should leverage those techniques as appropriate. The proposed approach should identify what is necessary for prioritization to be leveraged across multiple space organizations. It should also identify how decisions may impact the performance of different types of data streams.

- Adaptive autonomous network management is to enable smart network elements to make decisions within a predetermined playbook based upon awareness of local network conditions, policies and network end-to-end-objectives. Examples such as automated uplink/downlink scheduling have been demonstrated and are in operational use in limited circumstances. The concept is to shorten the time between a particular network anomaly and the resulting response by mission control allowing for more efficient utilization of the network. Studies must show how the shortened control loop yields better efficiency and how both conditions and automated responses are relayed back to a human operator.
- Cognitive networking with learning is to enable intelligent network elements to reason about reconfiguration decisions [at any layer in the protocol stack] even in unexpected conditions [whether to make decisions autonomously or to offer quantitative support to human operators] based upon situational awareness of network conditions and statistical learning about network behavior and consequences of prior interventions. Software defined and cognitive radios have been demonstrated for terrestrial use and are progressing towards broader cognitive network applications with limited and specific terrestrial demonstrations. Cognitive networking with learning is currently at the forefront of the state-of-the-art, with a multiplicity of approaches being developed for diverse applications such as Future Internet, mobile wireless, and tactical communications. Bidders are encouraged to narrow their focus to specific implementation issues in the domain and focus on adaptation for SCaN space networks. Desired performance metrics are relevant analytical estimates of potential benefits and feature cost-benefit.
- Enhanced security and trust management services for missions that have limited computational and power resources. Contact should not be assumed to be continuous and approaches should leverage proven security techniques where appropriate and provide a means to authenticate between assets and to provide a means to securely update network information (i.e. route injection). It will be important to identify how the proposed approach mitigates particular security risks while also remaining efficient in the space environment.
- Novel techniques for position determination, timing, and route computation are to provide essential services for missions that venture beyond GPS coverage and SCaN infrastructure particularly for missions limited in equipage they can carry or in the face of intentional service disruption. Human missions develop positional uncertainty at a rate of 10 km/hr due to random accelerations. Early lunar missions like LRO are without timing service. Route computation requirements emerge with formation flight, delta-V sensitive libration point and planetary highway orbits, and robotic surface exploration. [Metrics: convergence time, overhead (number of bytes used by routing algorithm to reach steady state)].

For more information on NASA's future space communication plans, please see the Space Communications and Navigation website at https://www.spacecomm.nasa.gov/

Performance metrics are listed by technology above.

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: Phase I report will analytically demonstrate technical feasibility of one or more space networking technologies identified above by characterizing:

- Technical requirements flow-down from generic objectives and summary of state-of-the-art to SCaN network-specific requirements on key performance metrics
- Identification of specific technical challenges to implementation for SCaN networks.
- Analysis of at least three alternative approaches to obtain this performance for SCaN networks.
- Assessment of cost-benefit of each (e.g. risk, complexity, added overhead)
- Selection of software or hardware concept and emphasis topics for further investigation.
- Plan for Phase II resolution of issues or uncertainties and hardware and software demonstration.

- Target TRL 3 at the end of Phase I efforts.

Phase II Deliverables: Phase II report will document:

- Updates to the technical requirements flow-down, identified technical challenges, and selected hardware or software concept based upon further investigation in Phase II.
- Analytical or experimental investigations undertaken to resolve issues and fur-her definition of the selected approach.
- Design and test approach selected for hardware or software demonstration with detailed description of assumptions and parameters.
- Conclusions based upon test results and recommendations for further investigation including any plans for commercialization or further development.
- Target TRL of 5 at the end of Phase II efforts.

TOPIC: O2 Space Transportation

Achieving space flight remains a challenging enterprise. It is an undertaking of great complexity, requiring numerous technological and engineering disciplines and a high level of organizational skill. Overcoming Earth's gravity to achieve orbit demands collections of quality data to maintain the security required of the range. The harsh environment of space puts tight constraints on the equipment needed to perform the necessary functions. Not only is there a concern for safety but the 2004 Space Transportation Policy directive states that the U.S. should maintain robust transportation capabilities to assure access to space. This crosscutting SBIR Topic seeks to enable commercial solutions for U.S. space transportation systems providing significant reductions in cost, and increases in reliability, flight-rate, and frequency of access to space. The goal is a breakthrough in cost and reliability for a wide range of payload sizes and types (including passenger transportation) supporting future orbital flight that can be demonstrated on interim suborbital vehicles. The vision is a competitive marketplace with multiple commercial providers of highly reusable space transportation systems and services with aircraft-like operations, high-flight rates, and short turnaround times (days-to-hours, rather than months). Lower cost and reliable space access will provide significant benefits to civil space (human and robotic exploration beyond Earth as well as Earth science), to commercial industry, to educational institutions, for support to the International Space Station National Laboratory, and to national security. While other strategies can support frequent, low-cost and reliable space access, this topic focuses on the technologies that dramatically alter reusability, reliability and operability of next generation space access systems.

O2.01 Secondary/Auxiliary Payload-to-Launch Vehicle Interface Technologies
Lead Center: KSC
Participating Center(s): DFRC

This subtopic includes two major technology areas:

(1) Small payload standard interface technologies (SPSIT)
(2) Entry and ascent experimental platform technologies (EAEPT)

Proposals will be accepted for either area.

Many expendable launch vehicle (ELV) launches do so with excess capacity. The utilization of specific excess volumes within a launch system must be accomplished at a low cost with minimal to no additional risk to the primary payload or launch vehicle. This subtopic seeks to develop commercial solutions that will allow and encourage new enabling launch capabilities and standardization of key payload-to-launch vehicle processes and interface standards with the goal of producing a low cost, low risk plat-form or process for integrating secondary or auxiliary payloads on existing NASA ELV launches.

The goal is to develop new launch vehicle capabilities such as adapters/platforms, processes, and/or avionics interface standards that can be collectively used to:

- Minimize integration tasks and/or duration of integration efforts to install secondary/auxiliary payloads onto NASA ELV launches
- Facilitate secondary/auxiliary spacecraft and subsystem design while reducing testing duration and complexity
- Impose no additional risk to the primary mission
- Enable novel mission concepts for secondary/auxiliary payloads

Small Payload Standard Interface Technologies
Currently, the Poly-Picosatellite Orbital Deployer (PPOD) provides a cost-efficient standard interface and deployment system for CubeSats in the 1 to 3 kg mass range. In addition, the Evolved ELV (EELV) Secondary Payload Adapter (ESPA) provides a standard structural interface for secondary payloads up to180kg and is designed for interface into Atlas V and Delta IV launch vehicles. A smaller version of the ESPA ring has been conceptualized for smaller launch vehicles. Both the ESPA and the small ESPA are most cost effective when they accommodate 6 payloads. In addition, for the most part, the avionics and electrical power interfaces are unique to each launch vehicle fleet. This subtopic seeks to develop commercial solutions that could allow the cost effective launch of one or more secondary/auxiliary payloads via an interface (structural, avionics and electrical) that is standard or expandable/upgradable to be compatible with the maximum number of domestic launch vehicles. NASA currently has Pegasus XL, Taurus XL, Falcon 1, Falcon 9, Atlas V and Delta IV on contract.

A significant fraction of mission costs are typically unique designs and approaches to perform relatively routine functions such as launch accommodations and subsystem-to-subsystem interface and communications. By standardizing many of these approaches, spacecraft and payload developers can design their systems with an expectation of a predictable, low-cost integration flow. Launch service providers can mitigate mission risk through the use of predictable and proven interfaces standardized to streamline analytical/physical integration processes and test flows.

This subtopic will focus on new interfaces for payloads in the mass range of 3 to 180 kg, which can be grouped as needed for any modularization concepts. A range of 11 to 100 kg has been specifically identified as a region where critical technology demonstrations and new space technologies could use affordable orbital launch opportunities to increase their TRL, potentially reducing their overall cost and risk to development. Enabling affordable launch capabilities in these ranges could also allow scientific and educational spacecraft (s/c) developers the ability to design to a specific mass range that will result in on-orbit research.

The technologies in this subtopic are highly desirable because although adapters that could support most missions exist, having multiple systems across multiple launch vehicles fleets will contribute to higher integration costs. Standards amongst the s/c and adapter community will reduce integration cost and therefore the per-kilogram cost-to-orbit.

Areas of interest (SPSIT):

- Launch adapters and systems and associated spacecraft standards
- Standardized spacecraft and/or payload integration test flows, processes and qualification techniques
- Standardized electrical interfaces, sometimes known as plug and play electrical power and data bus standards for streamlined subsystem integration.

The critical requirement for all areas of interest identified above is that the design, integration or implementation shall not increase base line risk to the primary spacecraft or the launch vehicle mission success. Implementation of the above enables support for any upcoming missions needing the capability to demonstrate new technology on-orbit by using a standard interface or process.

Phase I Deliverables (SPSIT):

- Assessments of current and future spacecraft/mission/space technologies in the mass ranges will identify current adapter systems, processes and determine the TRL for each system within 3 year timeframe from award date
- Develop draft standards for both spacecraft, adapter, integration process and avionics interfaces

At the completion of phase I, the goal is to have achieved a TRL 3 or better for the adapter systems and processes

Phase II Deliverables (SPSIT):

- Finalize standards within the mass range
- Complete adapter hardware designs
- “Plug-n-play” avionics standards hardware/software
- Conduct PDR and CDR of new technologies
- Finalize standards for the integration process

Higher TRL levels at the completion of Phase II will increase the likelihood of a path for infusion into NASA missions.

Entry and Ascent Experimental Platform Technologies

Current launch capabilities for aerodynamic and hypersonic research are limited to either high cost launches as a primary payload on a launch vehicle, or small packages (typical sounding rocket payload volume and mass ~ 10 ft3, 300 lbm). Sounding rockets that provide the technology testing capabilities are also limited in the altitude and the speeds they can achieve. Therefore, the conceptual design for a new platform is being sought to fill the technology-testing gap. For example, if the vehicle configuration had spare solid rocket motor capacity, this experimental platform could launch as a secondary payload, by occupying the location of a solid rocket motor on a launch vehicle such as the Atlas V or Delta IV.

The new experimental platform would provide expanded testing capabilities to accommodate payloads with larger (2-10 times) size and weight, obtaining greater altitudes and speeds than currently provided using sounding rockets. The platform would pro-vide an affordable way to demonstrate and test new technologies through hypersonic, intra-atmospheric, and reentry phases. The launch vehicle can be any vehicle used by NASA (currently, Pegasus XL, Taurus XL, Falcon 1, Falcon 9, Atlas V and Delta IV are on contract) and must be integrated onto the first stage of a vehicle per the areas of interest listed in Areas of interest section below.

Usage of this experimental platform could support development of a number of advanced technologies through flight-testing in representative environments, where their TRL could be validated and advanced. Such technologies could then be considered viable options for atmospheric entry and ascent technologies for governmental and commercial applications.

Technologies that could be tested in this experimental platform include but are not limited to:

- Thermal protection materials,
- Guidance, navigation and control,
- Vehicle configuration concepts for investigation of both ascent and entry designs for earth, lunar, and Mars space vehicles under supersonic and hypersonic conditions

Objective (EAEPT): Design a cost effective experimental platform with associated payload interface that minimizes the impact to the primary payload and launch vehicle's processing and certification for flight.

Areas of interest (EAEPT): NASA seeks platform designs incorporating the following characteristics:

- Ability to integrate with the launch vehicle late in the mission integration phase,
- Ability to fly a dummy payload(s) (in case the secondary payload does not meet the launch readiness date),
- Mo required mission unique interfaces with the launch vehicle (electrical, environmental control, etc.)
- Does not impose additional risk on the success of the primary mission
- Enables maximum use of the existing design and hardware (i.e., attach structures, case design) of the launch vehicle to minimize risk
- Has minimal impact to the vehicle external mold line and mass requirements, such that the aerodynamic flight environments, dynamic load environments, and thermal environments imposed are of similar or equivalent levels as compared to the vehicles as currently flown
- Is compatible with existing launch vehicle hardware
- Is compatible with current vehicle qualification environments
- Is compatible with vehicle mass requirements
- Facilitates manufacturing and production (support multiple and repeatable flights)
- Accommodates flight specific payload modifications.

Much of this information can be found on line on the Launch Provider's public websites:

- http://www.unitedlaunchalliance.com/site/docs/product_cards/guides/DeltaIVPayloadPlannersGuide2007.pdf
- http://www.unitedlaunchalliance.com/site/docs/product_cards/guides/DeltaIIPayloadPlannersGuide2007.pdf
- http://www.orbital.com/NewsInfo/Publications/Taurus_fact.pdf
- http://www.orbital.com/NewsInfo/Publications/TaurusII_fact.pdf
- http://www.spacex.com/Falcon9UsersGuide_2009.pdf
- http://www.spacex.com/Falcon1UsersGuide.pdf

Once awarded, NASA (LSP) will facilitate the development of a Non-Disclosure Agreement (NDA) between the small business and launch provider.

Phase I Deliverables (EAEPT):

A final report containing technology design concept(s) demonstrating technical feasibility including:

- Feasibility of concept
- A draft Systems Requirements Document (SRD)
- A detailed path towards Phase II level design maturity
- Detailed report presenting the results of Phase I analysis, modeling, etc.
- Expected TRL at end of Phase I is 3

Phase II Deliverables (EAEPT):

- Preliminary Design Review (PDR) and Critical Design Review (CDR) of the aforementioned platform for use on one of the existing ELVs within NASA's fleet
- Expected TRL at end of Phase II is 5

O2.02 Propulsion Technologies
Lead Center: GRC
Participating Center(s): DFRC, MSFC

Current launch to orbit vehicles, both expendable and reusable, require months of preparation for flight. Although there are available (in-production) practical propulsion options for such a vehicle, the costs for outfitting the booster stage are in the hundreds of millions of dollars. If reusable, additional months are required to verify all components and systems before re-flight. These costs severely limit what missions NASA can perform. The propulsion systems are a major focus during this time, yet aircraft engines are checked and certified for re-flight in less than an hour. While rocket engines actually have many similarities to aircraft engines, there are several factors that drive the complexity and therefore the cost of rocket engines. These include toxic propellants that require special protections for personnel and the environment, cryogenic propellants that require complex tank fill operations and costly specialized ground support equipment, high combustion chamber temperatures for increased performance and thrust, and high combustion chamber pressures for increased performance and reduced engine size and weight.

To move more toward low cost access to space, the above barriers to low-cost propulsion systems must be addressed and overcome. Of primary focus are non-toxic propellant combinations that provide adequate performance without requiring excessive specialized handling equipment and procedures, and engines that provide reliable and adequate performance without needing to push the far limits of temperature and pres-sure environments.

Component technologies that move toward these top-level goals that are of interest include:

- Manufacturing techniques that lower the cost of manufacturing complex components such as injectors and coolant channels. Examples include, but are not limited to, development and demonstration of rapid prototype techniques for metallic parts, power metallurgy techniques for the manufacture of geometrically complex parts, and application of nano-technology for near net shape manufacturing.
- Ablative materials and manufacturing techniques that increase capability while reducing production time and cost
- Innovative chamber cooling concepts that reduce manufacturing complexity, re-duce pressure drop, and minimize performance losses caused by cooling
- Low-cost nozzle materials, manufacturing techniques, and coatings to reduce the amount of active cooling required
- Sensors, instruments, and algorithms to diagnose the health of the engine and propulsion system without requiring hours of manual inspections
- Ignition concepts that require low part count and/or low energy to be used as either primary or redundant ignition sources

Specific target metrics include:

- A cost target of <50% of current earth-to-orbit propulsion with similar performance,
- Reduced ground support equipment, and
- Increased performance margin (e.g., operating temperature % of material limit, operating stress % of component limit, etc.)

These are critical technology improvements that are required in the next 3 – 8 years. Projects are required to demonstrate the component or technology to a TRL level of 5 – 6 in order to allow for infusion into low-cost earth-to-orbit propulsion systems.

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

Phase I Deliverables: Lab-scale component or technology demonstrations and reports of target metric performance.

Phase II Deliverables: Subscale component or technology demonstrations and reports of target metric performance.

O2.03 Spaceport Enhancement and Improvements
Lead Center: GSFC
Participating Center(s): DFRC, GRC, KSC

The key operating characteristics for a Spaceport focus are interoperability, ease of use, flexibility, safety/environmental protection, and multiple concurrent operations. The long-term vision is to have “airport-like” spaceport operations. Therefore, the development of effective spaceport technologies is of primary importance to NASA. These technologies will need to support both the existing and future vehicles and programs.

Space-Based Telemetry
NASA is seeking to reduce or eliminate the need for redundant range assets and deployed down-range assets that are currently used to provide for Line-of-Sight (LOS) Tracking Telemetry and Control (TT&C) with sub-orbital platforms and orbit-insertion launch vehicles.

There are varying applications for space-based transceivers, each necessitating a different set of requirements. The desired focus is very low size, weight, and power (SWaP), tactical grade, highly reliable, and easily reconfigurable transceivers capable of establishing and maintaining unbroken satellite communication links for telemetry and/or control. This technology will serve applications, which include low-cost sub-orbital missions, secondary communications systems for orbit insertion vehicles, low cost and size orbital payloads (typically LEO), and flight test articles. Durations will range from minutes to several weeks and the ability to operate on highly dynamic platforms is critical. High data rate links are highly desired, thus the use of NASA’s TDRSS is emphasized, although other commercial satellite systems, which can provide nearly global and high data rate links can also be explored. Factors to address include:

- Advancements in software based radios and encoding techniques,
- Use of the latest semiconductor technologies (GaN or other),
- Advanced heat dissipation techniques,
- Immunity to corona breakdown,
- Ease of data interfacing.

RF power output requirements range from a few watts to as high as 100 W. Special consideration should be given to transceiver capability vs. packaging that would allow for customizable configurations depending on the target application.

Range Weather
NASA seeks innovative technologies to remotely measure electric fields aloft to reduce the threat of destruction of a launch vehicle by rocket triggered lightning. Potential candidate technologies include new algorithms to take advantage of existing dual-polarized Doppler five-cm weather radar capability, or entirely new technologies for the remote sensing of electric fields. The ability to economically measure the incremental ballistic wind velocities along the predicted trajectory of launch vehicles at remote and evolving launch ranges at altitude up to 100 kft via fixed and mobile LIDAR approaches is also highly desirable.

The above technologies are considered to be highly desirable for NASA’s objectives and critical for the realization of true Spaceports.

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

Phase I Deliverables: A final report containing optimal design for the technology concept including feasibility of concept, detailed path towards Phase II hardware and software demonstration, and detailed results of Phase I analysis, modeling, prototyping, and testing.

Phase II Deliverables: A working proof-of-concept demonstrated and delivered to NASA for testing and verification with a TRL of 4 to 6.

O2.04 Advanced Composite Tank and Materials Technologies
Lead Center: MSFC
Participating Center(s): GRC, LaRC

This subtopic includes two major technology areas:

(1) Reusable, Reliable and Low Cost Composite Tanks
(2) Advanced Material Integration Technology Development

Proposals will be accepted for either area.

Reusable, Reliable and Low Cost Composite Propellant Tanks (RRLCCPT)
The objective of this subtopic is to help dramatically reduce the cost to low Earth orbit by advancing the technology involved in composite propellant tanks and advanced composite material development. The ability for launch vehicles to combine the significant weight savings of composite tanks with airline like operations could be possible if these tanks are also reusable, reliable, and need little to no maintenance between flights.

Purpose and Current State-of-the-Art: Composite tanks offer significant weight savings, but there are significant shortfalls in terms of reusability, especially when using cryogenic fluids. This lack of reusability severely hampers adoption of this enabling technology in future reusable vehicle. This subtopic will also address emerging composite tank technologies, specifically in the areas of testing and verification pertaining to damage tolerance, safe-life and checkout.

General Operational Needs and Requirements/ Performance Metrics:

<u>Airline-like Operations</u>
Government and commercial reusable launch vehicles are only economically viable if they can achieve high flight rates of dozens of flights per year or more per vehicle. These flight rates themselves are only possible if something akin to airline like operations becomes possible for spaceflight.

<u>Reusability and Reliability</u>
Reusable, reliable, and low cost composite tanks that need little to no maintenance between flights and minimal check-out are required for economic and operational sustainability. These developments can:

- Ease operability of the tank diagnostics
- Enable tank prognostics
- Enable tanks to handle high pressure cycles and loads without leaking or developing structural failure
- Promote ease of manufacture, and by more than one American company
- Promote ease of repair without returning tanks to the manufacturer’s facility
- Promote rapid certification/recertification techniques to meet expected FAA commercial RLV requirements

<u>Data and Technology Development</u>
Of specific concern and interest are safe-life and damage tolerance testing. There is much scrutiny regarding the manner and degree of testing in these areas, specifically after some number of pressure cycles. Also of concern is the

effect of temperature on and during cycling and material compatibility. Due to the limited amount of flight and long term performance data there is little to base future design on when the desire is heritage similarity. Thus, development in regards to these specific metrics (safe-life and damage tolerance testing) would be most beneficial to both short and long term missions.

The outcome of this portion of the SBIR is expected to be technologies and data that make possible composite propellant tanks that have improved reliability and performance that will enable a high degree of reusability. Data should show that proper material, manufacturing processes and design are used to produce a vessel that per-forms well under long-term use in a cryogenic condition. The vessel would minimize microcracking, should be damage tolerant and repairable, and have mounting capabilities.

For the proposed technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware demonstration and testing. Delivery of a demonstration unit for NASA testing at the completion of the Phase II contract is also required.

Phase I Deliverables (RRLCCPT): Final report containing:

- Optimal design and feasibility of concept,
- Detailed path towards Phase II demonstration,
- Detailed results of Phase I analysis, modeling, prototyping and development testing
- Material coupon data and a prototype sub-scale tank

Desired deliverables at the end of Phase I should be at TRL 3-4

Phase II Deliverables (RRLCCPT): By the end of Phase II, working proof-of-concept technologies, including features and demonstration of long term, high cycle performance at cryogenic temperatures, demonstrated and delivered to NASA for testing and verification.

Deliverables expected at the end of Phase II should be at TRL 5-6.

Advanced Material Integration Technology Development (AMITD)

Advanced materials including ceramic composites and metallic materials, will require technologies that will allow joining of these materials, specifically the development of advanced joining and integration technologies with enhanced temperature and performance capability. Typical materials are carbon and silicon carbide based composites and super alloys. The quality of joined sub-elements should also be evaluated nondestructively to assess the integrity and quality of the joints. Material systems may be similar or dissimilar in nature (composite to metals or composite to composites).

Purpose and Current State-of-the-Art: Currently the most commonly used fabrication approaches (CMC, CVI and PIP) have severe limitations in terms of size and shape of CMC components that can be manufactured with appropriate property attributes and a reasonable cost. Therefore, current design considerations for the manufacturing of large CMC components and structures will be utilizing technologies for joining/attaching smaller-sized components with simpler geometries and dissimilar material systems.

General Operational Needs and Requirements: Ceramic joining and integration is an enabling technology for the successful implementation of CMC's in a wide variety of high temperature applications. Among the various alternatives available to overcome the limitations of the many fabrication technologies for the manufacture of large CMC components and structures of complex shape, the joining of smaller components with simple geometry appears to be the most promising and practical. Application of simple equipments for curing and during the high temperature joining process is critical. Requirements include, but are not limited to:

- Materials to be joined are silicon carbide or carbon-based matrix fiber reinforced composites to a similar CMC or high temperature metallic alloy
- Proposed joining approach should be robust and able to produce joints with tailorable microstructures
- Thermo-mechanical properties of the joint interlayer should be tailorable and close to those of the base materials
- Proposed technologies are expected to be easy to apply in a manufacturing environment at high technology readiness levels
- For CMC-CMC joining, the joint interlayer material should be able to yield ceramic interlayers with temperature capability similar or better than the substrate materials with low porosity

Performance Metrics: The temperature capability of the ceramic joints in joined CMC should be similar to that of the CMC substrate materials. The chemical composition of the joints should not alter the stress rupture, creep, high temperature mechanical strength, and stiffness of the overall system in any significant manner. The environmental stability, time dependent mechanical properties, and performance of the joints should not be significantly different than the substrate materials.

For the proposed technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II sub-element and subcomponent development and testing. Delivery of a subcomponent demonstration unit for NASA testing at the completion of the Phase II contract is also required.

Phase I Deliverables (AMITD): Develop and demonstrate a robust joining concept, understand common test methods for joint testing, and assess the interfacial microstructure and mechanical properties of joints. Assess high temperature durability of joints and effect of joint design on thermo mechanical performance.

Desired deliverables at the end of Phase I should be at TRL 3-4.

Phase II Deliverables (AMITD): Produce and test additional joint prototypes (sub-elements and subcomponents) under representative flight conditions to include anticipated temperatures, heat fluxes, thermal gradients, and environmental effects. Full macro-structural and micro-structural material characterization of joints before and after testing will be required to assess life-limiting failure mechanisms and joint reliability. Provide joined CMC subcomponents or segmented structures with a method to non-destructively evaluate the joint quality.

Deliverables expected at the end of Phase II should be at TRL 5.

O2.05 Reusable, Reliable, Low Cost Thermal Protection Systems
Lead Center: ARC
Participating Center(s): DFRC

As NASA enables commercial space access, there is a critical need for reusable, reliable, low-cost thermal protection systems (TPS). New material and computational technologies offer the potential of more durable and operable TPS for space transportation vehicles that can tolerate high temperatures while improving operability and reducing maintenance time and costs.

This subtopic requests innovative proposals in the following areas:

- Technologies and systems offering a factor of two or greater reduction in maintenance time and costs compared to Shuttle TPS for:
    - Reusable space transportation vehicles being developed for Earth to orbit access and return,
    - In-space transportation systems using aero-braking and aero-capture, and
    - On-demand payload and crew return systems

- Multi-use and reusable TPS concepts applicable for insulated composite and metallic vehicle structures
  - With improved robustness
  - Reduced and/or automated inspection, repair and recertification,
  - While remaining weight competitive to current flight proven TPS

- TPS non-destructive evaluation techniques and new health management approaches and strategies
- Rapid TPS inspection, repair, and flight certifications techniques
- Designs and concepts for new TPS attachment methods,
- Designs for gaps and joints
- TPS designs for control surfaces and interfaces

Phase I Deliverables: Phase I deliverables include a final report detailing optimal design for the technology concept, including a feasibility assessment and summary of analysis, modeling and any prototype development and testing. For concepts that show good feasibility, the final report should also contain a plan for Phase II development and demonstration.

Desired deliverables at the end of Phase I should be at TRL 2-3.

Phase II Deliverables: Phase II deliverables include a working proof-of-concept available for NASA inspection and testing if applicable. Opportunities and plans should be identified and summarized for potential commercialization.

Deliverables expected at the end of Phase II should be at TRL 4-5 (minimum).

TOPIC: O3 Processing and Operations

The Space Operations Mission Directorate (SOMD) is responsible for providing mission critical space exploration services to both NASA customers and to other partners within the U.S. and throughout the world: from flying out the Space Shuttle, to assembling and operating the International Space Station; ensuring safe and reliable access to space; maintaining secure and dependable communications between platforms across the solar system; and ensuring the health and safety of our Nation's astronauts. Each of the activities includes both ground-based and in-flight processing and operations tasks. Support that ensures these tasks are accomplished efficiently and accurately enables successful missions and healthy crews.

This topic area, while focused on operational space flight activities, is broad in scope. NASA is seeking technologies that range from addressing how better to improve and lower costs related to ground and flight assets to how best maximize and extend the life of the International Space Station. A typical approach would include:

- Phase I: Research to identify and evaluate candidate technology applications to demonstrate the technical feasibility and show a path towards a hardware/software demonstration. Bench or lab-level demonstrations are desirable.
- Phase II: Emphasis should be placed on developing and demonstrating the technology under simulated flight conditions.

The proposal shall outline a path showing how the technology could be developed into space-worthy systems.

The contract should deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract and, if possible, demonstrate earth based uses or benefits.

O3.01 Mission Operations
Lead Center: ARC
Participating Center(s): JPL

The objective is to develop advanced capability software systems for mission operations in support of NASA's Space Communications Infrastructure. The current infrastructure for NASA Space Communications provides services for near-Earth spacecraft and deep space planetary missions. The infrastructure assets include the Deep Space Network (DSN), the Ground Network (GN), and the Space Network (SN).

NASA seeks automation technologies that will facilitate scheduling of oversubscribed communications resources. These capabilities should focus on the development of user interfaces and algorithms for the integration of diagnostic and situational awareness tools; and planning, scheduling, and resource optimization tools supporting:

- Increased numbers of missions and customers
- Increased number and complexity of constraints
- Decreased operations budgets
- Scheduling algorithms should be fault-tolerant

Current State-of-the-Art: Diagnosis software tools and resource optimization tools are mature independent software technologies, however the integration of the two is less mature. The challenge is to develop integrated software tools that can leverage the strengths of each class of tool. Diagnosis tools must inform the resource optimization algorithms of the active portions of the system, while the resource optimization tools must inform the diagnosis tools of the current plan in order to facilitate tracking of system state.

User Interfaces: Diagnosis software user interfaces rely on displaying diagnostic information either in fault tree form or spatially highlighting portions of schematics, which are suspect. On the other hand, planning/scheduling/resource optimization tools rely on the display of temporal information in Gantt charts, and other timeline-based methods. An integrated user interface would require the integration of the spatial and temporal information into a single display to facilitate the ease of use and understanding of the integrated tools.

Diagnosis and Situational Awareness: Space Communication Networks are complex systems made up of both physical and wireless connections. When faults occur in the network, isolating the faults in real-time is critical in order to maintain network capability. Model-based diagnostic systems are capable of modeling the connectivity of the system as well as propagating both nominal and off-nominal flow of information in the network. These systems can accurately characterize the state of the system in order to provide situational awareness for both humans as well as intelligent assistant and resource optimization tools. The utilization of the current state of the network is critical to reschedule resources that have failed or degraded.

Planning and Scheduling Tools for Resource Optimization: The goal of schedule optimization is to produce allocations that yield the best objectives. These may include maximizing DSN utilization, minimizing loss of desired tracking time, and optimizing project satisfaction. Each project may have their own definition of satisfaction such as maximal science data returned, maximal tracking time, best allocation of the day/week, etc. The difficulty is that we may not satisfy all of these objectives during the optimization process. Obviously, optimal solution for one objective may produce worse results for the other objectives. One possible solution is to map all of these objectives to an overall system goal. This mapping is normally non-linear. Technology needs to be developed for this non-linear mapping for scoring in addition to regular optimization approaches.

Areas of Interest: Integrated diagnosis and resource optimization tools are useful in different phases in the design and development of space communication networks. In early pre-planning phases of mission operations such tools are useful for: procedure development, contingency development, and other preparatory tasks. During the operations phase, such tools are useful for telemetry analysis; fault diagnosis, state determination and situational assessment;

plan, procedure, and rules revisions and execution; decision-making; commanding; fault responses; and data management among others.

NASA seeks proposals to develop the following capabilities in support of human situational awareness:

- Methods for acquiring, evaluating, and displaying telemetric information, so as to provide users with flexibility and easy access to desired information in desired format.
- Methods to determine situational information from multiple data sources, possibly noisy and incomplete, and present those to the user;
- Methods to track actions of other users or systems, including automated systems, and keep user aware of the situation.
- Methods to track user intent and provide the appropriate situational information;
- Methods for controlling the degree of automated/manual control, and tools for transitioning control between user and automation with minimal loss of context and situational awareness.
- Methods for creating, validating, evaluating, and revising model-based diagnostics models, taking into account collaborative aspects and reference materials required to build models (architecture diagrams/schematics, sensor definitions, fault modes, configurations and other reference materials).
- Techniques for checking or simulating model-based diagnostic models, in order to acquire a level of trust or assurance that the model is correct with respect to the configuration of the network.
- Methods for creating, validating, evaluating, and revising operations plans, taking into account collaborative aspects, complex flight rules, resource limitations and need for one-time constraints and exceptions.
- Techniques for checking or simulating plans, procedures, sequences and other combinations of commands and actions, in order to acquire a level of trust or assurance that the combination is correct and will satisfy desired safety and operations properties in actual execution
- Methods to change the planning/scheduling optimization functions to incorporate high priority requests.

Performance metrics: Measures of performance will compare human generated results vs. human/computer results for nominal and off-nominal network conditions. Experiments should be run on simulated communications test-bed(s), which can seed failures of different classes at different points in time.

Schedule quality will be determined by a number of factors including: (1) level of up time on the network, (2) degree of priority allocation (higher priority items scheduled first), (3) degree of contiguity allocation (items are scheduled as a group) and (4) other factors.

For the proposed technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware demonstration and testing. Delivery of a demonstration unit for NASA testing at the completion of the Phase II contract is also required.

Phase I Deliverables: Propose demonstration of integrated fault diagnosis/resource optimization tool on a number of communication asset allocation problem sets (involving dozens of missions, communications assets, and operational constraints). End Phase deliverable (TRL 4-5) would include a detailed rationale for technology return-on-investment (ROI) based on knowledge of current and future operations flows.

Phase II Deliverables: A demonstration of the integrated fault diagnosis/resource optimization tool with fault diagnosis/situational awareness system on actual or surrogate communication asset scheduling datasets. Deliverables (TRL 6) would include software system, use cases and evidence of utility of deployment of developed technology.

O3.02 ISS Utilization
Lead Center: JSC
Participating Center(s): ARC, GRC, KSC, MSFC

NASA is investigating the near- and mid-term development of highly-desirable systems and technologies that provide innovative ways either to leverage existing ISS facilities for new scientific payloads or, to provide on orbit analysis to enhance capabilities and reduce sample return requirements.

Current utilization of the ISS is limited by available upmass, downmass, and crew time as well as by the capabilities of the interfaces and hardware already developed. Innovative interfaces between existing hardware and systems which are common to ground research could facilitate both increased, and faster, payload development.

Desired capabilities include, but are not limited to, the below examples.

- Enabling additional cell and molecular biology culture techniques. Providing innovative hardware to allow for safe, contained transfer of cells from container to container within the Microgravity Sciences Glove Box (MSG) would permit new types of studies on ISS. On orbit analysis techniques that would reduce or remove the need for downmass - such as a system for gene array tests, or kits for DNA extractions for long term storage - are also examples of hardware possibilities that would extend and enable additional research.
- Providing compact Dynamic Light Scattering (DLS) hardware. Development of a compact robust DLS instrument based on diode lasers and photo detectors capable of providing significant power and weight savings would make it possible to measure the diffusion coefficient of experimental systems using the Light Microscopy Module (LMM). This peer-reviewed science was considered a decade ago but not developed due to technology limitations. It should now be possible to measure diffusion coefficients from which the molecular temperature of the location being viewed could be deduced for known particles and solvents using the Stokes-Einstein equation. Innovative additions of a local oscillator used in conjunction with analog detectors could mitigate errors introduced by stray light.
- Providing compact laser tweezers and supporting software. Development of a compact robust Holographic Laser Tweezers (LT) instrument based on the recent developments of holographic techniques could expand the types of experiments conducted on orbit. This peer-reviewed science was previously considered but not developed because of the size and technology limitations of a decade ago. LT holds open the possibility of performing scientific experiments that manipulate groups of particles that evolve uniquely in space when gravitational sedimentation and jamming no longer exist. Any new LT and its corresponding control software should allow for tracking of particle positions in 3D (before the concentration becomes too high) and impart rotational forces. Being able to accurately track the position of particles while measuring the forces on them is important for laying the foundations of colloidal engineering. Novel self-calibration methods could be added to commercially available designs to further enhance the instrument and its capabilities. The instrument would need to meet the size and volume limitations of the Light Microscopy Module (LMM).
- Providing additional on-orbit analytical tools. Providing flight qualified hardware that is similar to commonly used tools in biological laboratories could allow for an increased capacity of on-orbit analysis thereby reducing the number of samples which must be returned to Earth. Examples of tools that will reduce downmass or expand on-orbit analysis include: sample handling tools; mass measurement devices; a (micro)plate reader; a mass spectrometer; non-cryogenic sample preservation systems; autonomous in-situ bioanalytical technologies; centrifuges for analysis and for providing fractional-g environments; microbial and cell detection and identification systems; and fluidics and microfluidics systems to allow autonomous on-orbit experimentation and high throughput screening.
- Providing Nanorack compatible inserts to enable additional life science payloads. Development of 1, 2 and/or 4 cube design biological payload hardware for use with the ISS Nanorack platform would decrease the need for development of multiple control racks and reduce development time of future payload experiments.

- Enabling additional payloads. Innovative methods for further subdividing payloads lockers would allow for numerous pico-payloads. Developing multi-generational or multi-use habitats would reduce the upmass and downmass required to conduct biological experiments on ISS.

The existing hardware suite and interfaces available on ISS may be found at:
http://www.nasa.gov/mission_pages/station/science/experiments/Discipline.html

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

Phase I Deliverables: Written report detailing evidence of demonstrated technology (TRL 5 or 6) in the laboratory or in a relevant environment and stating the future path toward hardware and software demonstration on orbit.

Phase II Deliverables: Hardware and/or software prototype that can be demonstrated on orbit (TRL 7).

O3.03 ISS Life Extension and Operational Enhancements
Lead Center: JSC
Participating Center(s): ARC, GSFC

NASA is exploring a wide range of both critical and highly desirable technologies that would, in the mid-term, aid in ISS life extension or provide operational enhancements.

Potential areas of investigation include the following:

- Providing detection technologies for leakage from modules and fluid systems.
- Enhanced on-orbit maintenance capabilities such as corrosion detection and re-mediation.
- MMOD detection, MMOD damage detection, evaluation and recovery.
- Methods for re-lubrication of rotating parts.
- Technologies that can isolate and resolve issues without crew interaction or that can perform nominal crew housekeeping activities such as self-cleaning air inlet filters and surfaces are highly desirable and could improve efficiency enough to allow more crew time for operation of scientific payloads.

Technologies to aid in life extension or operational enhancements of the ISS are not limited to the above examples and other areas will be considered for award.

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

Phase I Deliverables: Written report detailing evidence of technology feasibility in the laboratory (TRL 2-4) or in a relevant environment and stating the future path toward hardware and software demonstration on orbit.

Phase II Deliverables: Hardware and/or software prototype that can be demonstrated, preferably on orbit (TRL 4-6).

O3.04 Vehicle Integration and Ground Processing
Lead Center: KSC
Participating Center(s): MSFC, SSC

This subtopic seeks to create new and innovative technology solutions, which improve safety and lower the life cycle costs of assembly, test, integration and processing of the ground and flight assets at our nation’s spaceports and propulsion test facilities.

Current State of the Art: The propulsion testing and launch vehicle processing activities at NASA account for a large portion of the life cycle costs of today's space programs. The technologies in use today at these facilities date back to the beginnings of manned space flight. A majority of the test infrastructure at Stennis Space Center and launch processing facilities at Kennedy Space Center indeed go back to the Apollo era and early shuttle design days of the 1960's and early 70's. Technology solutions typically take 3-6 years from inception in the SBIR Phase I program to having a direct impact on the processing activity. NASA needs to invest in these vehicle integration and ground-processing technology needs now to be in place for the NASA heavy launch vehicle concepts of the future.

Propellant servicing operation for both propulsion testing and launch operations are in need of technology advancement to make these operations safer and more cost efficient. The hardware and practices in use today do indeed date back to 1960's investments. Technology solutions are needed to increase visibility into processes real-time (smart instrumentation), more efficient cryogenic propellant storage solutions, a new generation of cryogenic couplings to allow cold mate and de-mate operations without ice or frost buildup, and to reduce our usage of massive amounts of gaseous helium (a scarce, non-renewable global resource).

Changes in environmental regulations have had a tremendous negative impact on the coatings used to protect our NASA test and launch infrastructure. Many of the coatings used in the last 10 years are no longer available due to changes in the environmental law banning the use of certain chemicals. KSC and SSC are located in some of the worst corrosion environments in the country. At KSC, the addition of the acidic exhaust plumes from solid rocket motors, make these conditions even worse. New advancements in coatings and materials are needed to reduce the infrastructure maintenance costs of these facilities.

Due to the lightweight, high strength properties, composite materials are being sought more often to solve weight reduction efforts on future launch vehicles. New materials mean new problems for the ground operations team charged with insuring these vehicles are safe to fly. New inspection tools are needed to confirm structural integrity during the processing flow after field repairs or accidental contact.

The following areas are of particular interest:

Propellant Servicing Technologies
Technologies for advanced, energy efficient cryogenic fluid storage, transfer and propellant servicing of launch vehicles and propulsion test facilities. These efforts include:

- Cost effective technology solutions to support helium facility supply infrastructure and helium conservation initiatives to reduce/eliminate helium usage during LH2 and LO2 system operations and recover /re-purify helium from large volume waste streams;
- Techniques and technologies to reduce parasitic heat loads in large cryogenic storage tank structural design to enable more economical zero boil-off storage concepts;
- Advances in smart instrumentation for in-situ fluid flow analysis and process control, surviving and operating under cryogenic and launch conditions to enable real-time monitoring of propellant servicing processes and high efficiency purging operations of cryogenic systems; and
- Non-frosting/icing quick-disconnect development to support cryogenic propellant servicing operations.

Control of Material Degradation
Technologies are needed for the prediction, prevention, detection and mitigation of corrosion/erosion in spaceport and propulsion test facility infrastructure and ground support equipment including steel refractory concrete. Material solutions must meet current and emerging environmental restrictions and endure today's corrosive and highly acidic launch environments. These needs include:

- Methodology to predict long-term corrosion protection performance of coatings for steel operating in a marine environment;

- Damage responsive coatings with corrosion inhibitors;
- Replacement options for poor-performing refractory concrete exhibiting low temperature cure characteristics or means of providing large area coverage with modular units that can be cured off site;
- Protective coatings for non-painted surfaces;
- Innovations in thermal spray metallic coatings equipment and alloys;
- Non-chrome protective coatings/sealants for aluminum alloys; and
- New environmentally friendly protective coating options to replace products lost due to EPA regulation changes.

Spaceport Processing Evaluation/Inspection Tools
Technologies in support of defect detection in composite materials; methods for determining structural integrity of composite materials and bonded assemblies; and non-intrusive inspection of Composite Overwrapped Pressure Vessels (COPV), Orion heat shield and other composite systems. Technologies must support identifying composite material defects, evaluating material integrity, damage inspection and/or acceptance testing of composite systems. Technology solutions are also desired for in-situ evaluation of refractory concrete as installed in the flame trenches associated with propulsion test and launch pad infrastructure. Provide solutions that reduce inspection times, provide higher confidence in system reliability, increase safety and lower life cycle costs.

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

Phase I Deliverables: Demonstration of technical feasibility (TRL 2-4).

Phase II Deliverables: Demonstration of technology (TRL 4-6)

The technology in this subtopic may also be applicable to Topic O2, Space Transportation.

O3.05 Advanced Motion Imaging
Lead Center: MSFC
Participating Center(s): JSC

Digital motion imaging technologies provide great improvements over analog systems, but also present significant challenges, including radiation damage to sensor systems and components. Cameras and sensors need to survive operations on orbit for years without debilitating radiation damage that degrades image quality and performance.

The focus of this subtopic is the development of components, systems, and core technologies that advance the capabilities to capture process and distribute high-resolution digital motion imagery.

Current State of the Art: HDTV cameras flown on the Space Shuttle and the International Space Station have proven to be highly susceptible to damage from ionizing radiation. This damage is manifested by bad pixels that eventually render the camera useless after short periods of on-orbit use, usually less than one year. In addition, upmass and downmass constraints make the use of large format motion picture film cameras impractical, so a digital equivalent is needed for large venue documentary film productions, such as IMAX films.

Areas of interest in the near term are for space environment, radiation tolerant, HDTV and digital cinema cameras and sensors. Mid and Long term goals include radiation tolerant reprogrammable encoders and improved distribution systems for video data signals. These systems are highly desired by the human spaceflight programs.

Technologies are sought that provide high resolution, progressively scanned motion imagery with limited or mitigated radiation damage to sensors, are viable for astronaut hand-held applications or external spacecraft use, and that provide imagery that meets standards commonly used by digital television or digital cinema production facilities. Commercial HDTV cameras used for internal hand-held use have generally been small and light (5” x 6” x 11”, between 2 and 3 pounds), run off rechargeable batteries, and utilize standard lens mounts. Future cameras for exterior applications ideally would be smaller and more modular in design (no larger than 4” x 5” x 7” and 2.5 pounds). The critical technology need is the radiation tolerance of the sensor, not the size, weight and mass of the camera that results from such a sensor.

While commercial HDTV and Digital Cinema cameras for use on Earth are mature technologies, there are no flight-proven radiation tolerant HDTV and Digital Cinema cameras and sensors currently available. Commercial cameras flown on the Shuttle and ISS thus far do function, but degrade within a year on orbit. While hard to classify, the current TRL for these cameras within the context of spaceflight operations could be considered to be a 5 or 6. The ultimate goal is to develop radiation-hardened camera sensors capable of surviving three or more years in space.

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

Phase I Deliverables: Deliverables for Phase I will include detailed designs and development plans with plausible data and rationale that demonstrates why the designs and plans should mitigate radiation effects on the sensors.

Phase II Deliverables: Deliverables for Phase II will include developmental hardware suitable for testing in a lab or space flight environment (TRL 6) as well as a test plan, relevant data, and define expected lifespan of the sensors.

O3.06 Advanced Acoustic Monitoring Technologies
Lead Center: JSC
Participating Center(s): ARC, GRC

This subtopic addresses acoustic monitoring technologies for current International Space Station (ISS) and future long duration spaceflight missions.

Specifically, this subtopic calls for proposals to develop and demonstrate acoustic sensor technology enabling real-time, remotely performed measuring and monitoring of sound pressure levels and noise exposure levels in long-duration space vehicles. These technologies are the building blocks towards a network of continuously monitored, real-time acoustic sensors providing sound pressure level information as a function of frequency and/or time at multiple locations. Additionally, these technologies shall provide:

- Typical sound level meter,
- Typical acoustic dosimeter processing and analysis functionality,
- Capability for hazard level alerting.

Current State of the Art: Acoustic monitoring is currently being performed on the ISS using a hand-held sound level meter (SLM) that is moved to 60 different locations where a 15 second measurement is performed. Each SLM survey session takes 2 hours of crew time, and the survey is per-formed once every 2 months, thus reduced crew time needed will be an important benefit.

Because of the length of the survey, only a portion of the ISS can be measured during a single session. Similarly, acoustic dosimetry at fixed locations is performed once every 2 months, but only at three locations for each session because of crew-time and hardware limitations. Advanced acoustic monitoring technology will provide the capability to allow for more frequent and directed acoustic measurements and will allow nighttime measurements. These benefits will permit more precise trending, environmental monitoring and will provide a better validation of acoustic models, i.e., we will be able to isolate the impacts of various operations or pieces of hardware.

Areas of interest: Current automated acoustic monitoring methods used in ground-based systems perform measurements in isolated areas, e.g., around airports. However, the technology employed is large and heavy, using conventional data acquisition boards, transducers, and transmitters.

NASA seeks proposals for acoustic monitors for spaceflight vehicle applications that:

- Are miniaturized,
- Are lightweight,
- Integrate data acquisition, sampling, and processing into the sensor
- Transmit the processed data wirelessly,
- Low-power consumption
- Can be a part of a multi-sensor system

The functional SLM goal is to provide average sound pressure level measurements over a short time duration (e.g. 20 seconds) as a function of frequency. The functionality required includes:

- Type II measurement accuracy over the octave band frequency range from 63 Hz to 20 kHz,
- Dynamic range of 90 dB or better,
- 1/3 octave band frequency representation,
- Narrow band frequency representation with selectable frequency resolution.

The following SLM functionality is desired:

- Type I measurement accuracy over the octave band frequency range from 63 Hz to 20 kHz,
- Octave band noise floor of 10 dB re 20 micropascals,
- Fractional octave (1/1, 1/3, 1/12) band frequency representation.

The functional Acoustic Dosimeter goal is to provide noise exposure levels and data logging, i.e., log of sound levels as a function of time. The functionality required includes:

- Type III accuracy over the audible frequency range,
- Logging of A-weighted Overall Sound Pressure Levels every 30 seconds for a period of 24-hours,
- Dynamic range of 90 dB or better.

The following Acoustic Dosimeter functionality is desired:

- Noise floor of 30 dB re 20 micropascals.

The goal for the hazard level alert functionality is to provide continuous acoustic monitoring with logic that sends a signal (to trigger a non-auditory alert) if hazardous noise levels of 85 dBA and above are detected. This is a new crew-health related function that will reduce the crew's risk for exposure to high noise levels, and will protect the crew in the case of an off-nominal noise event. The functionality desired includes:

- Perform continuous acoustic data sampling
- Send an electronic signal if noise levels are 85 dBA or above

The following hazard level alert functionality is desired:

- Pre-trigger capability so onset of hazardous noise is measured.

The technology from this SBIR subtopic is highly desired for use on ISS and for future long duration space missions for the long-term.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract. For Phase II, a demonstration in the JSC Acoustics and Noise Control Lab (ANCL) is being requested so that testing can be performed in the ISS Acoustic Mockup. As a result, an SBIR testing facility waiver will be needed.

Potential Phase III activities are envisioned to be a demonstration of the sensor's capability on board ISS as a Station Detailed Test Objective (SDTO)

Phase I Deliverables:

- Sensor preliminary design
- Breadboard microphone transducer (proof of concept)
- Test data showing acoustic performance of breadboard sensor
- Forward plan for sensor development, including plans for in-situ calibration
- The expected TRL at the end of Phase I is 3-5

Phase II Deliverables:

- Sensor design in flight-like package
- Test data showing acoustic performance of flight-like sensor
- Demonstration of multiple sensors in ground facility (NASA JSC ANCL)
- The expected TRL at the end of Phase II should be 6.

O3.07 Cryogenic Fluid Management Technologies
Lead Center: KSC

The ultimate objective of this Cryogenic Fluid Management (CFM) Technologies solicitation is to demonstrate a variety of critical CFM technologies in a micro-gravity space environment via a deployable or non-deployable test bed.

The initial phase (Phase I) will identify and develop prototype experiments that could be integrated into a universal platform for demonstration of these experiments in their relevant micro-gravity environment.

The second phase (Phase II) of this solicitation would develop a universal and innovative test bed platform that could be launched as a secondary payload on an expendable launch vehicle.

State of the art: CFM technologies are, for the most part, limited to ground tests that do not provide a complete and accurate demonstration of the technologies in their true operational environment. This increases risk in the development of emerging technologies for future applications in the areas of space based propellant depots, low gravity descent and ascent operations, and future space or planetary based architectures.

Areas of interest:

The purpose of these experiments would be to allow testing of:

- Designs for fluid and propellant transfer plumbing
- Multi-layer insulation (MLI) designs
- Various mass gauging designs

- Thermal control and boil-off control designs in a true micro-gravity space environment

Sample technologies in current queue at NASA centers that require testing in such type of platform include:

- Vapor Cooling
- Orientation
- Para-ortho H_2 conversion
- Fluid Transfer Coupling
- Thermodynamic Vent System
- Automated Rendezvous and Docking
- Thick MLI blanket
- Broad area cooling (vapor cooled, active cooled)
- Sun Shield
- Mass gauge
  - Radio Frequency (RF)
  - Pressure Volume Temperature (PVT)
  - Level Sensor (Cryo-Tracker)

- Instrumentation
  - Cryo tracker
  - Mass flow rate (fill, vent)
  - Tank pressure
  - Temperature (liquid, vent, tank wall, transfer lines, structure)
  - System acceleration

- Liquid Acquisition Device (LAD)
- Settling
- Propulsion (H_2/O_2 thruster, solar thermal)
  - H_2/O_2 thruster
  - Solar thermal

- Propellant Positional Device (PPD) (magnetic, screen)
- Cryo-Cooler
- Mixing (Vehicle maneuvers (roll), pumps)
- Structural interface (conic, struts)

The identification and design of critical CFM components that could be utilized in future exploration architectures in the space environment are being solicited for this platform. The technologies and future development of the platform supporting them would allow demonstration and proof of concepts for the designs and hardware necessary for mechanisms such as fluid transfers in propellant depots and in planetary spacecraft prior to the actual full development, design, fabrication, and launch of hardware. These CFM technologies and platform would provide a simple, low cost and innovative method to prove technologies and could avoid large and costly design modifications or possible multiple launch requirements for future space based architectures.

A viable option for the low cost approach involves launching as a secondary payload on launch vehicles currently in use such as an Atlas V or Delta IV. Such launch vehicles hold a high level of design maturity, contributing to a huge savings in development costs. In addition, through riding as a secondary payload, a majority of the launch costs could be absorbed by the primary mission. In a typical launch vehicle configuration, the secondary payload is attached to a launch vehicle’s second stage propellant tank beneath the primary payload. After separation of the primary payload, the platform would either deploy and operate as a free flying spacecraft and perform the various CFM demonstrations, or could remain attached to the propellant tank to prove fluid transfer capabilities, along with additional experiments. A third option is to utilize the residual propellants from the launch vehicle to fill a "receiver" tank on the platform, which would subsequently deploy to perform various additional demonstrations.

The platform would be processed and integrated in the typical fashion of spacecrafts launched today. A platform that remains completely passive (non-operational and containing no commodities) until separation of the primary payload greatly reduces ground-processing requirements. Individual experiments could also be integrated with the platform prior to integration to the launch vehicle to further reduce operational complexities.

The second phase of the project would design a platform so as to encompass additional requirements such as:

- The capability to support and integrate multiple CFM technology experiments per mission
- Demonstrating innovative, fluid transfer designs
- MLI designs
- Various mass gauging designs
- Thermal control and boil-off control designs
- Validation of CFD propellant models
- Testing of propellant management devices
- Mixing pumps
- Thermodynamic vapor cooling systems
- Environmental thermal shielding designs

Design of the platform would need to ensure that it does not impose additional risk to the mission success of the primary payload and is capable of remaining completely passive and inert until the primary payload is successfully deployed. This includes launching with empty tank(s), lines, etc., and maintaining the ability for residual cryogenic propellants to be transferred from the launch vehicle upper stage to the proposed secondary payload upon completion of the primary mission.

Optional configurations could include multiple tanks with self-contained fluids, however the use of residuals, with innovative propellant transfer lines, from an upper stage promotes cost savings in both the propellant commodities, pressurization systems required for pre-launch processing, limit hazard and safety concerns for the primary mission, and the passive nature reduces the complexities added in the analyses and operations required for integration with the launch vehicle and primary mission.

The platform, itself, would contain tank to tank fluid transfer capabilities, avionics, thermal control systems, telemetry capabilities and, if deployable, an attitude control system. The platform design would be capable of interfacing with the launch vehicle separation system and avionics. Additional potential experiments and uses include validation of CFD propellant models, testing of propellant management devices, mixing pumps, thermodynamic vapor cooling systems, and environmental thermal shielding designs.

Performance metrics: A platform that is capable of remaining passive and inert through completion of the primary mission on an EELV. The platform shall be capable of supporting at a minimum of four CFM demonstrations per mission. The designs for the experiments are to be such that they are capable of demonstrating CFM technologies supporting the operational requirements of future space based architectures in cryogenic temperature ranges.

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

Phase I Deliverables: Demonstration of technical feasibility (TRL 3-4).

Phase II Deliverables: Prototype design and demonstration of innovative technology testing platform, capable of integrating multiple CFM experiments (TRL 4-6). A ready to launch version of this as an EELV secondary payload performing demonstrations of CFM technologies is highly desired.

TOPIC: O4 Navigation

NASA is seeking innovative research in the areas of positioning, navigation, and timing (PNT) that have relevance to Space Communications and Navigation programs and goals, as described at http://www.spacecomm.nasa.gov. NASA's Space Communication and Navigation Office considers the three elements of PNT to represent distinct, constituent capabilities: (1) positioning, by which we mean accurate and precise determination of an asset's location and orientation referenced to a coordinate system; (2) 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; and (3) timing, by which we mean an asset's acquiring from a standard, maintaining within user-defined parameters, and transferring where required, an accurate and precise representation of time. This year, NASA seeks PNT technologies in three focus areas: metric tracking of launch vehicles, on-orbit PNT sensors and components, and flight dynamics technologies and software. Some of the subtopics in this topic could result in products that may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 for more details as to the requirements for flight opportunities.

O4.01 Metric Tracking of Launch Vehicles
Lead Center: KSC
Participating Center(s): GSFC, MSFC

Launch vehicles can exhibit high dynamics during flight and there can be external interference on the GPS frequency. The goal of this subtopic is to have a highly reliable way of tracking vehicles from launch to orbit utilizing GPS and/or inertial measurement unit.

Areas of interest:

Metric Tracking Hardware
Metric tracking of launch vehicles requires the development of accurate and stable integrated metric tracking and inertial measurement units. The focus is on technologies that enable and advance development of low Size, Weight, and Power (SWaP), tactical grade, integrated metric tracking units that provide accurate and stable positioning, attitude, and inertial measurements on highly dynamic platforms. Factors to address include:

- Ultra-tight coupling of rate sensors, accelerometers, and attitude-determining GPS receivers that will provide very high frequency integrated metric solutions,
- The ability to reliably function on spin-stabilized rockets (up to 7 rev/s), during sudden jerk and acceleration maneuvers, and in high vibration environments,
- Advancements in MEMs-based rate sensors and accelerometers, algorithm techniques and Kalman filtering, high bandwidth and low noise outputs, phased-based attitude determination, single aperture systems, quick Time to First Fix and reacquisition.

Use of GPS and Ability to Mitigate Interference Signals
NASA seeks innovative technologies to increase the accuracy of the L1 C/A navigation solution by combining the pseudo ranges and phases of the L1 C/A signals, and use of the L2 and L5 carriers. Factors to consider:

- GPS signal degradation can be obtained by differencing the available carrier phase and pseudo range measurements and then removing these differences from the navigation solution.
- Jamming of GPS signals are a concern during the tracking of launch vehicles.

- Technologies are sought that combine spatial processing of signals from multiple antennas with temporal processing techniques to mitigate intentional interference signals (jamming) received by the GPS receiver. The coordinated response of adaptive pattern control (beam and null steering) and digital excision of certain interfering signal components can minimize strong jamming signals. Adaptive nulling minimizes interfering signals by the optimal control of the GPS antenna pattern (null steering).

Proposals can either address a single subject as described above or a combination of subjects.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I (to reach TRL 3) and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract (to reach TRL 5).

Phase I Deliverables:

- Midterm Technical Report
- Final Phase I Technical Feasibility Report with a Phase II Integration Path. Proof-of-concept bench top demonstration preferred.

Phase II Deliverables:

- Final Phase II Technical Report
- Demonstration hardware/software/field test.

O4.02 On-Orbit PNT (Positioning, Navigation, and Timing) Sensors and Components
Lead Center: GSFC
Participating Center(s): GRC, JPL, JSC

This solicitation seeks proposals that will serve NASA's ever-evolving set of near-Earth and interplanetary missions that require precise determination of spacecraft position and velocity in order to achieve mission success. While the definition of "precise“ depends upon the mission context, typical scenarios have required meter-level or better position accuracies, and sub-millimeter-level per sec or better velocity accuracies. This solicitation is primarily focused on NASA's needs in four focused areas identified below.

Proposals are encouraged that leverage the following NASA developed state of-the-art capabilities:

- GEONS (http://techtransfer.gsfc.nasa.gov/ft_tech_gps_navigator.shtm)
- Navigator (http://techtransfer.gsfc.nasa.gov/ft_tech_gps_navigator.shtm)
- GIPSY (https://gipsy-oasis.jpl.nasa.gov/)
- Electra (http://descanso.jpl.nasa.gov/Monograph/series9_chapter.cfm)
- Blackjack (http://www.jpl.nasa.gov/releases/2000/blackjackgps.html)

NASA is not interested in funding efforts that seek to "re-invent the wheel" by duplicating the many investments that NASA and others have already made in establishing the current state-of-the-art.

General Operational Needs, Requirements and Performance Metrics:

Onboard Near-Earth Navigation Systems
NASA seeks proposals for development of a commercially viable transceiver with embedded orbit determination software providing enhanced accuracy and integrity for autonomous onboard GPS- based and TDRSS-based navigation, along with time-transfer in near-Earth space via augmentation messages broadcast by TDRSS. The augmentation message should include information on the TDRS orbits, status, and health that could be provided by future TDRS, and should provide information on the GPS constellation based on NASA's TDRSS Augmentation for

Satellites Signal (TASS). Proposers are advised that NASA's GEONS and GIPSY orbit determination software packages already support the capability to ingest TASS messages.

Onboard Deep-Space Navigation Systems
NASA seeks proposals to develop an onboard autonomous navigation and time-transfer system for reduction of DSN tracking requirements. Such a system should provide accuracy comparable to delta differenced one-way ranging (DDOR) solutions anywhere in the inner solar system, and exceed DDOR solution accuracy beyond the orbit of Jupiter. Proposers are advised that NASA's GEONS and DS-1 navigation software packages already support the capability to ingest many one way forward Doppler, optical sensor observation, and accelerometer data types.

Technologies Supporting Improved TDRSS-based Navigation
NASA seeks proposals providing improvements in TDRS orbit knowledge, TDRSS radiometric tracking, ground-based orbit determination, and Ground Terminal improvements that improve navigation accuracy for TDRS users. Methods for improving TDRS orbit knowledge should exploit the possible future availability of accelerometer data collected onboard future TDRS. The goal is navigation and communications integrated into a single processor.

Navigation Payload Technology for Lunar Relay Satellites
NASA seeks lunar relay navigation payload technologies that can:

- Transmit accurate spread spectrum signals (emphasizing the stability of the frequency reference yielding accurate timing and chipping rate of the PN code and a low noise carrier)
- Receive same in return (either in coherent mode (the relay transmits and receives using the same frequency reference) or non-coherent mode (where the accurate frequency reference is on one end of link, either the transmit side or the receive side)).

This relay navigation payload should be capable of receiving a satellite-to-satellite link with similar signal properties. The relay navigation payload has to measure the range (two-way), pseudo-range (one-way), and both one-way and two-way Doppler. The relay navigation payload must be able to de-commutate data received from Earth and lunar bases to maintain time synchronization with a master time source, use the data onboard to either slave its frequency reference or to update its reference, and turn-around the data to modulate onto the user data stream.

Additionally, the relay navigation payload must have:

- ‘Reasonable fidelity’ autonomous filtered navigation capability to fuse all data types listed above as well as antenna gimbal angles, accelerometer data, and rendezvous radar data, to estimate the lunar relay state
- Output data rates of 1 Hz for the states of multiple satellites and comprehensive fault detection and correction data
- State outputs that can be modulated on transmitted data streams
- TASS-like broadcast beacon capability for navigation. The data on the beacon can originate either at a base location (earth, moon), the relay, or another asset with which the relay communicates.
- Dissemination of time and navigation data for the local environment

Proposals can either address a single subject as described above or a combination of subjects.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I (to reach TRL 3) and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract (to reach TRL 5).

Phase I Deliverables:

- Midterm Technical Report
- Final Phase I Technical Feasibility Report with a Phase II Integration Path. Proof-of-concept bench top demonstration preferred.

Phase II Deliverables:

- Final Phase II Technical Report
- Demonstration hardware/software/field test.

O4.03 Flight Dynamics Software and Technologies
Lead Center: GRC
Participating Center(s): GSFC, JPL

NASA is beginning to invest in re-engineering its suite of tools and facilities that provide navigation and mission design services for design and operations of mid-term and long-term near-Earth and interplanetary missions. This solicitation seeks proposals that will develop the highly desired flight dynamics technologies and software that support these efforts.

Proposals that leverage state-of-the-art capabilities already developed by NASA are especially encouraged, such as:

- GPS-Enhanced Onboard Navigation Software (http://techtransfer.gsfc.nasa.gov/ft_tech_gps_navigator.shtm)
- General Mission Analysis Tool (http://sourceforge.net/projects/gmat/)
- GPS-Inferred Positioning System and Orbit Analysis Simulation Software (http://gipsy.jpl.nasa.gov/orms/goa/)
- Optimal Trajectories by Implicit Simulation (http://otis.grc.nasa.gov/)

Proposers who contemplate licensing NASA technologies are highly encouraged to coordinate with the appropriate NASA technology transfer offices prior to submission of their proposals.

Areas of interest: In the context of this solicitation, flight dynamics technologies and software are algorithms and software that may be used in ground support facilities, or onboard a spacecraft, so as to provide Position, Navigation, and Timing (PNT) services that re-duce the need for ground tracking and ground navigation support. Flight dynamics technologies and software also provide critical support to pre-flight mission design, planning, and analysis activities.

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

- Applications of cutting-edge estimation techniques, such as, but not limited to, sigma-point and particle filters, to spaceflight navigation problems.
- Applications of estimation techniques that have an expanded state vector (be-yond position and velocity components) to monitor non-Gaussian state noise processes and/or non-Gaussian measurement noise processes.
- Applications of estimation techniques that combine measurements from multiple sensor suites in a highly coupled manner to improve upon the overall system ac-curacy.
- Addition of novel estimation techniques to existing NASA mission design software that is either freely available via NASA Open Source Agreements, or that is licensed by the proposer.
- Applications of advanced dynamical theories to space mission design and analysis, especially in the context of unstable orbital trajectories in the vicinity of small bodies and libration points.

- Addition of novel measurement technologies to existing NASA onboard navigation software that is licensed by the proposer.
- Addition of orbit determination capabilities to existing NASA mission design software that is either freely available via NASA Open Source Agreements, or that is licensed by the proposer.

Technologies and software should support a broad range of spaceflight customers. Technologies and software specifically focused on a particular mission's or mission set's needs, for example rendezvous and docking, or formation flying, are the subject of other solicitations by the relevant sponsoring organizations and should not be submitted in response to this solicitation.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I (to reach TRL 3) and show a path toward Phase II hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase II contract (to reach TRL 5).
Phase I Deliverables:

- Midterm Technical Report
- Final Phase I Technical Feasibility Report with a Phase II Integration Path

Phase II Deliverables:

- Final Phase II Technical Report
- Algorithm Specification
- Delivery of software package
- Demonstration of software package

9.2 STTR

The STTR Program Solicitation topics correspond to strategic technology research areas of interest at the NASA Centers. The subtopics reflect the current highest priority technology thrusts of the Centers in their particular area of interest.

TOPIC: T1 Small Probe Entry Descent and Landing System, and Information Technologies for Intelligent Planetary Robotics

The Small Probe Entry Descent and Landing System topic seeks proposals in relevant technology areas that will enable low cost approaches to obtaining flight data and qualify thermal protection systems in mid TRL levels and/or using small probe as a way to conduct bio, space and materials science experiments in space and bring back samples for laboratory analysis. The Information Technologies for Intelligent Planetary Robotics subtopic seeks proposals to develop information technologies that enable planetary robots to better support human exploration, with robotic support for human tasks such as advance scouting, site surveys, and site prep and documentation tasks that will enable long-duration missions.

T1.01 Small Probe Entry Descent and Landing Systems
Lead Center: ARC

The Entry, Descent and Landing (EDL) system of a spacecraft allows the payload to enter the atmosphere, survive the heating pulse, and touch down in a manner that doesn't harm the payload. The system generally consists initially of a spacecraft bus and an entry probe. The entry probe contains the payload.

During the initial entry portion of the mission the spacecraft bus provides power, avionics and maneuvering that governs the entry angle and a small de-orbit burn that sets the payload on the desired trajectory. This portion of the spacecraft is generally jettisoned before entry and is burned up in the atmosphere.

The Thermal Protection System (TPS) protects the payload from the severe heating encountered during hypersonic flight through a planetary atmosphere. In general, there are two classes of TPS: reusable and ablative. Typically, reusable TPS applications are limited to relatively mild entry environments like that of Space Shuttle. No change in the mass or properties of the TPS material results from entry with a significant amount of energy being re-radiated from the heated surface and the remainder conducted into the TPS material. Typically, a surface coating with high emissivity (to maximize the amount of energy re-radiated) and with low surface catalycity (to minimize convective heating by suppressing surface recombination of dissociated boundary layer species) is employed. The primary insulation has low thermal conductivity to minimize the mass of material required to insulate the primary structure. Ablative TPS materials, in contrast, accommodate high heating rates and heat loads through phase change and mass loss. All NASA planetary entry probes to date have used ablative TPS.

The payload contained in the thermal protection system may have special system constraints that will govern the design of the probe, such as peak deceleration loads and thermal control. For example a biological sample returning from space station may be limited to a few g's and max temperature rise on the order of 25 deg C.

The final portion of the entry is the landing system, typically defined as occurring during the supersonic and subsonic portions of the entry. The final touchdown can be via parachute or by direct impact of the probe with the planetary surface. While the parachute system adds mass and complexity to the mission it provides a final touchdown velocity small enough not to damage the probe. If the goal of the mission is to recover the probe without any impact damage the parachute and probe system can be snatched by aircraft during the terminal descent phase. Direct impact probes avoid the complexity of the parachute system and generally protect the payload with a crushable core to protect the payload from the high terminal velocity. The payload must be able to withstand the high deceleration loads in this type of a system.

NASA has successfully tackled the complexity of thermal protection systems for numerous missions to inner and outer planets in our solar system in the past; the knowledge gained has been invaluable but incomplete. In particular, ground test to flight traceability issues are incompletely understood.

An upcoming application of EDL technology is the desire to return small probes (i.e. cubesats and nanosats with payloads on the order of 1 kg) from low earth orbit. These missions will generally be launched as secondary payloads on much larger mass missions, or may be used to return biological samples from the International Space Station (ISS).

We are interested in building an integrated approach of probes or small platforms of probes with a spacecraft and a de-orbit system for multiple purposes: (1) As a TPS testbed wherein different TPS materials may be characterized during an actual re-entry, (2) Space/Bio Science mission including space station sample return, (3) materials in space testing such as exposure to space radiation and (4) Instrumentation packaging and demo (earth demo for planetary entry) and this may include such things as TPS instrumentation.

Areas of expertise are sought in all aspects of EDL design for these small entry probes as well as spacecraft integration with small probes that includes novel ideas for de-orbiting small probes. Advances in Multidisciplinary Design Optimization (MDO) are sought specifically in application to address combined aerothermal environments, material response, vehicle thermal-structural performance, payload thermal control, vehicle shape, vehicle size, aerodynamic stability, mass, vehicle entry trajectory/GN&C, and landing systems, characterizing the entry vehicle design problem.

The expected Technology readiness level is 4.

T1.02 Information Technologies for Intelligent Planetary Robotics
Lead Center: ARC

The objective of this subtopic is to develop information technologies that enable planetary robots to better support human exploration. Since February 2004, NASA has been actively engaged in a long-term program to explore the Moon, Mars, and other destinations. Several NASA studies have concluded that extensive and pervasive use of intelligent robots can significantly enhance human exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

Robots can do a variety of work to increase the productivity of human explorers on planetary surfaces. Robots can perform tasks that are highly repetitive, long-duration, or tedious. Robots can perform tasks that help prepare for subsequent crew activity. Robots can perform "follow-up" work, completing tasks started by humans. Example tasks include: robotic recon (advance scouting), systematic site surveys, documenting sites or samples, and unskilled labor (initial site prep, site clean-up, etc.).

Proposals are sought which address the following technology needs:

- Advanced user interfaces for remote robotic exploration, which include Web-based collaboration methods, panoramic and time-lapse imagery, support for public outreach/citizen science, social networking and/or visualization of geospatial information. The primary objectives are to enable more efficient interaction with robots, to facilitate situational awareness, and to enable a broad range of users to participate in robotic exploration.
- Ground control data systems for robotic exploration. Proposals should focus on software tools for planning variable-duration and adjustable autonomy command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; for managing; and/or for automating ground control functions.
- Mobile robot navigation (localization, hazard avoidance, etc.) for multi-km traverses in unstructured environments. Novel "infrastructure free" techniques that utilize passive computer vision (real-time dense stereo, optical flow, etc.), active illumination (e.g., line striping), repurposed flight vehicle sensors (low light imager, star trackers, etc.), and/or wide-area simultaneous localization and mapping (SLAM) are of particular interest.
- Robot software architecture that radically reduces operator workload for remotely operating planetary rovers. This may include: on-board health management and prognostics, on-board automated data triage (to

prioritize information for downlink to ground), and learning algorithms to improve hazard detection and selection of locomotion control modes.

TOPIC: T2 Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts

Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts Flight Research separates "the real from the imagined" and makes known the "overlooked and the unexpected." NASA's flight research mission is to prove unique and novel concepts through discoveries in flight. The chief areas of research interests encompass aerospace flight research and technology integration; validation of space exploration concepts; and airborne sensing and science. This topic solicits innovative proposals that would advance aerospace technologies for the nation in all flight regimes.

T2.01 Foundational Research for Aeronautics Experimental Capabilities
Lead Center: DFRC

This subtopic is intended to solicit innovative technologies that enhance flight research competences at Dryden by advancing capabilities for in-flight experimentation and for the supporting test facilities in the following areas:

- Methods and associated technologies for conducting flight research and acquiring test information from experiments in flight.
- Numerical techniques for the planning, analysis and validation of flight-test experimentation conditions through simulation, modeling, control, or test information assessment.

The emphasis of this subtopic is proving feasibility, developing, and maturation technologies for advanced flight research experimentation that demonstrate new methodologies, technologies, and concepts (or new applications of existing approaches). It seeks advancements that promise significant gains in Dryden's flight research capabilities or addresses barriers to measurements, operations, safety, and cost. Proposals that demonstrate and confirm reliable application of concepts and technologies suitable for flight research and the test environment are a high priority. Proposals in any of these areas will be considered:

- Measurement techniques are needed to acquire aerodynamic, structural, flight control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The goals are to improve the effectiveness of flight-testing by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence. Sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability.
- Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influences of structural dynamics, thermal dynamics, steady and unsteady aerodynamics, and the control system to increase understanding of the complex interactions between the vehicle dynamics and subsystems.
- Proposals for novel multidisciplinary nonlinear dynamic systems modeling, identification, and simulation for control objectives are encouraged. Control objectives include feasible and realistic boundary layer and laminar flow control, aero-elastic maneuver performance and load control (including smart actuation and active aero-structural concepts), autonomous health monitoring for improved stability, safety, performance, and drag minimization for high efficiency and extended range capability.

Proposals are encouraged that advocate technologies or methodologies that enable real-time location independent collaboration from experimenters from both domestic and international organizations. This approach holds the promise of increasing effectiveness, reducing cost, and adding significant value to the experimental results. This topic solicits proposals for improvements in all flight regimes - subsonic, transonic, supersonic, and hypersonic.

TOPIC: T3 Technologies for Space Exploration

This topic seeks to solicit advanced innovative technologies and systems in space power and propulsion to fulfill our Nation's goal of space exploration. The anticipated technologies should advance the state-of-the-art or feature enabling technologies to allow NASA to meet future exploration goals.

T3.01 Technologies for Space Power and Propulsion
Lead Center: GRC

Development of innovative technologies are sought that will result in durable, long-life, lightweight, high performance space power and in-space propulsion systems to substantially enhance or enable future missions.

Innovations for space power systems are sought that will offer significant improvements in efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, design flexibility/reconfigurability, autonomy, and affordability. In the area of power generation, advances are needed in photovoltaic cell technology (e.g., materials, structures, and incorporation of nanomaterials); solar array module/panel integration (e.g., advanced coatings, advanced structural materials, monolithic interconnects, and high-voltage operational capability); and solar array designs (e.g., ultra-lightweight deployment techniques for planar and concentrator arrays, restorable/redeploy able designs, high power arrays, and planetary surface concepts). For energy storage technology, advances are needed in primary and rechargeable batteries, fuel cells, flywheels, regenerative fuel cell systems, and innovative design methods. Advances are also needed in power management and distribution systems, power system control, energy conversion technology (such as Stirling and Brayton systems) and integrated health management. Advanced nuclear power concepts are also sought.

Innovations, advanced concepts and processes are sought for in-space propulsion, including electric propulsion, chemical propulsion, advanced rocket propellants/alternative fuels, nuclear propulsion, and tether technology. In electric propulsion, concepts for subcomponent improvements are needed for ion and Hall thruster systems, including cathodes, neutralizers, electrode-less plasma production, low-erosion materials, high-temperature permanent magnets, and power processing systems. Innovations are also needed for xenon and krypton fuel distribution systems. In small chemical thruster propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

TOPIC: T4 Advanced Terrestrial, Airborne, and Spaceborne Instruments

As part of its mission, NASA needs advanced remote sensing measurements to improve the scientific understanding of the Earth, its responses to natural and human-induced changes, and to improve model predictions of climate, weather, and natural hazards. By using improved technologies in terrestrial, airborne, and spaceborne instruments, NASA seeks to better observe, analyze, and model the Earth system to aid in the scientific understanding and the possible consequences for life on Earth.

This STTR solicitation is to help provide advanced remote sensing technologies to enable future measurements. Components are sought that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (Unmanned Aircraft Systems (UAS) or aircraft). New approaches, instruments, and components are sought that will:

- Enable new Earth Science measurements;
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal resolution, accuracy, range of regard); and/or
- Substantially reduce the resources (cost, mass, volume, or power) required to attain the same measurement capability.

T4.01 Lidar, Radar, and Passive Microwave
Lead Center: GSFC

Lidar Remote Sensing Instruments and Components
Lidar instruments and components are required to furnish remote sensing measurements for future Earth Science missions. NASA particularly needs advanced components for direct-detection lidar that can be used on new UAS platforms available to NASA, on the ground as test beds, and eventually in space. Important aspects for components are electro-optic performance, mass, power efficiency and lifetimes. Key components for direct-detection lidar techniques (particularly efficient lasers and sensitive detectors) are solicited that enable or support the following Earth Science measurements:

- Profiling of cloud and aerosol backscatter, with emphasis on multiple wavelength as relevant to the Aerosol-Clouds-Ecosystems (ACE) mission. A particular interest is development of novel scanning telescopes capable of scanning over 360 degrees in azimuth with nadir angle fixed in the range of 30 to 45 degrees, scalable to spaceborne operation without imposing requirements for momentum compensation.
- Wind measurements (using direct-detection techniques). A particular interest is photon-counting detectors (either single element or array) with high quantum efficiency (>70%) and low noise (< 100 counts/second) to improve direct-detection wind profiling at 355 nm.
- Trace gas measurements. Specifically, novel (preferably wave-guided) reference gas cells with fixed long path-lengths of ~20 m up to 100 m for laser wavelength locking and calibration in fiber optic C-band and L-band for flight missions. The gas cells must be compact , lightweight, insensitive to vibration and deformation, low in excess insertion loss (<10dB preferred), free of multi-pass interference (MPI) and other spectral fringes that upset wavelength locking and calibration.

Radar Remote Sensing Instruments and Components
Active microwave remote sensing instruments are required for future Earth Science missions with initial concept development and science measurements on aircraft and UASs. New systems, approaches, and technologies are sought that will enable or significantly enhance the capability for: (1) tropospheric wind measurements within precipitation and clouds at X- through W-band, and (2) precipitation and cloud measurements. Systems and approaches will be considered that demonstrate a capability that can be mounted on a relevant platform (UAS or aircraft). Specific technologies include:

- High-speed digital transceivers for cloud/precipitation radar remote sensing.
- Scanning Ka or W-band Doppler radar technologies with high sensitivity for clouds.
- High power, high-speed, low loss W- and Ka-band radar receiver protection.
- Ultra-low sidelobe pulse compression technologies for cloud/precipitation applications.
- Frequency selective surface for W-and Ka-band radar front ends.

TOPIC: T5 Next Generation In Situ Compositional Mapping Tools

This topic addresses the need for low mass, low power technologies that support in situ compositional analysis and mapping. Two areas are of particular interest: micro-scale analysis and mapping of the mineralogy, organic compounds, chemistry and elemental composition of planetary materials, related to rock fabrics and textures; and remote mapping of geologic outcrops and features. Such technologies are particularly relevant for the planned Mars

2018 rover mission, but may also be proposed to future landed missions to the moon, comets, asteroids, Europa, Titan, and other planetary bodies.

T5.01 Technologies for In Situ Compositional Analysis and Mapping
Lead Center: JPL

This subtopic is focused on developing and demonstrating technologies for in situ compositional analysis and mapping that can be proposed to future planetary missions, including the Mars 2018 Rover.

Possible areas of interest include:

- Improved sources such as lasers, LEDs, X-ray tubes, etc. for in situ 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 in situ 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 in situ instruments used to study the elemental, chemical, and mineralogical composition of planetary materials.

Projects selected under this subtopic should address at least one of the above areas of interest. Multiple-area proposals are encouraged. Proposers should specifically address:

- The suitability of the technology for flight applications, e.g. mass, power, compatibility with expected shock and vibration loads, radiation environment, interplanetary vacuum, etc.;
- Advantages of the proposed technology compared to the competition;
- Relevance of the technology to NASA’s planetary exploration science goals.

TOPIC: T6 Innovative Technologies and Approaches for Space

To accomplish the Agency's goals and objectives for a robust space exploration program, innovative technologies and approaches are needed to meet these major challenges for human space explorers. This topic solicits technologies to support inflatable modules and advanced portable sensor technologies for high-purity oxygen determination. These technology innovations could help minimize launch mass, size and costs. The anticipated proposed technologies shall have a dramatic impact on achieving NASA’s goals.

T6.01 Inflatable Modules
Lead Center: JSC

This subtopic solicits innovative structural concepts that support the development of lightweight structures technologies that could be applicable to space applications. The targeted innovative lightweight structures are for primary pressurized volumes. Innovations in technology are needed to minimize launch mass, size and costs, while increasing operational volume and maintaining the required structural performance for loads and environments.

Of particular interest are inflatable structures, which are viable solutions for increasing the volume in habitats, airlocks, and potentially other crewed vessels. To build confidence in the use of these structures; design, analysis and manufacturing methods that produce optimal structure on a consistent basis need development above the current state of the art.

The development, analysis, and testing of dual purpose materials that show significant benefits in more than one area such as structural, thermal protection, micrometeoroid/ orbital debris protection, radiation protection, atomic oxygen protection, and such are of particular interest.

The folding, packaging and deployment of multi-layer systems especially those with an integrated window or hatch penetration and particularly those of a torus shape surrounding a cylindrical body are also an area of interest.

Also of interest are low permeable bladder materials and the development and testing of a low permeable interface between a gas barrier and a structural core or hatch penetration that is durable over time and does not degrade due to effects such as cold flow. Development of low permeability bladder materials that can tolerate flexure at cold temperatures are of particular interest.

Developments can include material development and testing, conceptual design and demonstration, analysis methods and verification, and/or manufacturing techniques. Technological improvements focus on risk reduction/mitigation, and development of reliable yet robust designs under this announcement. Research demonstrates the technical feasibility during Phase I and shows a path toward a Phase II hardware demonstration, and when possible, delivers a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

T6.02 Advanced Portable Sensor Technology for High-Purity Oxygen Determination
Lead Center: JSC

Determining the purity of oxygen near 100% is problematic using portable electrochemical sensor-based devices. Accurate laboratory analysis is based on techniques such as separation (e.g., gas chromatography, GC) followed by peak integration or mass-spectral analysis. Though accurate, these devices are not readily portable, usually delicate and often require a carrier or calibration gas. While not specifically excluded, a carrier gas is strongly discouraged and calibration should require a minimum of consumables.

This solicitation seeks a reliable technique that can be applied to accurately assess oxygen purity in the range of 99.0% to 99.7% (see an example below)*. The technique or technology should be able to determine oxygen purity with a variety of simple diluents such as nitrogen, argon, hydrogen, water vapor and trace amounts of low molecular weight organics, CO and/or CO_2. It is not important that the technique specifically identify or quantify the diluents(s). The target accuracy for oxygen purity in the range is 0.05%.

Proposed technologies should be easily calibrated in remote locations, should be highly resistant to drift (i.e., long time between calibration cycles) and have potential to be adapted to a size and portability suitable to space missions. Potential applications include on-orbit determination of high-purity oxygen or other remote applications. A minimum of support equipment, maintenance, power and consumables is a key characteristic sought.

The first phase should address potential approaches with anticipated ranges of accuracy and precision along with known or potential limitations and interferences. Subsequent phase will be to develop and demonstrate a working prototype.

Example: The proposed technology should be able to reliably determine and differentiate the oxygen concentration between the following two example gas streams:

- 99.7% Oxygen, 0.2% Argon, 0.1% Nitrogen with a dew point of -60°C;
- 99.4% Oxygen, 0.4% Argon, 0.2% Nitrogen with a dew point of -40°C.

TOPIC: T7 Wireless SAW Sensor Arrays

The Kennedy Space Center has been supporting the development of wireless SAW sensor arrays through prior research activities. A new communication system has been demonstrated, namely Orthogonal Frequency Coding, that allows access to an array of SAW sensors, each with its own unique identifier to measure temperature, cryogenic levels, humidity, and hydrogen. However, further development in other types of wireless monitoring is desired such as: pressure, strain, near-by impacts/structural acoustic events, acceleration, proximity detection, magnetic/electric field, current, and hypergols (monomethyl-hydrazine or nitrogen tetroxide). The goal is to maximize the ability to acquire information on these and other parameters while minimizing the need for cabling and preventative maintenance requirements. Wireless SAW sensor arrays appear to promote this goal.

T7.01 Wireless SAW Sensor Arrays
Lead Center: KSC

Wireless surface acoustic wave (SAW) sensor arrays may have significant application in the ground processing of future spacecraft. These sensors do not require an embedded power source; instead they are powered by an RF interrogation pulse. Consequently, they have the promise of being essentially maintenance free, allowing them to be installed in normally inaccessible areas and provide environmental information for many years. In addition, as opposed to microprocessor-based transponders, SAW devices can be designed to operate from cryogenic temperatures up to about 1000 degrees C. These characteristics have resulted in interest in this technology, not only for ground processing, but recently from both the NASA research and flight centers.

The Kennedy Space Center has been supporting the development of wireless SAW sensor arrays through prior STTR activities. A new communication system has been demonstrated, namely Orthogonal Frequency Coding, that allows access to an array of SAW sensors, each with its own unique identifier. Also specific sensors have been developed to measure temperature, cryogenic level, humidity, and hydrogen under prior year funding. These are all of interest, but further development in other types of wireless SAW sensors is desired. This call requests proposals for wireless SAW sensors that can monitor, for example, pressure, strain, near-by impacts/structural acoustic events, acceleration, proximity, magnetic field, current, electric field, and hypergols (monomethyl-hydrazine or nitrogen tetroxide). This list is not exclusive and other sensors may also be of interest as well. In addition, alternative communication or multiplexing concepts are of interest, and enabling technologies, such as antenna design for SAW sensors, are welcome.

Applications for these sensors are diverse. When a vehicle is moved to the pad on a mobile launch platform strain sensors and accelerometers monitor the vehicle's sway, pressure sensors could be placed under sprayed on foam insulation to ensure bonding integrity up to launch, moisture sensors could be used to determine if water has migrated into inaccessible areas. Electric field sensors might help with lightening warnings, chemical sensors can improve safety, and magnetic field or current sensors can monitor valve performance. The goal is to maximize the ability to acquire information on these and other parameters while minimizing the need for cabling, maintenance, and operator labor. Wireless SAW sensor arrays appear to promote this goal.

TOPIC: T8 Lidar, Radiosotope Generators, and Circuit Board Materials

For Space Environment Resistant Materials there are opportunities to improve the performance of engineering materials that support spacecraft performance, lifetime, and mission assurance. Areas of opportunity to improve material performance for low earth orbiting satellites are reflective coatings and emissive coatings that maintain properties for extended periods with resistance to high-energy radiation and atomic oxygen. Other areas of interests include materials that resist internal electrostatic discharge in highly charged radiation belt environments. The outer planet environments, such as Jupiter, have predominantly highly charged trapped electrons, which pose challenges for protecting critical spacecraft components inside the bus from internal electrostatic discharge. Charged environments can be on Earth at geosynchronous and medium orbits where interactions with trapped radiation belts that are charged by solar space weather are prevalent. Polymeric and composite materials that can assist in reducing adverse affects of spacecraft charging and internal electrostatic discharge are sought without the loss of coating, electrical, adhesive, thermal, and mechanical properties. Research and development of space environment resistant materials support the mission assurance of NASA earth science, exploration, and space science spacecraft missions outlined in the decadal survey.

T8.01 Flexible Charge Dissipation Coatings for Spacecraft Electronics
Lead Center: LaRC
Participating Center(s): JPL

Many NASA spacecraft and satellites operate in radiation environments: geostationary and medium earth orbits, radiation belts in the outer planets, solar wind, and Lagrangian points near the sun. With highly charged particles that penetrate spacecraft, internal electrostatic discharge risks mission assurance. The Jovian environment has radiation levels 7 times greater that Earth’s geostationary orbit, which is the NASA Europa Jupiter System Mission environment. In order to reduce the risk of internal electrostatic discharge on sensitive spacecraft electronic components, NASA seeks a conformal conductive coating that dissipates charge on the surface of electronic boards. It is highly desired for the coating to be applied to electronic boards using a standard industry method such as painting or other brush technique in a cleanroom environment. The coating must dissipate charge, have low outgassing, and have low water absorption. The coating is highly desired to be optically clear for visual inspection of components. The coating is also highly preferred to be thermoplastic for removal if needed. The minimum maximum service temperature for the coating is 70 deg C. Charge dissipation testing can be done using electron gun, which can be screened using a scanning electron microscope (SEM). At the macroscopic level, the volume resistivity of the conductive coating must be in the range of 1 x 10 e8-e12 ohm cm. The paint or coating must be able to adhesively bond to conventional electronic epoxy and polyimide circuit boards without damaging metal circuits, resistors, capacitors, and semiconductor surfaces. Improved charge dissipation supports the mission assurance of NASA satellites and spacecraft that operate in charging environments.

T8.02 Spacecraft Internal Electrostatic Discharge (IESD) Resistant Circuit Board Materials
Lead Center: LaRC
Participating Center(s): JPL

The improvement in the performance of spacecraft circuit board materials with resistance to IESD will enhance performance, lifetime, and mission assurance. Circuit boards are sought from composite materials, such as graphite fibers and epoxy or polyimide resins that dissipate electron charge. It is important for the circuit board materials to be compared for circuit board physical properties (dielectric constant, temperature range, breakdown voltage, coefficient of thermal expansion, and etc.) with the current commercial state of the art materials, such as FR4 and others. A typical volume resistivity of 10e12 ohm cm is needed for the circuit board material and the ability to leak electron charge at the microscopic level. Charge dissipation studies can be initially performed by electron gun or scanning electron microscope (SEM) for initial screening. The outer planet environments, such as Jupiter, have predominantly highly charged trapped electrons, which pose challenges for protecting critical spacecraft components inside the bus from internal electrostatic discharge. Charged environments can be found at geosynchronous and medium Earth orbits where interactions with trapped radiation belts that are charged by solar space weather are prevalent. Polymeric and composite circuit board materials that can assist in reducing adverse affects of internal electrostatic discharge are sought without the loss of electrical, thermal, and mechanical properties. Research and development of spacecraft IESD resistant circuit board materials support the mission assurance of NASA earth science, exploration, and space science missions outlined in the decadal survey.

T8.03 Innovative Green Technologies for Renewable Energy Sources
Lead Center: LaRC

NASA is interested in advancing green technology research for achieving sustainable and environmental friendly energy sources for terrestrial and space applications. Dependence on fossil fuels has to be balanced with other potential sources of energy for minimizing deleterious effects of their byproducts. In the case of Lunar, Mars and other planetary explorations including development of human habitats, use of clean and renewable energy sources would help advance mission objectives to a greater extent besides reducing waste products.

Proposals are sought to develop innovative renewable sources of energy that generate minimal emissions, environmentally safe and are sustainable over extended periods of time. Proposed technologies should advance the state-of-the art systems and/or components by focusing on techniques that either reduce or replace the use of fossil fuels in a cost effective manner.

Clean energy source technologies and methodologies including but are not limited to those based on solar, wind, hydro, biomass, geothermal, and atmospheric constituents such as hydrogen, carbon dioxide are solicited. Innovative space based solar power generation and effective transport to benefit terrestrial and space applications are desired. Proposals related to efficient operation over wide temperature ranges under harsh environmental conditions are also sought. Energy sources that enable future missions which otherwise would be difficult with conventional resources are desired.

TOPIC: T9 Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing

Achieving NASA's exploration goals will hinge on continued development of improved capabilities in propulsion system design and manufacturing techniques. NASA is interested in innovative design and manufacturing technologies that enable sustained and affordable human and robotic exploration of the solar system. The development of and operation of these propulsion systems will benefit greatly from improvements in design and analysis tools and from improvements in manufacturing capabilities.

T9.01 Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing
Lead Center: MSFC

This subtopic solicits partnerships between academic institutions and small businesses in the following specific areas of interest: Innovative design and analysis techniques, manufacturing, materials, and processes relevant to propulsion systems launch vehicles, crew exploration vehicles, orbiters, and landers. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components.

- Polymer Matrix Composites (PMCs) Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing; damage-tolerant, repairable, and self-healing technologies; advanced materials and manufacturing processes for both cryogenic and high-temperature applications.
- Ceramic Matrix Composite (CMCs) and Ablatives CMC materials and processes are projected to significantly increase safety and reduce costs simultaneously while decreasing system weight for space transportation propulsion.

- Solid-state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites, and high strength and high temperature or functionally graded materials.
- New advanced super alloys that resist hydrogen embrittlement and are compatible with high-pressure oxygen; innovative thermal-spray or cold-spray coating processes that substantially improve material properties, combine dissimilar materials, application of dense deposits of refractory metals and metal carbides, and coating on nonmetallic composite materials.
- Advanced NDE Methods Portable and lightweight NDE tools provide characterization of polymer, ceramic and metal-matrix composites, areas include, but are not limited to, microwaves, millimeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.
- Improvement in techniques for predicting the self-generated dynamics of space propulsion system when operated at off-design conditions.
- Improvement in techniques for predicting the acoustic field produced by the operation of a space propulsion system in near ground operation.
- Predictive capability of the performance and internal environment for systems, solid or liquid propellants, undergoing multi-phase combustion. Of special interest are systems utilizing nano-energetics solid fuels.
- Predictive capability improvements for the coupled fluid-structural problem with focus on accurate prediction of heat-transfer that occurs in the chamber of a nuclear thermal rocket.
- Design and analysis tools that accurately model small valves and turbopumps.
- Development of databases and instrumentation advances required for validation of previously mentioned predictive capabilities.

TOPIC: T10 Rocket Propulsion/Energy Conservation

NASA's Stennis Space Center (SSC) seeks advanced technologies to support its testing rocket engines including innovative approaches for measurement of propellant tank volume, new tools for prediction operational life of critical components, and health monitoring and management of test facilities infrastructure. Technologies are also sought to improve the Center's energy conservation and Sustainability

T10.01 Test Area Technologies
Lead Center: SSC

Innovative Approaches to Tank Volume Measurement
Develop new innovative non-contact methods to measure liquid propellant tank volume and tank fluid level with improved accuracy, repeatability and minimal tank entries for maintenance and ca-libration. Currently, differential pressure measurements or multiple float switched are typically used. Differential pressure measurements do not provide sufficient accuracy for low density flu-ids such as liquid hydrogen, and multiple float switch gages only offer readings at discrete tank liquid levels, and are subject to mechanical failure and expensive maintenance. Accuracies of 0.5% or better are desired. Need for improved technology is mid-term, and highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

Robust Components Technologies
Develop new innovative tools to predict operational capability and life for key facility components (e.g., valves, valve seals and seats, actuators, flowmeters, tanks, etc.) for ultra high (>8000 psi) pressure, high flow rates, and cryogenic environments. Tools would be used for the design, procurement, and modification of facility components and ideally also incorporated in system models for simulation of test stand operation. Current TRL is 3 for modeling valves and flowmeters. Need for improved technologies are mid-term, and are highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 5.

Infrastructure Health Monitoring
Infrastructure health monitoring and management for test facilities and for widely distributed sup-port systems (WDSS) such as gas distribution and cooling water. Capabilities being sought for WDSS include remote monitoring of vacuum lines, gas leaks, and fire; using wireless technologies in order to eliminate running miles of power and data wires. Proposed innovative systems must lead to improved safety and reduced test costs by use of technologies for automated anomaly detection; diagnosis; determination of faults and their effects; prediction of future anomalies; capture and analysis of usage information; tools for rapid and effective analysis of data, information, and knowledge; and efficient user interfaces to enable integrated awareness of the system condition by users. Effectiveness of technologies in addressing the stated needed capabilities: robustness of wireless monitoring systems, effectiveness of anomaly detection (percent of anomalies captured, percent of false alarms), improvements in safety, and reduction in costs. Need for improved technologies is mid-term, and highly desirable. Expected TRL at end of Phase I is 3, and at the end of Phase II is 6.

Cost-Saving Vacuum System Technologies
The objective here is to prototype and field test vacuum monitoring devices that minimize "touch maintenance" thereby reducing costs and preclude cabling by working wireless. Current state of the art for vacuum jacketed liquid hydrogen (LH) lines is walking the lines and manually performing the required periodic checks and sensor maintenance. The new altitude test stand will produce high vacuum inside a large rocket engine test chamber with ambient pressure outside. Some locations will be difficult or impossible to reach. Due to the unique and harsh environmental nature of this test facility, new technologies and vacuum measurement techniques are needed to monitor this environment. Performance metrics include high accuracy and sensitivity in the 0.1 to 1 psia, insensitivity to high levels of noise and vibration, and ruggedness. Need for improved technologies is short term, and highly desirable. Expected TRL at end of Phase I is 2, and at the end of Phase II is 6.

T10.02 Energy Conservation and Sustainability
Lead Center: SSC

John C Stennis Space Center (SSC) is a large rocket propulsion test facility located in southern Mississippi close to the Louisiana state line. Due to the size of the test facilities, energy consumption is very large. In an effort to conserve on energy, there is an interest in pursuing innovation in the following areas:

Innovative Geothermal Technology
SSC is interested in innovative geothermal technology in an effort to reduce energy consumption, reducing the Center's carbon footprint. The feasibility and application of geothermal technology has not been investigated for use at SSC. SSC is looking for geothermal technology that is cost effective to implement and maintain. There are potential commercial and residential applications. The feasibility of geothermal technology will require an assessment of the local topography, underground soil composition, location of water "sinks", and determination of the area's ground "constant" temperature. Concepts will be evaluated based on their potential efficiency, ease of implementation and maintenance, and flexibility of applications (including, but not limited to, HVAC, preheating hot water heaters, and other means of extracting energy), as well as, applicability to the Center's mission. Proposals will also be evaluated based on the maturity level to which the technology will be developed and innovative techniques.

Innovative Lighting Technology
Stennis Space Center is interested in developing innovative technologies, systems, or methodologies that will reduce the energy consumption and heat generation from facility lighting while maintaining the desired level of illumination for safety and effective work environments. SSC is interested in innovative lighting technologies for the test area and parking lots. These lighting technologies will need to reduce energy consumption while maintaining a comfortable and safe working environment. SSC is particularly interested in replacing costly lighting in the test area (test stands, hydrogen/oxygen environments, hazardous and potentially corrosive environments). The lighting should be in compliance with IESNA RP 7-01, Practice for Industrial Lighting. Proposals will be evaluated based on the

maturity level to which the technology will be developed and innovative techniques that will provide a reasonable life expectancy. Proposals will also be evaluated on implementation strategy and ease of maintenance.

Innovative Solar Technology
Reduction in energy consumption and subsequent energy cost is a high priority at SSC. SSC is interested in developing new technologies for the efficient and effective use of photovoltaic/solar cell to reduce energy costs. Major issues in the development and use of solar panel include efficient system design and installation as well as effective maintenance. Innovative approaches and tools to facility the design of efficient solar cell systems, effective application of solar cells systems for building rooftops or a separate field area of solar cells are desired as well as innovative approaches to the monitor the health of the system and maintenance methods to insure the most effective and efficient operations of the system in an environment with high humidity, extensive rain showers, high pollen counts, rapid mold and fungal growth, etc.

Technologies for Propellant Conservation
Objective is to minimize usage of costly gases (helium and hydrogen) through devices that can recover/recycle efflux from cryogenic test facilities (currently no recovery is done). This could include technologies such as real time gas sampling/contamination monitoring system for propellant and purge systems that could also help minimize use of non renewable resources such as Helium, or Helium reclamation carts for recapture of inert/purges.

Appendices

Appendix A: Example Format for Briefing Chart

NASA SBIR/STTR Technologies

Title of Proposal
Firm
City, ST
Proposal No.: _ _ . _ _ - _ _ _ _

Identification and Significance of

Estimated TRL (1 – 9) at beginning and end of contract:

<Place graphic related to innovation here>

Technical Objectives and Work Plan

NASA and Non-NASA Applications

Firm Contacts

NON-PROPRIETARY DATA

Appendix B: Technology Readiness Level (TRL) Descriptions

Technology Readiness Level - (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 or application formulated	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture. Underlying Algorithms are clarified and documented.	Documented description of the application/concept that addresses feasibility and benefit
3	Analytical and/or experimental critical function or characteristic proof-of-concept	Analytical studies place the technology in an appropriate context and laboratory demonstrations, modeling and simulation validate analytical prediction.	Development of limited functionality to validate critical properties and predictions using non-integrated software components	Documented analytical/experimental results validating predicitions of key parameters
4	Component or breadboard validation in laboratory	A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments and associated performance predicitions 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 Evironments defined and performance in this environment predicted.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of relevant environment.
5	Component or breadboard validation in a relevant environment	A mid-level fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	End to End Software elements implemented and interfaced with existing systems conforming to target environment, including the target o software environment. End to End Software System, Tested in Relevant Environment, Meets Predicted Performance. Operational Environment Performance Predicted.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements
6	System/subsystem 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 software partially integrated with existing hardware/software sytems and demonstrated on full-scale realistic problems.	Documented test performance demonstrating agreement with analytical predictions
7	System prototype demonstration in space	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 is fully integrated with operational harware/software sytems demonstrating operational feasibility.	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).	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).	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.	The final product is successfully operated in an actual mission.	Documented mission operational results

Appendix C: NASA SBIR/STTR Technology Taxonomy

Aeronautics/Atmospheric Vehicles
Aerodynamics
Air Transportation & Safety
Airship/Lighter-than-Air Craft
Avionics (see also Control and Monitoring)
Analysis
Analytical Instruments (Solid, Liquid, Gas, Plasma, Energy; see also Sensors)
Analytical Methods
Astronautics
Aerobraking/Aerocapture
Entry, Descent, & Landing (see also Planetary Navigation, Tracking, & Telemetry)
Navigation & Guidance
Relative Navigation (Interception, Docking, Formation Flying; see also Control & Monitoring; Planetary Navigation, Tracking, & Telemetry)
Space Transportation & Safety
Spacecraft Design, Construction, Testing, & Performance (see also Engineering; Testing & Evaluation)
Spacecraft Instrumentation & Astrionics (see also Communications; Control & Monitoring; Information Systems)
Tools/EVA Tools
Autonomous Systems
Autonomous Control (see also Control & Monitoring)
Intelligence
Man-Machine Interaction
Perception/Vision
Recovery (see also Vehicle Health Management)
Robotics (see also Control & Monitoring; Sensors)
Biological Health/Life Support
Biomass Growth
Essential Life Resources (Oxygen, Water, Nutrients)
Fire Protection
Food (Preservation, Packaging, Preparation)
Health Monitoring & Sensing (see also Sensors)
Isolation/Protection/Radiation Shielding (see also Mechanical Systems)
Medical
Physiological/Psychological Countermeasures
Protective Clothing/Space Suits/Breathing Apparatus
Remediation/Purification
Waste Storage/Treatment
Communications, Networking & Signal Transport
Ad-Hoc Networks (see also Sensors)

Amplifiers/Repeaters/Translators
Antennas
Architecture/Framework/Protocols
Cables/Fittings
Coding & Compression
Multiplexers/Demultiplexers
Network Integration
Power Combiners/Splitters
Routers, Switches
Transmitters/Receivers
Waveguides/Optical Fiber (see also Optics)
Control & Monitoring
Algorithms/Control Software & Systems (see also Autonomous Systems)
Attitude Determination & Control
Command & Control
Condition Monitoring (see also Sensors)
Process Monitoring & Control
Sequencing & Scheduling
Telemetry/Tracking (Cooperative/Noncooperative; see also Planetary Navigation, Tracking, & Telemetry)
Teleoperation
Education & Training
Mission Training
Outreach
Training Concepts & Architectures
Electronics
Circuits (including ICs; for specific applications, see e.g., Communications, Networking & Signal Transport; Control & Monitoring, Sensors)
Manufacturing Methods
Materials (Insulator, Semiconductor, Substrate)
Superconductance/Magnetics
Energy
Conversion
Distribution/Management
Generation
Sources (Renewable, Nonrenewable)
Storage
Engineering
Characterization
Models & Simulations (see also Testing & Evaluation)
Project Management
Prototyping

Quality/Reliability
Software Tools (Analysis, Design)
Support
Imaging
3D Imaging
Display
Image Analysis
Image Capture (Stills/Motion)
Image Processing
Radiography
Thermal Imaging (see also Testing & Evaluation)
Information Systems
Computer System Architectures
Data Acquisition (see also Sensors)
Data Fusion
Data Input/Output Devices (Displays, Storage)
Data Modeling (see also Testing & Evaluation)
Data Processing
Knowledge Management
Logistics
Inventory Management/Warehousing
Material Handing & Packaging
Transport/Traffic Control
Manufacturing
Crop Production (see also Biological Health/Life Support)
In Situ Manufacturing
Microfabrication (and smaller; see also Electronics; Mechanical Systems; Photonics)
Processing Methods
Resource Extraction
Materials & Compositions
Aerogels
Ceramics
Coatings/Surface Treatments
Composites
Fluids
Joining (Adhesion, Welding)
Metallics
Minerals
Nanomaterials
Nonspecified

Organics/Biomaterials/Hybrids
Polymers
Smart/Multifunctional Materials
Textiles
Mechanical Systems
Actuators & Motors
Deployment
Exciters/Igniters
Fasteners/Decouplers
Isolation/Protection/Shielding (Acoustic, Ballistic, Dust, Radiation, Thermal)
Machines/Mechanical Subsystems
Microelectromechanical Systems (MEMS) and smaller
Pressure & Vacuum Systems
Structures
Tribology
Vehicles (see also Autonomous Systems)
Microgravity
Biophysical Utilization
Optics
Adaptive Optics
Fiber (see also Communications, Networking & Signal Transport; Photonics)
Filtering
Gratings
Lenses
Mirrors
Telescope Arrays
Photonics
Detectors (see also Sensors)
Emitters
Lasers (Communication)
Lasers (Cutting & Welding)
Lasers (Guidance & Tracking)
Lasers (Ignition)
Lasers (Ladar/Lidar)
Lasers (Machining/Materials Processing)
Lasers (Measuring/Sensing)
Lasers (Medical Imaging)
Lasers (Surgical)
Lasers (Weapons)
Materials & Structures (including Optoelectronics)

Planetary Navigation, Tracking, & Telemetry
Entry, Descent, & Landing (see also Astronautics)
GPS/Radiometric (see also Sensors)
Inertial (see also Sensors)
Optical
Ranging/Tracking
Telemetry (see also Control & Monitoring)
Propulsion
Ablative Propulsion
Atmospheric Propulsion
Extravehicular Activity (EVA) Propulsion
Fuels/Propellants
Launch Engine/Booster
Maneuvering/Stationkeeping/Attitude Control Devices
Photon Sails (Solar; Laser)
Spacecraft Main Engine
Surface Propulsion
Tethers
Sensors/Transducers
Acoustic/Vibration
Biological (see also Biological Health/Life Support)
Biological Signature (i.e., Signs Of Life)
Chemical/Environmental (see also Biological Health/Life Support)
Contact/Mechanical
Electromagnetic
Inertial
Interferometric (see also Analysis)
Ionizing Radiation
Optical/Photonic (see also Photonics)
Positioning (Attitude Determination, Location X-Y-Z)
Pressure/Vacuum
Radiometric
Sensor Nodes & Webs (see also Communications, Networking & Signal Transport)
Thermal
Software Development
Development Environments
Operating Systems
Programming Languages
Verification/Validation Tools
Spectral Measurement, Imaging & Analysis (including Telescopes)

Infrared
Long
Microwave
Multispectral/Hyperspectral
Non-Electromagnetic
Radio
Terahertz (Sub-millimeter)
Ultraviolet
Visible
X-rays/Gamma Rays
Testing & Evaluation
Destructive Testing
Hardware-in-the-Loop Testing
Lifetime Testing
Nondestructive Evaluation (NDE; NDT)
Simulation & Modeling
Thermal Management & Control
Active Systems
Cryogenic/Fluid Systems
Heat Exchange
Passive Systems
Vehicle Health Management
Diagnostics/Prognostics
Recovery (see also Autonomous Systems)

Research Topics Index

AERONAUTICS RESEARCH

EXPLORATION SYSTEMS

SCIENCE

SPACE OPERATIONS

STTR