SBIR/STTR 2008-1

National Aeronautics and Space Administration

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

Program Solicitations

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

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2008 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 2008 Solicitation period for Phase 1 proposals begins July 7, 2008, and ends September 4, 2008.

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 250 SBIR and 30 STTR Phase 1 proposals will be selected for negotiation of fixed-price contracts in November 2008. Historically, the ratio of Phase 1 proposals to awards is approximately 6:1 for SBIR and STTR, and approximately 45% of the selected Phase 1 contracts are selected for Phase 2 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: This Solicitation is issued pursuant to the authority contained in P.L. 106-554 in accordance with policy directives issued by the Small Business Administration. The current law authorizes the program through September 30, 2008.

STTR: This Solicitation is issued pursuant to the authority contained in P.L. 107-50 in accordance with policy directives issued by the Small Business Administration. The current law authorizes the program through September 30, 2009.

Executive Order: This Solicitation complies with Executive Order 13329 (issued February 24, 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.

1.3 Program Management

The Innovative Partnerships Program Office under the Office of the NASA Associate Administrator provides overall policy direction for implementation of the NASA SBIR/STTR programs. The NASA SBIR/STTR Program Management Office, which operates the programs in conjunction with NASA Mission Directorates and Centers, is hosted at the NASA Ames Research Center. NASA Shared Services Center 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.aerospace.nasa.gov/
Exploration Systems	http://www.exploration.nasa.gov/
Science	http://science.hq.nasa.gov/
Space Operations	http://www.hq.nasa.gov/osf/

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 1

The purpose of Phase 1 is to determine the scientific, technical, and commercial merit and feasibility of the proposed innovation, and the quality of the SBC's performance. Phase 1 work and results should provide a sound basis for the continued development, demonstration and delivery of the proposed innovation in Phase 2 and follow-on efforts. Successful completion of Phase 1 objectives is a prerequisite to consideration for a Phase 2 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 1 results.

Maximum value and period of performance for Phase 1 contracts:

Phase 1 Contracts	**SBIR**	**STTR**
Maximum Contract Value	$ 100,000	$ 100,000
Maximum Period of Performance	6 months	12 months

1.4.2 Phase 2

The purpose of Phase 2 is the development, demonstration and delivery of the innovation. Only SBCs awarded Phase 1 contracts are eligible for Phase 2 funding agreements. Phase 2 projects are chosen as a result of competitive evaluations based on selection criteria provided in Section 4.2.

The maximum value for SBIR/STTR Phase 2 contracts is $600,000 with a maximum period of performance of 24 months.

Phase 2 Enhancement: On active Phase 2 awards, NASA may entertain negotiations with Phase 2 awardees to create an option for "Phase 2 Enhancement" (Phase 2-E) that will encourage transition of SBIR/STTR projects into NASA programs and projects. Selected contractors may not submit an application package for the Phase 2-E any earlier than the beginning of the 15th month of the Phase 2 contract and no later than the end of the 22nd month of the contract.

The objective of the Phase 2-E Option is an incentive to Phase 3 awards through providing cost share extension of the R&D efforts to the current Phase 2 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 2 project, moving it into Phase 3. 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 2 project for up to 4 months to perform additional research. The total cumulative award for the Phase 2 contract plus the Phase 2-E match will not exceed $750,000.00 of SBIR/STTR funding. The non-SBIR or non-STTR contribution is not limited since it is regulated under the guidelines for Phase 3 award. Additional details will be provided as part of the Phase 2 negotiations process and the Phase 2 contract.

1.4.3 Phase 3

NASA may award Phase 3 contracts for products or services with non-SBIR/STTR funds. The competition for SBIR/STTR Phase 1 and Phase 2 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 3 project is not required to conduct another competition in order to satisfy those statutory provisions. Phase 3 work may be for products, production, services, R/R&D, or any combination thereof. A Federal agency may enter into a Phase 3 agreement at any time with a Phase 1 or Phase 2 awardee.

There is no limit on the number, duration, type, or dollar value of Phase 3 awards made to a business concern. There is no limit on the time that may elapse between a Phase 1 or Phase 2 and a Phase 3 award. The small business size limits for Phase 1 and Phase 2 awards do not apply to Phase 3 awards.

1.5 Eligibility Requirements

1.5.1 Small Business Concern

Only firms qualifying as SBCs, as defined in Section 2.16, are eligible to participate in these programs. Socially and economically disadvantaged and women-owned SBCs are particularly encouraged to propose.

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

1.5.2 Place of Performance

For both Phase 1 and Phase 2, the R/R&D must be performed in the United States (Section 2.21). 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. U.S. Citizenship is not a requirement for selection. 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 2008 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 1 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 at least 40 percent of the work (before any cost sharing or fee/profit proposed by the firm) is performed by the SBC and at least 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 HUBZone-Owned SBC

"HUBZone" is an area that is located in one or more of the following:

- A qualified census tract (as defined in section 42(d)(5)(C)(i)(1) of the Internal Revenue Code of 1986);
- A qualified "non-metropolitan county" that is: not located in a metropolitan statistical area (as defined in section 143(k)(2)(B) of the Internal Revenue Code of 1986), and
    - in which the median household income is less than 80 percent of the non-metropolitan State median household income, or
    - that based on the most recent data available from the Secretary of Labor, has an unemployment rate that is not less than 140 percent of the statewide average unemployment rate for the State in which the county is located;
- Lands within the external boundaries of an Indian reservation.

To participate in the HUBZone Empowerment Contracting Program, a concern must be determined to be a "qualified HUBZone small business concern." A firm can be found to be a qualified HUBZone concern, if:

- It is small,
- It is located in a "historically underutilized business zone" (HUBZone),
- It is owned and controlled by one or more U.S. Citizens, and
- At least 35% of its employees reside in a HUBZone.

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 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.

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

Any activity that is (1) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied, (2) a systematic study directed specifically toward applying new knowledge to meet a recognized need, or (3) a systematic application of knowledge toward the production of useful materials, devices, systems, or methods, including the 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).

2.14 SBIR/STTR Technical Data

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

2.15 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.

2.16 Small Business Concern (SBC)

An SBC is one that, at the time of award of Phase 1 and Phase 2 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.

2.17 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).

2.18 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.

2.19 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.

2.20 Technology Readiness Level (TRLs)

Technology Readiness Level (TRLs) are 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.

2.21 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.

2.22 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.

2.23 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 may be submitted only under that one subtopic within each program. An offeror may 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 1 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
In order to help the contractor and NASA make better use of the SBIR/STTR products, the Phase 1 and 2 contractor (with help from designated NASA personnel) will be required to update, as a deliverable, their Technology Infusion Form. The essence of the form is to identify one or more specific NASA projects, project points of contacts, and project problems. The NASA project points of contacts will also have electronic access to these subsequent deliverables for comment.

All Phase 1 contracts shall require the delivery of interim and final reports that present (1) the work and results accomplished, (2) the scientific, technical and commercial merit and feasibility of the proposed innovation and Phase 1 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 1 results into products and services for NASA mission programs and other potential customers. Phase 1 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 2 contracts require the deliverable of interim and final reports. The delivery of a prototype unit, software package, or a complete product or service, for NASA testing and utilization is highly desirable and, if proposed, must be described and listed as a deliverable in the proposal. The Phase 2 reports shall present (1) the work and results accomplished, (2) the scientific, technical and commercial merit and feasibility of the proposed innovation and Phase 2 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 2 results into follow-on investment, development, testing and utilization for NASA mission programs and other potential customers.

Report deliverables for Phase 1 and Phase 2 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 1 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 1 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 should be 1.0 inch (2.5 cm). **Proposals exceeding the 25-page limitation will be rejected 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,
(2) Proposal Summary (Form B),
(3) Budget Summary (Form C),
(4) 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 – see box below**), including all graphics, with a table of contents,
(5) Briefing Chart (Not included in the 25-page limit and must not contain proprietary data).

STTR: Each STTR proposal must also contain a Cooperative R/R&D Agreement between the SBC and RI following the required items listed above. The agreement is included as part of the 25-page limit.

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.

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.

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 1 and Phase 2 including an assessment of technology readiness

levels (TRLs) at the end of the Phase 1 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 1 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.

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. NASA will not fund the purchase of equipment, instrumentation, or facilities under SBIR/STTR contracts as a direct cost (Section 5.15).

Phase 1 Travel
The NASA SBIR/STTR program does not require or expect to incur travel expenses during the performance of a Phase 1 contract. For this reason, travel expenses should not be included in the proposed budget for a Phase 1 proposal. If the Technical Monitor and Contracting Officer determine that travel is necessary, the budget can be altered during contract negotiations to allow for this.

Phase 1 Delivery Schedule
The standard reporting requirements for Phase 1 are an updated Technology Infusion Form, an interim 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.

Profit
A profit or fee may be included in the proposed budget as noted in Section 5.10.

Cost Sharing
See Section 5.9.

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 1 Table of Contents

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

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 1 R/R&D effort including the technical questions that must be answered to determine the feasibility of the proposed innovation.

Part 4: Work Plan

Include a detailed description of the Phase 1 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. 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.

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 1 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 1 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 2008 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 1 and Phase 2). Discuss the significance of the Phase 1 effort in providing a foundation for the Phase 2 R/R&D effort and for follow-on development, application and commercialization efforts (Phase 3).

Part 8: Company Information and Facilities
Provide adequate information to allow the evaluators to assess the ability of the offeror to carry out the proposed Phase 1 and projected Phase 2 and Phase 3 activities. The offeror should describe the relevant facilities and equipment, their availability, and those to be acquired, to support the proposed activities. *NASA will not fund the purchase of equipment, instrumentation, or facilities under Phase 1 contracts as a direct cost.* Special tooling may be allowed. (Section 5.15)

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 prohibit 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 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. Documentation of subcontract costs must be made available during negotiations to substantiate the budget estimate.

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 one-third of the research and/or analytical work (as determined by the total cost of the proposed effort, before any cost sharing or fee/profit proposed by the firm, which corresponds to Item 6 in the Budget Summary, Total Costs).	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 effort, before any cost sharing or fee/profit proposed by the firm, which corresponds to Item 6 in the Budget Summary, Total Costs).

Part 10: Potential Post Applications (Commercialization)
The Phase 1 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 1 proposals to NASA. However, it is unlawful to receive funding for essentially equivalent work already funded under any Government program. The Office of Inspector General has full access to all proposals submitted to NASA. 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 (not to be confused with 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 2 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 2. 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 3 Awards resulting from NASA SBIR/STTR Awards
If the SBC has received any Phase 3 awards resulting from work on any NASA SBIR or STTR awards, provide the 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 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. An example chart is provided in Section 8, Appendix A.

3.3 Phase 2 Proposal Requirements

3.3.1 General Requirements
The Phase 1 contract will serve as a request for proposal (RFP) for the Phase 2 follow-on project. Phase 2 proposals are more comprehensive than those required for Phase 1. Submission of a Phase 2 proposal is in accordance with Phase 1 contract requirements and is voluntary. NASA assumes no responsibility for any proposal preparation expenses.

A competitive Phase 2 proposal will clearly and concisely (1) describe the proposed innovation relative to the state of the art and the market, (2) address Phase 1 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 1 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 2 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 should be 1.0 inch (2.5 cm). **Proposals exceeding the 50-page limitation may be rejected 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,
(2) Proposal Summary (Form B),
(3) Budget Summary (Form C),
(4) Technical Content (11 Parts in order as specified in Section 3.3.4), including all graphics, and starting with a table of contents,
(5) Briefing Chart (Not included in the 50-page limit and must not contain proprietary data).

STTR: Each STTR proposal must also contain a Cooperative R/R&D Agreement between the SBC and RI following the required items listed above. The agreement is included as part of the 50-page limit.

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.

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.

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 1 and Phase 2 including an assessment of technology readiness levels (TRLs) at the end of the Phase 2 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.

3.3.3.3. Budget Summary (Form C)

The offeror shall complete the Budget Summary, following the instructions provided with the form (Section 8), not to exceed $600,000. 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.

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. NASA will not fund the purchase of equipment, instrumentation, or facilities under SBIR/STTR contracts as a direct cost (Section 5.15).

Phase 2 Travel

Travel during a Phase 2 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 accounting of all proposed travel expenses. All travel and related expenses are subject to negotiation and approval by the Contracting Officer and COTR.

Phase 2 Deliverables

All proposed deliverables (other than interim and final reports) must be listed. This may include a prototype unit, software package, or a complete product or service, for NASA testing and utilization.

Profit

A profit or fee may be included in the proposed budget as noted in Section 5.10.

Cost Sharing

See Section 5.9.

Requirement for Approved Accounting System

Offerors should note that in order to receive progress payments under a Phase 2 contract, an offeror must have in place, prior to award, 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. The lack of an adequate accounting system may preclude you from receiving a Phase 2 contract or may cause extended delays in award. 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 2 Table of Contents

Part 1: Table of Contents……………………………………………………………………………Page #
Part 2: Identification and Significance of the Innovation and Results of the Phase 1 Proposal
Part 3: Technical Objectives

Part 4: Work Plan
Part 5: Related R/R&D
Part 6: Key Personnel
Part 7: Phase 3 Efforts, Commercialization and Business Planning
Part 8: Company Information and Facilities
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 1 Proposal
Drawing upon Phase 1 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 2 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 2, and discuss their qualifications in terms of education, work experience, and accomplishments relevant to the project.

Part 7: Phase 3 Efforts, Commercialization and Business Planning
Present a plan for commercialization (Phase 3) 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 Information and Facilities

Describe the capability of the offeror to carry out Phase 2 and Phase 3 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.

This section shall also provide adequate information to allow evaluators to assess the ability of the SBC to carry out the proposed Phase 2 activities. The offeror should describe the relevant facilities and equipment currently available, and those to be purchased, to support the proposed activities. NASA will not fund the acquisition of equipment, instrumentation, or facilities under Phase 2 contracts as a direct cost. Special tooling may be allowed. (Section 5.15)

Note: Government-wide SBIR and STTR policies prohibit 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. Documentation of subcontract costs must be made available during negotiations to substantiate the budget estimate.

Subcontractors' and consultants' work must be performed in the United States. The following restrictions apply to the use of subcontracts/consultants:

SBIR Phase 2 Proposal	STTR Phase 2 Proposal
A minimum of one-half of the work (as determined by the total cost of the proposed effort, before any cost sharing or fee/profit proposed by the firm, which corresponds to Item 6 in the Budget Summary, Total Costs) must be performed by the proposing SBC.	A minimum of 40 percent of the work (as determined by the total cost of the proposed effort, before any cost sharing or fee/profit proposed by the firm, which corresponds to Item 6 in the Budget Summary, Total Costs) must be performed by the proposing SBC and 30 percent by the RI.

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 1 Proposal Requirements, Part 11).

3.3.5 Capital Commitments Addendum Supporting Phase 2 and Phase 3
Describe and document capital commitments from non-SBIR/STTR sources or from internal SBC funds for pursuit of Phase 2 and Phase 3. Offerors for Phase 2 contracts are strongly urged to obtain non-SBIR/STTR funding support commitments for follow-on Phase 3 activities and additional support of Phase 2 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 2 and/or Phase 3 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 3 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 2 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 2 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 2 proposal. This addendum will not be counted against the 50-page limitation.

3.3.6 Phase 3 Awards resulting from NASA SBIR/STTR Awards
If the SBC has received any Phase 3 awards resulting from work on any NASA SBIR or STTR awards, provide the 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 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. An example chart is provided in Section 8, Appendix A.

3.4 SBA Data Collection Requirement

Each SBC applying for a Phase 2 award is required to update the appropriate information in the Tech-Net database for any of its prior Phase 2 awards. In addition, upon completion of Phase 2, the SBC is required to update the appropriate information in the Tech-Net database and is requested to update the information annually thereafter for a minimum period of five years. For complete information on what to enter, go to http://technet.sba.gov.

4. Method of Selection and Evaluation Criteria

All Phase 1 and 2 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 1 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 should provide all information needed for complete evaluation. Evaluators will not seek additional information. Evaluations will be performed by NASA scientists and engineers. 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 1 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 5.15).

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 1 objectives. The methods planned to achieve each objective or task should be discussed in detail. The proposed path beyond Phase 1 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 3 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 1 proposals, Technical Merit carries more weight 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.

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 2 Proposals

4.2.1 Evaluation Process
The Phase 2 evaluation process is similar to the Phase 1 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
The evaluation of Phase 2 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 1 objectives were met, the feasibility of the innovation, and whether the Phase 1 results indicate a Phase 2 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 5.15).

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 2 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 3 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 1 proposals. Where technical evaluations are essentially equal in potential, cost to the Government may be considered in determining successful offerors. For Phase 2 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.

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 1 and Phase 2 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 and perhaps 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 1 Debriefings

For Phase 1 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 2 Debriefings

To request debriefings on Phase 2 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 1 and Phase 2 awards are subject to availability of funds. NASA has no obligation to make any specific number of Phase 1 or Phase 2 awards based on this Solicitation, and may elect to make several or no awards in any specific technical topic or subtopic.

SBIR	STTR
➢ NASA plans to announce the selection of approximately 250 proposals resulting from this Solicitation, for negotiation of Phase 1 contracts with values not exceeding $100,000. Following contract negotiations and awards, Phase 1 contractors will have up to 6 months to carry out their programs, prepare their final reports, and submit Phase 2 proposals. ➢ NASA anticipates that approximately 45 percent of the successfully completed Phase 1 projects from the SBIR 2008 Solicitation will be selected for Phase 2. Phase 2 agreements will be fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.	➢ NASA plans to announce the selection of approximately 30 proposals resulting from this Solicitation, for negotiation of Phase 1 contracts with values not exceeding $100,000. Following contract negotiations and awards, Phase 1 contractors will have up to 12 months to carry out their programs, prepare their final reports, and submit Phase 2 proposals. ➢ NASA anticipates that approximately 45 percent of the successfully completed Phase 1 projects from the STTR 2008 Solicitation will be selected for Phase 2. Phase 2 agreements will be fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.

5.1.2 Contracting

To simplify contract award and reduce processing time, all contractors selected for Phase 1 and Phase 2 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 1 Reporting

An updated Technology Infusion Form plus interim 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 1 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 1 contract, identifying the purpose of the R/R&D effort and describing the findings and results, including the degree to which the Phase 1 objectives were achieved, and whether the results justify Phase 2 continuation. The potential applications of the project results in Phase 3 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.

5.3 Payment Schedule for Phase 1

All NASA SBIR and STTR contracts are firm-fixed-price contracts based on performance payments.

The exact payment terms for Phase 1 will be included in the contract, but payments are normally authorized as follows: one-third at the time of award, one-third at project mid-point after award, 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.

5.4 Release of Proposal Information

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

5.5 Access to Proprietary Data by Non-NASA Personnel

5.5.1 Non-NASA Reviewers

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

5.5.2 Non-NASA Access to Confidential Business Information

In the conduct of proposal processing and potential contract administration the Agency may find it necessary to provide 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.

5.6 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 1 proposals will be retained for a minimum of one year after the Phase 1 selections have been made. Successful proposals will be retained in accordance with contract file regulations.

5.7 Proprietary Information in the Proposal Submission

Information contained in unsuccessful proposals will remain the property of the applicant. The Government may, 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.

5.8 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 1 or Phase 2 contract. NASA will not entertain requests to modify or eliminate this clause. The following is a brief description of FAR 52.227-20.

5.8.1 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.

5.8.2 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.

5.8.3 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.

5.8.4 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.

5.8.5 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 the Patent Rights Clause (FAR 52.227-11), 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.

Costs associated with patent applications are not allowable.

5.8.6 Invention Reporting
NASA SBIR and STTR contracts will include the invention reporting requirements in the Patent Rights Clause at FAR 52.227-11, SBIR/STTR contractors must disclose all subject inventions to NASA within two (2) months of the inventor's report to the awardee, 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.

The notification to NASA of an invention will be in provided in the form of a "New Technology Report". Regardless of whether a SBIR or STTR contractor has an invention, all SBIR and STTR contractors will be required to submit a "New Technology Report" (NTR) as one of the final deliverables under the contract. The NTR will be filed using the NASA eNTRe Website (http://invention.nasa.gov) and a copy of the report must be uploaded into the EHB. The NTR will identify any new technology discovered during the contract or indicate that no new technology resulted from the project.

5.9 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.

5.10 Profit or Fee

Both Phase 1 and Phase 2 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.

5.11 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 2.16. 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 1 proposal.

5.12 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.

5.13 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 1 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 1 contracts, nor does it contain specific wording of these clauses. Copies of complete provisions will be made available prior to contract negotiations.

5.13.1 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.

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

5.13.3 Examination of Records
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.

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

5.13.5 Termination for Convenience
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.

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

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

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

5.13.9 Affirmative Action for 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.

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

5.13.11 Officials Not to Benefit
No member of or delegate to Congress shall benefit from an SBIR or STTR contract.

5.13.12 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.

5.13.13 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.

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

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

5.13.16 Export Control Laws
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.

5.14 Additional Information

5.14.1 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.

5.14.2 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.

5.14.3 Required Registrations and Submissions

5.14.3.1 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 strongly encouraged to register prior to submitting a proposal.**

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

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

5.14.3.2 ORCA Registration

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.

5.14.3.3 VETS 100 Reporting

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 https://vets100.vets.dol.gov/. NASA will not enter into any contract wherein the firm is not compliant with the requirements stipulated herein.

5.14.4 Software Development Standards

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

5.15 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. An SBC will furnish its own facilities to perform the proposed work as an indirect cost to the contract. Special tooling required for a project may be allowed as a direct cost.

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.

5.16 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.

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 1 and 3.3.4 for Phase 2.

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 3.2.7 and 3.3.6).

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. Proposals can be uploaded multiple times with each new upload replacing the previous version. 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 but only the final uploaded and electronically endorsed version will be considered for review.

6.3 Deadline for Phase 1 Proposal Receipt

All Phase 1 proposal submissions must be received no later than 5:00 p.m. EDT on Thursday, September 4, 2008, 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 2008 Phase 1 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 24, 2008, 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 Manager at the address listed below:

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

The copy of any protest shall be received by the NASA SBIR/STTR Program Manager within one 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 Strategic Plan: http://www.nasa.gov/about/budget/index.html
NASA Organizational Structure: http://www.nasa.gov/centers/hq/organization/index.html
NASA Innovative Partnerships Program: 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: 703-605-6585
URL: http://www.ntis.gov

8. Submission Forms and Certifications

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Form A – SBIR Cover Sheet

Subtopic Number

1. PROPOSAL NUMBER: **08 - _ _ . _ _ _ _ _ _**
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
As defined in Section 3.2.4 Part 11 of the Solicitation indicate if		
h. Work under this project has been submitted for Federal funding only to the NASA SBIR Program	Yes	No
i. 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:		
j. All 11 parts of the technical proposal are included in part order	Yes	No
k. Subcontracts/consultants proposed?	Yes	No
i) If yes, limits on subcontracts/consultants met	Yes	No
l. 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 5.13.16 of the Solicitation as applicable		
m. The offeror will comply with export control regulations	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 6a, 6b, 6c, 6d, 6e, 6f, 6g, 6h and 6i (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 choose “No” to confirm that work under this project has not been funded under any other Federal grant, contract or subcontract.

   6k. 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.

   6l. 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, 5.15). 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.

   6m. 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 **08 -** _ _ . _ _ _ _ _ _.
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) or TRL Range upon completion 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) or TRL Range upon completion of contract. See Section 2.20 and Appendix B for TRL definitions. The TRL range shall span no more than two levels (ie. the 3-4 or 4-5, but not 3-5).

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	
	$	
	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)	$ ______

PHASE 1 DELIVERABLES: Upon selection, SBCs will be required to submit mandatory deliverables such as technical reports, final report and New Technology report as per their contract. Samples of all required contract deliverables are available in the NASA SBIR/STTR Firms Library via the NASA SBIR/STTR Website (http://sbir.nasa.gov). If your firm is proposing any additional deliverables, list them below:

Deliverable	Quantity	Project Delivery Milestone
______	______	______
______	______	______

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

____

AUDIT AGENCY: If a Federal agency has ever audited your accounting system, please identify the agency, office location, and contact information below:

Agency: ______________ Office/Location: ______________
Phone: ______________ Email: ______________

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 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.

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 1 for acceptance by NASA. Show how this rate is determined. 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 required and estimate costs.
- Documentation Costs or Page Charges: Estimate cost of preparing and publishing project results.
- Subcontracts: Include a completed budget including hours and rates and justify details. (Section 3.2.4, Part 9.)
- Consultant Services: Indicate name, daily compensation, and estimated days of service.
- Computer Services: Computer equipment leasing is included here.

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 1 proposal, and any travel expenses listed for a Phase 2 proposal must include a detailed accounting of all said expenses.

Note: NASA will not fund the purchase of capital equipment or supplies that are not to be delivered to the government or consumed in the production of a prototype. The cost of capital equipment should be depreciated and included in G&A if appropriate.

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. 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 5.9 and 5.10. Profit to be added to total budget, shared costs to be subtracted from total budget, as applicable.

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

Deliverables and Audit Information (9):

Deliverables: List any additional deliverables, if applicable. Include the deliverable name, quantity (include unit of measurement, i.e., 2 models or 1.5 lbs. of material), and the proposed delivery milestone (i.e., end of contract). This section should only be completed if the offeror is proposing a deliverable in addition to the mandatory deliverables (technical report, final report and New Technology Report).

Audit Agency: Complete the “Contact Information” section if your firm’s accounting system has been audited by a Federal agency. Provide the agency name, the office branch or location, and the phone number and/or email.

SBIR Check List

For assistance in completing your Phase 1 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 3.2.7).
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 4, 2008** (Section 6.3).

Form A – STTR Cover Sheet

1. PROPOSAL NUMBER: **08 -** _ _ . _ _ _ _ _ _
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
As described in Section 2.11 of the Solicitation, the partnering institution qualifies as a:			
g.	FFRDC	Yes	No
h.	Nonprofit research institute	Yes	No
i.	Nonprofit college or university	Yes	No
As described in Section 3 of the Solicitation, the offeror meets the following requirements completely:			
j.	Cooperative Agreement signed by the SBC and RI enclosed	Yes	No
k.	All eleven parts of the technical proposal included in part order	Yes	No
l.	Subcontracts/consultants proposed? (Other than the RI)	Yes	No
	i) If yes, limits on subcontracts/consultants met	Yes	No
m.	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
n.	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:			
o.	Work under this project has been submitted for funding only to the NASA STTR Program	Yes	No
p.	Funding has been received for work under this project by any other Federal grant, contract, or subcontract	Yes	No
In accordance with Section 5.13.16 of the Solicitation as applicable			
q.	The offeror will comply with export control regulations	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 6a, 6b, 6c, 6d, 6e, 6f, 6g, 6h, 6i, 6k, 6n (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.

   6j. Cooperative Agreement signed by the SBC and RI: By answering yes, the SBC/RI certifies that a Cooperative Agreement signed by both SBC and RI is enclosed in the proposal (see Sections 3.2.2, 3.2.5).

   6l. 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.

   6m. 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, 5.15). 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 choose “No” to confirm that work under this project has not been funded under any other Federal grant, contract or subcontract.

   6q. 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 **08 -** _ _ . _ _ _ _ _ _.
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) or TRL Range upon completion 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) or TRL Range upon completion of contract. See Section 2.20 and Appendix B for TRL definitions. The TRL range shall span no more than two levels (ie. the 3-4 or 4-5, but not 3-5).

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	
	$	
	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)	$ ______

PHASE 1 DELIVERABLES: Upon selection, SBCs will be required to submit mandatory deliverables such as technical reports, final report and New Technology Report as per their contract. Samples of all required contract deliverables are available in the NASA SBIR/STTR Firms Library via the NASA SBIR/STTR Website (http://sbir.nasa.gov). If your firm is proposing any additional deliverables, list them below:

Deliverable	Quantity	Project Delivery Milestone
____________	______	____________
____________	______	____________

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: If a Federal agency has ever audited your accounting system, please identify the agency, office location, and contact information below:

Agency: ____________________ Office/Location: ____________________
Phone: ____________________ Email: ____________________

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 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.

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 1 for acceptance by NASA. Show how this rate is determined. 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 required and estimate costs.
- Documentation Costs or Page Charges: Estimate cost of preparing and publishing project results.
- Subcontracts: Include a completed budget including hours and rates and justify details. (Section 3.2.4, Part 9.)
- Consultant Services: Indicate name, daily compensation, and estimated days of service.
- Computer Services: Computer equipment leasing is included here.

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 1 proposal, and any travel expenses listed for a Phase 2 proposal must include a detailed accounting of all said expenses.

Note: NASA will not fund the purchase of capital equipment or supplies that are not to be delivered to the government or consumed in the production of a prototype. The cost of capital equipment should be depreciated and included in G&A if appropriate.

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. 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 5.9 and 5.10. Profit to be added to total budget, shared costs to be subtracted from total budget, as applicable.

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

Deliverables and Audit Information (9):

Deliverables: List any additional deliverables, if applicable. Include the deliverable name, quantity (include unit of measurement, i.e., 2 models or 1.5 lbs. of material), and the proposed delivery milestone (i.e., end of contract). This section should only be completed if the offeror is proposing a deliverable in addition to the mandatory deliverables (technical report, final report and New Technology Report).

Audit Agency: Complete the “Contact Information” section if your firm’s accounting system has been audited by a Federal agency. Provide the agency name, the office branch or location, and the phone number and/or email.

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 1 activities, at a minimum. If the_______ ______________(Proposal Title)_________ Project is selected to continue into Phase 2, the agreement may also be binding in Phase 2 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 3 activities that are funded by NASA.

After notification of Phase 1 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 __________________________, 200___.

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 1 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 3.2.7).
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 4, 2008** (Section 6.3).
13. Signed Allocation of Rights Agreement available for Contracting Officer at time of selection.

Appendix A: Example Format for Briefing Chart

NASA SBIR/STTR Technologies

Title of Proposal

PI: PI's Name / Firm – City, ST
Proposal No.: 08-1 _ _ . _ _ - _ _ _ _

Identification and Significance of Innovation Expected TRL Range at the end of Contract (1-9):	<Place graphic related to innovation here>
Technical Objectives and Work Plan	NASA and Non-NASA Applications 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

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/

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TOPIC: A1 Aviation Safety

The Aviation Safety Program focuses on the Nation's aviation safety challenges of the future. 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 future aircraft and to eliminate safety-related technology barriers. The program is focusing on a foundational approach to advancing knowledge in core disciplines (e.g., computational methods, material science), which in turn are used to build integrated multidisciplinary system-level models, tools, and technologies. This year, the scope of the aviation safety subtopics has been focused to develop specific technologies that are needed to accomplish program goals. It is expected there will be approximately one award per A1 subtopic with quality proposals.

This approach focuses on furthering our understanding of the underlying physics, chemistry, materials, etc. of aeronautics phenomena when broken down to these most basic elements. 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 missions, vehicle classes, and crew configurations.

Example areas of program interest include research directed at the detection, prediction and mitigation/management of aging-related hazards of future civilian and military aircraft; designs of revolutionary adaptive flight decks; in-flight detection, diagnosis, prognosis of aircraft health, preventative and adaptive systems for in-flight operability; informed logistics and maintenance graceful recovery from in-flight failures; software safety assurance and formal verification methods for safety-critical systems; as well as system-level integrated resilient control technologies.

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.

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

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 contribution to solving the problem of aging and damage processes in future vehicles is research to identify changes in fundamental material properties as indicators of material aging-related hazards before they become critical. Degraded and failing fiber composites can exhibit a number of micromechanisms such as fiber buckling and breakage, matrix cracking, and delamination.

In order to provide early detection of these processes and hazards, new sensing and diagnostic capabilities to support nondestructive evaluation (NDE) systems are needed, as well as associated computational techniques and maintenance methods. 'Virtual' inspection methods are being sought for composite materials. 'Virtual' inspections would include modeling the changes in critical material properties as indicators of material aging and then quantifying the levels of detectability of these material properties with a particular NDE technique. This computational tool should accurately model the interaction between the changes in the material properties and the probing energy of a particular NDE technique to allow the development of the inspection parameters needed for application on a particular structure. Actual NDE technologies are also being sought for the nondestructive characterization of age-related degradation in complex composite materials. Innovative and novel approaches to using NDE technologies to measure properties related to material aging (i.e. thermal diffusivity, elastic constants, density, microcrack formation, fiber buckling and breakage etc.) in complex composite material systems, adhesively bonded/built-up and/or polymer-matrix composite sandwich structures.

The anticipated outcome of successful proposals would be a both Phase 2 prototype NDE technology for the use of the developed technique to characterize age-related degradation and a demonstration of the technology showing its ability to measure a relevant material property in a carbon fiber/epoxy composite used for structural applications on 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, computational methods, and validation techniques are needed to provide the basis for these higher level (e.g., design) tools. Proposals are sought that apply innovative methods, models and analytic tools to the following specific applications:

- Probabilistic models are sought for improved structural analysis of complex metallic and composite airframe components. The methods used for these solutions need to detail the initiation and progression of damage to determine accurate estimates of residual life and/or strength of complex airframe structures.
- Tools and models 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 methods are 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.

A1.04 Aviation External Hazard Sensor Technologies
Lead Center: LaRC

NASA is concerned with new and innovative methods for airborne 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 sensors. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are needed.

Under this subtopic, proposals are invited that explore new and improved airborne 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. In some cases the development of ground-based sensor technology may be supported as a precursor to eventual airborne applications.

At this time, the following hazards are of particular interest: in-flight icing conditions and wake vortices. Proposals associated with sensor investigations addressing these hazards are encouraged, and some suggestions follow.

To enable remote detection and classification of in-flight icing hazards for the future airspace system and emerging aircraft, NASA is soliciting proposals for the development of sensor systems for the detection of icing conditions. Examples include the following practical remote sensing systems:

- Low-cost, ground-based, vertical-pointing with potential scanning capability X-band radar that can operate unattended 24/7/365 and provide calibrated reflectivity and velocity data with hydrometer/cloud particle classification (based upon the reflectivity and velocity data).
- Low-cost, high-frequency (> 89 GHz) microwave or infrared radiometer technology capable of providing air temperature, water vapor, and liquid water measurements for both ground-based and airborne applications.

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. Lidar systems have been used successfully for wake detection from off-axis viewing angles, and there is reason to believe that detection is possible from near-axial viewing angles. Other sensor technologies may have untapped potential for wake detection. NASA is soliciting new and innovative research toward the detection of wakes from aircraft, particularly in the terminal area. Specific areas suggested for investigation are sensor measurables (i.e. physical aspects of the hazard that are detectable or measurable by a sensor) associated with wake detection and wake strength; sensor capabilities for detection, tracking, and strength measurement; practical methods for wake hazard analysis, including hazard level evaluation and the bounding of hazardous airspace; and the removal of technical barriers to the use of sensors for airborne wake detection. Proposals may address any or all of the suggested areas. Additional wake vortex research topics are covered in Subtopic A3.02. Proposals may address any or all of the suggested areas.

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

NASA seeks highly innovative, crew-centered, technologies to improve aerospace system safety through the development of more effective joint human-automation systems in aviation. This is to be accomplished through increased awareness of operator and crew functional state (both in terms of functional readiness and in situ assessment), and through improved interactions among intelligent agents (human and automated) while participating in flight operations on the flightdeck. We seek proposals for the development of advanced technologies that:

- Allow flightdeck systems to conform to individual operator's characteristics in a manner that improves performance, and that help characterize such individual differences;
- Improve our capability to non-intrusively sense and characterize operator and crew functional state in the ambient conditions of flight, or in flight simulation facilities;
- Convey operators state information to other intelligent agents (human and automated, proximal and remote) to improve coordinated performance;
- Modulate interactions among intelligent agents so as to minimize risk and optimize performance objectives across all possible mission scenarios;
- Intelligently aid operators such that the potential for and effects of human error are minimized, and so that operators can maintain appropriate functional states during flight operations; and/or
- Provide methods, metrics, and tools that help to assess the effectiveness of the above-mentioned technologies in human-in-the loop simulation and/or flight studies.

Proposals should describe novel technologies with high potential to serve the objectives of the Robust Automation/Human Systems element of NASA's Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/rahs.htm). Successful Phase 1 proposals should culminate in a final report that specifies, and a Phase 2 proposal that would realize, technology that improves the effectiveness of joint human-automation systems in aviation, or improves the ability to assess effectiveness of such systems.

A1.06 Technologies for Improved Design and Analysis of Flight Deck Automation
Lead Center: ARC

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 performance;
- Design tools and methods that improve the application of human-centered design principles to the design and certification of mixed human-automated systems;
- Tools and methods for modeling the complex information management systems required for future flight deck systems;
- Methods of data uncertainty estimation during the flight deck system design phase particularly as applied to predicting overall system integrity;
- Design and analysis methods or tools to better predict and assess human and system performance in relevant operational environments.

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 1 proposals should culminate in a final report that specifies, and a Phase 2 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 On-Board Flight Envelope Estimation for Unimpaired and Impaired Aircraft
Lead Center: LaRC
Participating Center(s): ARC

A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomalies. These may occur in a variety of forms, including failed actuators, failed sensors, damaged surfaces or abrupt changes in aerodynamics or large changes in aerodynamics during upsets. As part of the Aviation Safety Program research, the Integrated Resilient Aircraft Control (IRAC) Project is investigating advanced control system concepts to provide greater aircraft resiliency to adverse events. The goal of the IRAC project is to arrive at a set of validated multidisciplinary aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions.

Research on advanced technical approaches (such as direct and indirect adaptive control) has focused on accomplishing stability and safe operability in the presence of anomalies. To be able to effectively develop and apply such methods, it is highly desirable, if not essential, to characterize each anomaly and assess the limits of operation of the impaired vehicle, as control application without regard to the vehicle impairment or adverse condition could have significant detrimental consequences. In particular, it would be desirable to characterize and isolate the anomalous condition, and then estimate the level of controllability, limits of maneuverability, and achievable flight envelope of the vehicle. This SBIR subtopic will develop analytical tools and prototype software to assess the ability of the vehicle to accomplish safe operation under specified anomalous conditions. Specific technology areas where contributions are sought include the following:

- Adaptive mathematical framework for control-centric onboard aircraft models that can accommodate real-time changes to subsystem dynamics;
- Real-time system identification capability for updating an onboard vehicle model with an adaptive structure to satisfy sub-system constraints under adverse conditions;
- Real-time fault diagnostic and prognostics capability needed in adaptive flight, propulsion, structural control applications;
- Real-time control power map identification with inclusion of aircraft sub-system constraints under adverse conditions;
- Real-time dynamic flight envelope identification and prediction capability; and
- Metrics and assessment models for safety-of-flight diagnostics and prognostics.

A1.08 Engine Lifing and Prognosis for In-Flight Emergencies
Lead Center: GRC

The object of this research topic is to develop innovative methodologies to determine probability of an engine system failure under emergency flight conditions that demand a boost in the engine performance, thus potentially sacrificing the engine, to increase the engine control effectiveness for a safe take-off or landing.

Aircraft engine design and life are based on a theoretical operation flight profile that in practice is not seen by most engines in service. The ability to predict remaining engine life with a defined reliability in real time is a condition precedent to emergency operation risk assessment. It is expected that this research will result in a demonstration of an integrated life monitoring and prognosis methodology that will utilize existing and under development probabilistic codes for engine life usage and for risk assessment for future operations that may require enhanced performance. The expected outcome of the research will be a demonstration of an integrated engine life module for:

- Engine life prediction, including a reliability model for off-nominal conditions.
- Risk assessment and trade-off tool for emergency operation.

NASA resources available for the research will be an engine component database for turbine disks and blades, and probabilistic computer codes for life prediction and reliability.

A1.09 Robust Flare Planning and Guidance for Unimpaired and Impaired Aircraft
Lead Center: ARC
Participating Center(s): DFRC, LaRC

A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomalies. These may occur in a variety of forms, including damaged surfaces or failed actuators that can limit the maneuverability and achievable flight envelope of the vehicle. As part of the Aviation Safety Program research, the goal of the Integrated Resilient Aircraft Control (IRAC) Project is to arrive at a set of validated multidisciplinary aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions. Research on advanced technical approaches includes adaptive flight control for providing stability, flight and maneuvering envelope identification for determining safe operability limits, and emergency flight planning and guidance for achieving a flyable path to an approach for landing.

This SBIR subtopic seeks innovations in providing flare planning and guidance technologies that aid aircraft during the critical phase of landing under damage conditions and weather disturbances such as heavy crosswind or wind shear. The research will develop feasibility studies of different methods for safe landing under these hazardous conditions when the aircraft performance is impaired due to damage and failures. The research will address automatic flare maneuvers of aircraft with a large crab angle and possibly bank angle for a stable trim approach, different flap deployment strategies, high speed approaches, and large trim alpha variations. Differential engine throttle may be used to compensate for large sideslip, as may other novel automatic flare methods for off-nominal landing. The research should also determine when a different approach profile (such as a lateral offset and/or shallower glide-slope) is desired, so that this information could be used by a flight planning system as a target endpoint.

A1.10 Detection of In-Flight 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 anomalies from adverse events in hardware, software, and the interactions between these two classes of systems. This involves the integration of novel sensor technologies for structures, propulsion systems, and other subsystems within the aircraft and/or the development of novel methods to detect failures in software systems. 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 detect failures in software systems which have already undergone verification and validation;
- Methods to differentiate sensor failure from actual system or component failure;
- Characterizing, quantifying, and interpreting multi-sensor outputs;
- Integration of propulsion, airframe, and software health information for improved vehicle state-awareness;
- New sensors and sensory materials that operate in harsh environments; and
- New methods to provide better and more accurate information to diagnostic computational algorithms that reconstruct damage fields from sensor values.

Emphasis is on novel methods to detect failures in electrical, electromechanical, electronic, structural, propulsion, and software systems. 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 Integrated Diagnosis and Prognosis of Aircraft Anomalies
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC, SSC

The capability to identify faults and predict their progression is critical to determining appropriate mitigation actions to maintain aircraft safety. This effort is to develop innovative methods and tools for the diagnosis and prognosis of aircraft faults and failures. Proposals are sought for the development of a health management methodology which integrates a prognosis approach with the nature, severity, and uncertainty information from the diagnosis of the faulted system.

Diagnosis: The diagnosis element of IVHM 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 gas path monitoring, 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.

Computational demonstrations using realistic data or prototype hardware implementations of the diagnostic capabilities would be expected at the conclusion of a Phase 2 effort. Other methods could also be employed that appropriately model the uncertainties in the subsystem due to noise 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. 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, along with a measure of the certainty in the diagnosis. Understanding and addressing the system integration and validation issues are critical components of this effort.

Prognosis: The prognosis element of IVHM includes the development of technologies, tools, and techniques to determine, given information from detection and diagnosis health management systems and other systems, estimates (with a measure of confidence) of the remaining useful life (RUL) of candidate faults generated by diagnostic engines. 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. Areas of interest include developing methods for making predictions of RUL which take the uncertainties provided by a candidate diagnostic engine into account, representing and managing uncertainties inherent in such predictions, and developing and applying assessment methodologies for comprehensive and objective evaluation of prognostic algorithm performance.

Research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path toward a Phase 2 technology demonstration. Proposals are solicited that address aspects of the following areas:

- The development of an integrated approach for diagnostics and prognostics that demonstrate a mathematically rigorous method for propagating diagnostic uncertainty and its effect on subsequent estimates of remaining useful life.
- Physics-based damage propagation models for one or more relevant aircraft subsystems such as composite or metallic airframe structures, engine turbo-machinery and hot structures, avionics, electrical power systems, electromechanical systems, and electronics. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.
- Novel approaches to assess the quality and accuracy of remaining useful life estimates through the fusion of different models, active probing of components, etc.
- Uncertainty representation and management 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.
- Mathematically rigorous methodologies for assessing the quality of remaining useful life predictions and associated uncertainties.
- Verification and validation methods for prognostic algorithms.

A1.12 Mitigation of Aircraft Structural Damage
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

This topic is jointly supported by the Integrated Vehicle Health Management (IVHM) project and the Aircraft Aging and Durability (AAD) project.

Healing Material System Concepts for IVHM/AAD
The development of integrated multifunctional self-sensing, self-repairing structures will enable the next generation of light-weight, 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.

Similarly, the mitigation and management of aging and other durability-related hazards in future civilian and military aircraft will require the development of advanced materials, concepts, and techniques. NASA is engaged in the research of materials (metals, ceramics, and composites) and characterization/validation test techniques for mitigation of aging and durability issues and to enable advanced material suitability and concepts. Innovations are sought for in these mitigation technologies: concepts for autonomous self-healing of composite aerospace structures. Passive approaches are sought where sensors or external energy are not required to activate the healing process. Desired performance objectives include improved compression-after-impact performance and retarded/arrested damage growth. To be competitive with lightweight traditional (non-healing) aerospace structures, self-healing concepts must not introduce extensive passive weight, such as a reservoir tank of resin, etc.

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

- Fundamental research in all disciplines to enable very-high speed flight and re-entry into planetary atmospheres
- High-temperature materials; thermal protection systems; advanced propulsion; aero-thermodynamics; multi-disciplinary analysis and design; guidance, navigation, and control (GNC); advanced experimental capabilities

Supersonics

- Eliminate environmental and performance barriers that prevent practical supersonic vehicles
- Supersonic deceleration technology for Entry, Descent, and Landing into Mars

Subsonic Fixed Wing (SFW)

- Develop revolutionary technologies and aircraft concepts with highly improved performance 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 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 is available at 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 Programs research thrusts (Subsonic Fixed Wing, Subsonic Rotary Wing, Supersonic, Hypersonic) 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 and should be linked to improvements in aircraft performance indicators such as vehicle weight, noise, lift, drag, lifetime, and emissions. The technologies of interest cover five research subtopics:

Fundamental Materials Development, Processing and Characterization

- Multifunctional materials and structural concepts for engine and airframe structures, such as, novel approaches to mitigating lightning strike, aircraft engine fan cases with integrated acoustic treatments and ballistic impact resistance.
- Adaptive materials and structural concepts for engine and airframe structures, such as shape memory alloys and polymers for active and highly flexible airframe and engine components, piezoelectric ceramics and polymers for self-damping engine and airframe components, materials and structures with integrated self-diagnostic, self-healing and actuation capabilities.
- Advanced high temperature materials for aircraft engine and airframe components and thermal protection systems, including advanced blade and disk alloys, ceramics and CMCs, and coatings to improve environmental durability.
- Innovative processing methods to reduce component manufacturing costs and improve damage tolerance and reliability, including processing and joining of ceramics, metals, polymers, composites, and hybrids, as well as nanostructured and multifunctional materials and coatings.
- 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.

Structural Analysis Tools and Procedures

- Design methods 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.
- Rapid design methods for airframe structures.
- Prediction tool for advanced engine containment systems, including multifunctional approaches.
- Integrated structural design and analysis methods for advanced composite materials.
- Design, development, analysis, and verification methods for structural joining technologies for high-temperature composite airframe and propulsion structures including bonding, fastening, and sealing.

Computational Materials Development Tools

- Computational materials tools for the development of durable high temperature materials.
- Computational tools to predict materials properties based upon chemistry and processing for conventional as well as nanostructured, multifunctional and/or adaptive materials.

Advanced Structural Concepts

- Innovative structural concepts and materials and/or robust thermal protection systems leading to reliable, high-mass planetary entry, descent and landing systems including deployable heat shields, high temperature films and fabrics.
- Improved thermal protection systems using innovative structural and material concepts, including structurally integrated multifunctional systems.

- Advanced mechanical component technologies including self lubricating coatings, oil-free bearings, and seals.
- Advanced material and component technologies to enable the development of a mechanical and electrical drive system to distribute power from a single engine core to drive multiple propulsive fans, in particular, 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 (lower efficiencies and mass-per-input-power that give the same or better refrigeration and mass are acceptable). Input power between 10 and 100 kW is envisioned in applications, but scalable small demonstrations are acceptable.

Durable Structural Sensor Technology for Extreme Environments (>1800°F)

- Development and validation of advanced high-temperature sensor technology to measure strain, temperature, heat flux, and/or acceleration of structural components.
- Development and validation of improved sensor bonding methods (i.e., adhesives, plasma spraying techniques, etc.) for attaching structural sensors on advanced high-temperature materials.

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

Combustion research is critical for the development of future aerospace vehicles. Vehicles for subsonic and supersonic flight regimes will be required to emit extremely low amounts of gaseous and particulate emissions to satisfy increasingly stringent emissions regulations. Hypersonic vehicles require combustion systems capable of sustaining stable and efficient combustion in very high speed flow fields where fuel/air mixing must be accomplished very rapidly and residence times for combustion are extremely limited. 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 include:

- Development of laser-based diagnostics and novel experimental techniques for measurements in reacting flows;
- Two-phase flow simulation models and validation data under supercritical conditions;
- Development of ultra-sensitive instruments for determining the size-dependent mass of gas-turbine engine particle emissions;
- High frequency actuators (bandwidth ~1000 Hz) that can be used to modulate fuel flow at multiple fuel injection locations (with individual Flow Numbers of 3 to 5) with minimal fuel pressure drop for active combustion control;
- Combustion instability modeling and validation;
- Novel combustion simulation methodologies;
- Combustor and/or combustion physics and mechanisms, enhanced mixing concepts, ignition and flame holding, turbulent flame propagation, vitiated-test media and facility-contamination effects, hydrogen/hydrocarbon-air kinetic mechanisms, multi-phase combustion processes, and engine/propulsion component characterizations;
- 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;

- 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, 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 aero-acoustic analysis, which can be adapted for design codes;
- Prediction of aero-acoustic noise sources including engine and airframe noise sources 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 flowfield;
- Computational and analytical structural acoustics techniques for aircraft and advanced aerospace vehicle interior noise prediction, particularly for use early in the airframe design process;
- Prediction and control of high-amplitude aero-acoustic 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 airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise sources typical of jets, separated regions, vortices, shear layers, etc.;
- Concepts for active and passive control of aero-acoustic 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 advanced 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;
- Development and application of flight procedures for reducing community noise impact while maintaining or enhancing safety, capacity, and fuel efficiency.

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, 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

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 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;
- 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: LaRC
Participating Center(s): ARC, DFRC, GRC

Development of accurate tools to predict aerothermal environments and their effects on space vehicles is critically important to achieving the goals of current NASA missions. These tools will also enable the development of advanced spacecraft for future missions by reducing uncertainties during design and development.

The large size and high re-entry velocity of the Crew Exploration Vehicle and the conditions encountered in proposed aerocapture missions to Titan, Neptune, and Venus require study of shock layer radiation phenomena, radiative heat transfer, and non-equilibrium thermodynamic and transport properties; these in turn require understanding of the internal structure and dynamics of the constituent gases.

Transition and turbulence effects are particularly complex in hypersonic flows, where unique problems are posed by shocks, real gas effects, body surfaces with complex and possibly time-dependent roughness, nose bluntness, ablation, surface catalyticity, separation, and an unknown free-stream disturbance environment.

At the heating rates encountered during hypersonic re-entry, surface ablation products blowing into the boundary layer introduce new interactions including chemical reactions and radiation absorption, that strongly affect surface heating rates and integrated heat loads.

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

- Computational analysis methods for radiation and radiation transport in the shock layer surrounding planetary entry vehicles;
- Advanced physics-based thermal and chemical non-equilibrium models for thermodynamics, transport, and radiation;
- Studies of the interactions of gases in the shock layer with ablating materials from the vehicle thermal protection system;
- Experimental methods and diagnostics to measure the characteristics of hypersonic flow fields, either in flight or in ground-based facilities;
- Software tools coupling radiation, non-equilibrium chemistry, Reynolds-averaged Navier-Stokes, and large eddy simulation codes to enable the design and validation of mission configurations for entry into planetary atmospheres.

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

Enabling advanced aircraft configurations for subsonic, supersonic and hypersonic flight, and high performance "Intelligent Engines" will require advancement in the state-of-the art dynamic modeling and flight/propulsion control. The need to minimize the carbon footprint will necessitate new trajectory planning and control concepts. Control methods need to be developed and validated for "optimal" and reliable performance of complex, unsteady, and nonlinear systems with significant modeling uncertainties while ensuring operational flexibility, enabling unique concepts of operations with novel configurations, lower emissions and noise, and safe operation over a wide operating envelope. New dynamic modeling and simulation techniques need to be developed to investigate dynamic performance issues and support development of control strategies for innovative aircraft configurations with enhanced control effectors and propulsion systems. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance, and load control including smart actuation and active aerostructural concepts, active control of propulsion system components, and drag minimization for high efficiency and range performance. Technology needs specific to different flight regimes are summarized in the following:

Subsonic Fixed Wing Aircraft
Technologies of interest, with application to both flight and propulsion control, include: methods for development of dynamic models and simulations of the integrated component/control system being considered; defining actuation requirements for novel control approaches and developing prototype actuators for flight-like environments; developing and applying innovative control methods and validating them through laboratory test, vehicle simulations and sub-scale flight test as appropriate. Technologies related to the development and integration of modular, open-

system control elements leading to the transition to distributed control architecture in the engine environment are of special interest.

Supersonic Flight
Technologies of interest include: methods for developing integrated dynamic models and simulation including propulsion and aeroelastic effects and suitable for control design; novel control design methods for integrated aero-propulsion-servo-elastic control leading to acceptable flying qualities over the operating flight envelope; novel, and feasible, takeoff and approach to landing procedures to accommodate the visibility challenges due to long fore-bodies; integrated inlet/engine control to ensure safe (no inlet unstart or compressor surge/stall) and efficient operation.

Hypersonic Flight
Technologies of interest include: system dynamic models incorporating the essential coupled dynamic elements with varying fidelity for control design, analysis and evaluation; methods for characterizing uncertainty in the dynamic models to enable control robustness evaluation; hierarchical GNC (Guidance, Navigation and Control) architectures and energy management techniques to enable trajectory shaping and control over a wide operating envelope with integrated flight/propulsion control; adaptive and robust control methods that can handle large modeling uncertainties; simulation test beds for evaluating hypersonic concept vehicle control under various types of uncertainty, system wide coupling and associated model misspecification.

A2.08 Aircraft Systems Analysis, Design and Optimization
Lead Center: 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:

(1) Design Environment Development;
(2) Variable Fidelity, Physics-Based Design/Analysis Tools;
(3) Technology Assessment and Integration; and
(4) 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.

(1) 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.

(2) 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.

(3) 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.

(4) 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. Meeting this challenge will require innovative technologies and methods, with an emphasis on integrated, multidisciplinary, first-principle computational tools specifically applicable to the unique problems of rotary wing aircraft. Technologies of particular interest are as follows:

Propulsion-Variable Speed Drive Systems/Transmissions
Technologies, and predictive capability, related to enabling concepts and techniques for variable speed drive systems/transmissions suitable for large rotorcraft application are encouraged. Specifically, this would include concepts for controlling and enabling variable speed drives as well as lightweight and reliable drive system components. Efficient drive-system speed-variability on the order of 30-50% should be the focus of the proposed technologies and analysis tools.

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.

Acoustics
Interior and exterior rotorcraft noise generation, propagation and control. Topics of interest include, but are not limited to, external noise prediction methods for manned and unmanned rotorcraft, improved acoustic propagation models, psychoacoustics analysis of rotorcraft noise, interior noise prediction methods and active/passive noise control applications for rotorcraft including engine and transmission noise reduction, advanced acoustic measurement systems for flight and wind tunnel applications, acoustic data acquisition/reduction/analysis, rotor noise reduction techniques, noise abatement flight operations. Rotor noise, including broadband, harmonic, blade-vortex interaction, high-speed impulsive; alternate tail rotor and auxiliary power concepts, rotor/tail rotor, and rotor/rotor interactional noise. Frequency range includes not only audible range, but very low frequency rotational noise (blade-passage frequency below 20 Hz) as well. Optimized active/passive concepts and noise tailoring, including rotorcraft designs that are inherently designed for lower noise as a constraint.

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.
- Tools and methods are sought to optimize the turbine cooling design including film cooling and internal cooling, especially considering the ability to incorporate such tools into the engine design cycle. Currently, turbine cooling designs are developed via empirical information which may be derived from idealized cases not applicable to the actual turbine flow environment. It would benefit the community greatly to have a validated computational tool for optimizing the turbine cooling design. This tool should allow the prediction of turbine wall temperatures with sufficient accuracy and within reasonable time scales to allow optimization of the film and internal cooling geometrical features. Consideration should be given to the ability of the tool to handle CAD-based geometries.

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 Highly Reliable Reusable Launch Systems (HRRLS). The HRRLS 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-unique 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 two areas:

- Flow control concepts and analysis tools that enable
  - "Fail safe" systems to control shock wave boundary layer interactions and reduce dynamic distortion in supersonic inlets;
  - Innovative stability systems for highly integrated supersonic inlets utilizing flow control and minimizing bleed;
  - Control of subsonic diffuser flows to increase total pressure recovery and reduce distortion;
  - Nozzle area control;
  - Boat tail drag reduction and shock mitigation for low-boom supersonic applications;
  - Thrust vectoring.
- Unsteady coupled Inlet/Fan Analysis Tools to investigate
  - Engine transients affect on inlet unstart;
  - Mode transition for a hypersonic dual Turbine engine/RAM-SCRAM flowpath;
  - Inlet and fan aero/mechanical loads;
  - Engine/inlet control system development;
  - Distortion tolerance.

TOPIC: A3 Airspace Systems

NASA's Airspace Systems (AS) Program is investing in the development of innovative concepts and technologies to support the development of the Next Generation Air Transportation System (NGATS is also commonly known as NextGen). NASA is working to develop, validate and transfer advanced concepts, technologies, and procedures through partnership with the Federal Aviation Administration (FAA) and other government agencies represented in the Joint Planning and Development Office (JPDO), and in cooperation with the U.S. aeronautics industry and academia. As such, the AS Program 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. The AS Program integrates the two projects, NextGen Airspace and NextGen Airportal, to directly address the fundamental research needs of NextGen vision in partnership with the member agencies of the JPDO. The NextGen Airspace Project develops and explores fundamental concepts and integrated solutions that address the optimal allocation of ground and air automation technologies necessary for NextGen. The project will 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 aircraft safely and efficiently through the NAS. The NextGen Airportal Project develops and validates algorithms, concepts, and technologies to increase throughput of the runway complex and achieve high efficiency in the use of airportal resources such as gates, taxiways, runways, and final approach airspace. NASA research in this project will lead to development of solutions that safely integrate surface and terminal area air traffic optimization tools and systems with 4-D trajectory operations. Ultimately, 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.

Additional information is available at http://www.aeronautics.nasa.gov/programs_asp.htm.

A3.01 NextGen Airspace
Lead Center: ARC
Participating Center(s): DFRC, LaRC

The primary goal of the NASA Next Generation Air Transportation System (NextGen) Airspace effort is to develop integrated solutions for a safe, efficient, and high-capacity airspace system. Of particular interest is the development of core capabilities, including: (1) Performance-based services, which will enable higher levels of performance in proportion with user equipage level; (2) Trajectory-based operations, which is the basis for changing the way traffic is managed in the system to achieve increases in capacity and efficiency; (3) Super-density operations, which maximizes the use of limited runways at the busiest airports; (4) Weather assimilated into decision making; (5) Equivalent visual operations, which will allow the system to maintain visual flight rule capacities in instrument flight rule conditions. These core capabilities are required to enable key NGATS-Airspace functions such as Dynamic Airspace Configuration, Traffic Flow Management, Separation Assurance, and the overarching Evaluator that integrates these air traffic management (ATM) functions over multiple planning intervals.

In order to meet these challenges, innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's NextGen Airspace effort. The general areas of primary interest are Dynamic Airspace Configuration, Traffic Flow Management, and Separation Assurance. Specific research topics for NextGen Airspace include:

- 4D trajectory based operations;
- Air/ground automation concepts and technologies;
- Airspace modeling and simulation techniques;
- Automated separation assurance;
- Collaborative decision making techniques involving multiple agents;
- Equivalent visual operations;
- "Evaluator" integrated solutions of ATM functions over multiple planning intervals;
- Human factors for ATM;
- Locus of control across humans and automation;
- Multi-aircraft flow and airspace optimization;
- Performance based services;
- Safety analysis methods;
- Spacing and sequencing management;
- Super density terminal area operations;
- Traffic complexity monitoring and prediction;
- Traffic flow management concepts/techniques;
- Trajectory design and conformance;
- Weather assimilated into ATM decision-making.

A3.02 NextGen Airportal
Lead Center: LaRC
Participating Center(s): ARC, DFRC, LaRC

The Airportal research of NASA's Airspace Systems (AS) Program focuses on key capabilities that will increase throughput of the Airportal environment and achieve the highest possible efficiencies in the use of Airportal resources such as terminal airspace, runways, taxiways, and gates. The primary capabilities addressed are: (1) Super-density operations, (2) Equivalent visual operations, (3) Aircraft trajectory-based operations, and (4) Improved understanding of wake vortices.

Super-density operations will include conflict detection and resolution for closely spaced approaches, reduced aircraft wake vortex separation standards, and less restrictive run-way/taxiway operations. Additional mechanisms to increase the feasible density of operations will also be considered.

Equivalent visual operations will provide aircraft with the critical information needed to maintain safe distances from other aircraft during non-visual conditions, including a capability to operate at "visual performance" levels on the airport surface during low-visibility conditions. Advances in equivalent visual operations for the Airportal air navigation service provider are also of interest.

Aircraft trajectory-based operations will utilize 4D trajectories (aircraft path from block-to-block, including path along the ground, and also including the time component) as the basis for planning and executing system operations.

Wake vortices are often the ultimate limitation for many advanced, high-efficiency operational concepts. Advances in sensors, simulations of wake vortices and sensors, weather modeling and measurements, and understanding of impacts to aircraft flight are all of interest.

NASA's AS Program has identified the following Next Generation Air Transportation System (Next Gen) Airportal research activities: optimization of surface aircraft traffic; dynamic airport configuration management (including the optimal balancing of Airportal resources for arrival, departure, and surface aircraft operations); predictive models to enable mitigation of wake vortex hazards; new procedures for performing safe, closely spaced, and converging approaches at closer distances than are currently allowed; modeling, simulation, and experimental validation research focused on single and multiple regional airports (metroplex); and other innovative opportunities for transformational improvements in Airportal/metroplex throughput. Inherent to the AS Program 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 research areas relevant to NASA's Next Gen/Airportal effort. The general areas of interest are surface management optimization, converging and parallel runway operations, safety risk assessment methodologies, and wake vortex solutions inside Metroplex boundaries. Specific research topics for Next Gen/Airportal include:

- Airborne spacing algorithms and wake avoidance procedures for airports with closely spaced runways;
- Algorithms for determining wake vortex encounters from aircraft flight data recorders;
- Automated separation assurance and runway/taxiway incursion prevention algorithms ;
- Automatic taxi clearance and aircraft control technologies;
- Characterization of wake vortex and atmospheric hazards to flight in terms of aircraft and flight crew responses;
- Collaborative decision making between airlines and airport traffic control tower personnel for optimized surface operations, including push back scheduling and management of airport surface assets;
- Development of wake vortex hazard assessment algorithms;
- Dynamic airport configuration management;
- Fusion of data from weather sensors and models for input into weather prediction models;
- High resolution CFD and real-time modeling of wake vortex strength and location;
- Human/automation interaction and performance standards;
- Improved wake vortex circulation estimates derived from Pulsed Lidar;
- Innovations in wake vortex sensors;
- Integration of decision-support tools across different airspace domains;
- Lidar Simulation tools for wake vortices;
- Measurements of wind, temperature, and turbulence from departing and arriving aircraft;
- Methodologies and/or algorithms to estimate environmental impacts of increased traffic on the surface and in the terminal airspace, and to reduce the environmental impacts under increased levels of traffic;

- Methodologies to estimate and assess the risk of transformational airspace operations for which little historical risk data may exist and for which operations may be constrained by the potential for extremely rare events;
- Modeling and simulation of airport operations for validating aircraft taxi planning concepts;
- Optimized 4D aircraft trajectory generation and conformance monitoring for surface and terminal airspace operations, including departure and arrival planning for individual flights;
- Radar simulation tools for wake vortices;
- Radically innovative approaches for detection of wake vortices;
- Scheduling algorithm for aircraft deicing and integration with a surface traffic decision-support tool;
- Surface and terminal airspace traffic modeling and simulation of multiple regional airports;
- Virtual airport traffic control towers;
- Weather sensors for supporting wake vortex predictions;
- Other technologies and approaches to achieving 2-3X improvement in the throughput of Airportal/metroplexes.

Note: The development of technologies for the airborne detection of wake vortices is covered in Subtopic A1.04.

TOPIC: A4 Aeronautics Test Technologies

NASA has implemented the Aeronautics Test Program (ATP) within its Aeronautics Research Mission Directorate (ARMD). The purpose of the ATP is to ensure 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) needs. Furthermore, ATP provides rate stability to the aforementioned user community. The ATP facilities are located at the NASA Research Centers, including at Ames Research Center, Dryden Flight Research Center, Glenn Research Center and Langley Research Center. Classes of facilities within the ATP include low speed wind tunnels, transonic wind tunnels, supersonic wind tunnels, hypersonic wind tunnels, hypersonic propulsion integration test facilities, air-breathing engine test facilities, the Western Aeronautical Test Range (WATR), support aircraft, 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. To operate a facility in this manner requires the use of state-of-the-art test technologies and test techniques, creative facility performance capability enhancements, and novel means of acquiring test data. NASA is soliciting proposals in the areas of instrumentation, test measurement technology, test techniques and facility development that apply to the ATP facilities to help in achieving the ATP goals of sustaining and improving our test capabilities. Proposals that describe products or processes that are transportable across multiple facility classes are of special interest. The proposals will also be assessed for their ability to develop products that can be implemented across government-owned, industry and academic institution test facilities. Additional information: http://www.aeronautics.nasa.gov/atp/index.html.

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

NASA is concerned with operating its ground test facilities with new and innovative methods for test measurement technology and with continually improving on the efficiency and effectiveness of operation of its ground test facilities. NASA's aeronautics and space research and development pushes the limits of technology, including the ground test facilities that are used to confirm theory and provide validation and verification of new technologies. By using state-of-the-art test measurement technologies, novel means of acquiring test data, test techniques and creative facility performance capability enhancements, NASA will be able to operate its facilities more efficiently and effectively and also be able to meet the challenges presented by NASA's cutting edge research and development programs. Therefore, NASA is seeking highly innovative and commercially viable test measurement technologies, test techniques, and facility performance technologies that would increase efficiency or overcome research and development technology barriers for ground test facilities.

The emphasis for this subtopic is in the area of test measurement technology. Examples of the types of technology solutions sought, but not limited to, are: skin friction experimental measurement techniques; improved flow transition detection methodologies; new or novel, non-intrusive measurement technologies for pressure, temperature, and force measurements; force measurement (balance) technology development; and improvement of current cutting edge technologies, such as particle imaging velocimetry (PIV), that allow the technology to be used more reliably in a production wind tunnel environment. Solutions are also sought with regards to the instrumentation used to characterize ground test facility performance. This could be in the area of aerodynamics performance characterization (flow quality, turbulence intensity, etc.) or, for example, in the case of specialty facilities, the measurement of liquid water content, ice water content, and cloud droplet size conditions in an icing wind tunnel.

Proposals that lead to products or processes 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 government-owned, industry and academic institution aerospace ground test facilities.

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

NASA's flight research is reliant on a combination of both ground and flight research facilities. By using state-of-the-art techniques, measurement and data acquisition technologies, NASA will be able to operate its flight research facilities more effectively and also meet the challenges presented by NASA's cutting edge research and development programs. The scope of this subtopic is broad, with emphasis on emissions, noise, and performance. Research technologies applicable to this subtopic should address (but are not limited to): Western Aeronautical Test Range (WATR), Flight Loads Laboratory (FLL), Research Flight Simulation Hardware-in-the-Loop Simulation (HILS), Testbed and Support Aircraft (e.g. F-15, F-18, ER-2, Gulfstream-III, Ikhana), as well as modeling, identification, simulation, and control of aerospace vehicle applications in flight research, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts. 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. The benefit of this effort will ultimately be an increased understanding of the complex interactions between the vehicle dynamics subsystems with an emphasis on flight research validation methods for control-oriented applications. 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, aeroelastic maneuver performance and load control (including smart actuation and active aerostructural concepts), autonomous health monitoring for stability and performance, and drag minimization for high efficiency and range performance. Methodologies should pertain to any of a variety of types of vehicles ranging from low-speed, high-altitude long-endurance to hypersonic and access-to-space aerospace vehicles. Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this subtopic is the development of sensors, sensor systems, sensor arrays, or instrumentation systems for improving the state-of-the-art in aircraft ground or flight research. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight research 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, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This topic solicits proposals for improving airborne sensors and sensor instrumentation systems in all flight regimes – particularly transonic and hypersonic. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability. This subtopic further solicits innovative flight research experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment.

Therefore, NASA is seeking highly innovative and viable research technologies that would increase efficiency or overcome limitations for flight research. Other areas of interest include: Verification & Validation techniques for non-deterministic and complex redundant systems; Design Tools integrated into the simulation environment for early research and validation; Flight Measurements & Data Acquisition: Aerodynamic forces, flow quality & conditions; Skin Friction; Flight Hardened Systems & Miniaturization; Signal Processing & Reconfigurable Systems; Wireless technologies.

9.1.2 EXPLORATION SYSTEMS

The Exploration Systems Mission Directorate (ESMD) is developing a constellation of new capabilities and supporting technologies and conducting foundational research to enable sustained and affordable human and robotic exploration. In order to support this complex mission, program offices have been established at the NASA Centers to manage the development of the next generation of space vehicles and systems. The Constellation Program (CxP), which is developing and building the Orion crew exploration vehicle and the Ares launch vehicles, is located at the Johnson Space Center (JSC). CxP also develops and builds the lunar lander, Earth departure stage, EVA, and lunar surface systems.

The Human Research Program (HRP), which performs research and technology development that addresses the highest risks to the human system in support of exploration, is also located at JSC. Advanced technologies will be developed for Orion, Ares, and other space vehicles and systems by the Exploration Technology Development Program (ETDP) at the Langley Research Center (LaRC). These three major ESMD Programs will maximize the use of SBIR Phase 1 through 3 technology research projects to minimize technology development costs and expedite the activation of explorations systems as soon as possible.

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TOPIC: X1 Avionics and Software

Exploration Technology Development Program (ETDP) leads the Agency in the development of advanced avionics, software and information technology capabilities and research for Exploration Systems. The Avionics and Software elements perform mission-driven research and development to enable new system functionality, reduce risk, and enhance the capability for NASA's exploration missions. NASA's focus has clarified around Exploration, and the agency's expertise and capabilities are being called upon to support these missions. The Ares Launch Vehicle, the Orion Crew Exploration Vehicle (CEV), the Altair Lunar Lander, and future lunar surface systems will each require unique advances in avionic and software technologies such as integrated systems health management, autonomous systems for the crew and mission operations, radiation hardened processing, 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.

X1.01 Automation for Vehicle and Habitat Operations
Lead Center: ARC
Participating Center(s): JPL

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. Reusable automation software must be adaptable to new applications without undue difficulty, and easily adjusted as the application operations change. The software and the adaptation to a given application must also be trusted before it can be accepted. 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 in applying such tools across projects. Examples of needed capabilities include:

- Graphical tool for monitoring and debugging plan execution;
- Graphical tool 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. Decision support tools are needed that:

- Command and supervise complex tasks while projecting the outcome of actions 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;
- Integrate a planning and scheduling system as part of an on-board, closed loop controller;
- Scale up existing techniques to larger problem applications.

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).

X1.02 Reliable Software for Exploration Systems
Lead Center: ARC
Participating Center(s): JPL, JSC, LaRC

The objective of this subtopic is to develop software engineering technologies that enable engineers to cost-effectively develop and maintain NASA mission-critical software systems. Particular emphasis will be on software engineering technologies applicable to the high levels of reliability needed for human-rated space vehicles. A key requirement is that proposals address the usability of software engineering technologies by NASA engineers, and not only specialists in the technology.

Many of the capabilities needed for successful human exploration of space will rely on software. In addition to traditional capabilities, such as GNC (guidance, navigation, and control) or C&DH (command and data handling), new capabilities are under development: integrated vehicle health management, autonomous vehicle-centered operations, automated mission operations, and, further out, mixed human-robotic teams to accomplish mission objectives. It will be challenging, but critical to NASA's exploration objectives to ensure that these capabilities are reliable and can be developed and maintained affordably. Mission phases that can be addressed include not only the software life-cycle (requirement engineering through verification and validation) but also upstream activities (e.g., mission planning that incorporates trade-space for software-based capabilities) and post-deployment (e.g., new approaches for computing fault tolerance, rapid reconfiguration, and certification of mission-critical software systems).

Software engineering tools and methods that address reliability for exploration missions are sought, including:

- Automated software generation methods from engineering models that ensure integrity; for example, methods ensuring semantic equivalence between UML models and generated code, generated code optimizations that preserve semantics, and tools that provide navigable two-way traceability from models to code.
- Methods for ensuring safe modification and updates to existing code.
- Scalable verification technologies for complex mission software.
- Automated testing technology that ensures coverage targeted both at the system level and software level.
- Technology for calibrating software-based simulators and testbeds against high-fidelity hardware-in-the-loop testbeds in order to achieve dependable test coverage.
- Cost-effective architectures and methods for software fault tolerance for real-time mission-critical applications.

This subtopic also collaborates with the Small Spacecraft Build effort highlighted in Topic S4 (Low-Cost Small Spacecraft and Technologies). Respondents are encouraged to consider a possible flight opportunity for their proposed work under small spacecraft in addition to considering Exploration customers.

X1.03 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors
Lead Center: LaRC
Participating Center(s): GSFC, MSFC

The goal of leaving low Earth orbit for the purpose of human and robotic exploration will require avionic systems and components that are capable of operating in 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 total ionizing dose (TID) of 100 krads (Si) or more and providing single-event latchup immunity (SEL) of 100 MeV cm^2/mg or more.

Considering the extreme environment performance parameters for thermal and radiation extremes, proposals are sought in the following specific areas:

- Low power, high efficiency, radiation-hardened processor technologies optimized for numerically intensive algorithms and applications, capable of a sustained processor throughput of 5 GMACS for 16-bit operations and a sustained processor efficiency of 5 GMACS/W.
- Field Programmable Gate Array technologies providing reliable reprogrammable capabilities that are radiation hardened by design and/or radiation hardened by process.
- Innovative radiation hardened volatile and nonvolatile memory technologies.
- 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.

X1.04 Integrated System Health Management for Ground Operations
Lead Center: ARC
Participating Center(s): KSC, JPL, MSFC, SSC

Innovative health management technologies are needed throughout NASA's Constellation architecture in order to increase the safety and mission-effectiveness of future spacecraft and launch vehicles. In human space flight, a significant concern for NASA is the safety of ground and flight crews under off-nominal or failure conditions. The stringent launch availability requirements of the Constellation Program challenge traditional vehicle processing and launch operations. Some of the challenges for the new architecture include optimization of sensors (placement, physical and functional redundancy, weight and cost), validation of inherently unreliable sensors, increasing the effective capability for state determination using innovative analysis algorithms, and integration of sensor information distributed across ground support equipment and the vehicles in multiple processing locations and phases. Diagnostic and prognostic analyses which provide an accurate assessment of system and component health will ensure the completion of complex launch processing flows on schedule. Projects may focus on one or more relevant subsystems such as solid rocket motors, liquid propulsion systems, structures and mechanisms, thermal protection systems, power, avionics, life support, and communications. Proposals that involve the use of existing testbeds or facilities at one of the participating NASA centers (ARC, MSFC, KSC, or JPL) for technology validation and maturation are strongly encouraged. Specific technical areas of interest related to integrated systems health management include the following:

- Innovative methods for sensor validation and robust state estimation in the presence of inherently unreliable sensors. Proposals should focus on data analysis and interpretation during pre-flight checkout using legacy sensors rather than development of new sensors or sensor systems.
- Model-based methods for fault detection and isolation in rocket propulsion systems based on existing sensor suites during pre-launch propellant loading and during mission operations.
- Concepts for advanced built-in-tests for spacecraft avionics that reduce or eliminate the need for extensive functional verification and to predict remaining life of avionics systems based on usage history.
- Prognostic techniques able to anticipate system degradation and enable further improvements in mission success probability, operational effectiveness, and automated recovery of function. Proposals in this area should focus on systems and components commonly found in spacecraft.
- Innovative human-system integration methods that can convey a wealth of health and status information to pre-flight check-out crews, ground operations and mission support staff quickly and effectively, especially under off-nominal and emergency conditions.

- Innovative approaches to effective utilization of health information from NASA spacecraft and launch vehicles with seamless integration to ground based systems using commercial health information from programmable logic controller systems and commercial Reliability, Availability and Serviceability (RAS) systems.

TOPIC: X2 Environmental Control and Life Support

Environmental Control and Life Support (ECLS) encompasses the process technologies and equipment necessary to provide and maintain a livable environment within the pressurized cabin of crewed spacecraft and to support associated human systems, such as EVA (Extra Vehicular Activity). Functional areas of interest to this solicitation include thermal control and ventilation, atmosphere resource management and particulate control, waste management and habitation systems, environmental monitoring and fire protection systems. Technologies must be directed at lunar transit and surface missions, including such vehicles as lunar landers, surface habitats and pressurized rovers. Requirements include operation in micro- and partial- (1/6th) gravity and compatibility with cabin atmospheres of up to 34% O_2 by volume and pressures as low as 7.6 psia. Special emphasis is placed on developing technologies that will fill existing gaps; have a significant impact on reduction of mass, power, volume and crew time; and increased safety and reliability. Results of a Phase 1 contract should show feasibility of the technology and approach. A resulting Phase 2 contract should lead to development and evaluation of prototype hardware. Specific technologies of interest to this specific solicitation are addressed in each subtopic.

X2.01 Spacecraft Cabin Ventilation and Thermal Control
Lead Center: JSC
Participating Center(s): ARC, GRC, GSFC, JPL, KSC, LaRC, MSFC

Advanced technologies are sought for cabin ventilation and thermal management for next generation human spacecraft including lunar lander, lunar habitat, and pressurized rovers.

Spacecraft Ventilation
Controlling acoustic noise levels within spaceflight vehicles is needed to provide for adequate voice and ground communications, habitability, and alarm audibility. This will become very important with longer duration missions such as Lunar Habitat and Mars missions. Past experience has shown that controlling acoustic noise levels inside the spacecraft depend upon development of quiet ventilation system and environmental control system fans and pumps, as well as inclusion of effective noise controls to reduce the noise that is created (i.e., source and path technologies).

Advances are sought in the general areas of source noise-level reduction, vibration isolation, acoustic absorption, and sound blocking and sealing (i.e., source and packaging). Noise reduction technology should achieve significant noise reductions (> 5dB) with minimal impacts to performance characteristics (pressure rise and flow rate). Noise reductions and performance capabilities should be demonstrated. Materials should meet flight requirements for flammability, frangibility, and off-gassing. Ventilation fans and fluid pumps are the major source of interior spacecraft noise. Fan and pump technologies that prevent the generation of acoustic noise or limit its transmission to mounting structure or surrounding air are desired. Technologies achieving 5 dB or greater attenuation and accommodating variable equipment speeds, variable acoustic spectrums, and atmospheric pressures from 8 to 15 psia are required.

Thermal Control Systems
Future spacecraft will require more sophisticated thermal control systems that can dissipate or reject greater heat loads at higher input heat fluxes while using fewer of the limited spacecraft mass, volume and power resources. The thermal control designs also must accommodate the harsh environments associated with these missions including dust and high sink temperatures. Modular, reconfigurable designs could limit the number of required spares.

The lunar environment presents several challenges to the design and operation of active thermal control systems. During the Apollo program, landings were located and timed to occur early in the lunar day, resulting in a benign thermal environment. The long duration polar lunar bases that are foreseen in 15 years will see extremely cold thermal environments, as will the radiators for Martian transit spacecraft. Long sojourns remote from low-Earth orbit will require lightweight, but robust and reliable systems.

Innovative thermal management components and systems are needed to accomplish the rejection of heat from lunar bases. Advances are sought in the general areas of radiators, thermal control loops and equipment. Variable emissivity coatings, clever working fluid selection, or robust design could be used to prevent radiator damage from freezing at times of low heat load. Also, the dusty environment of an active lunar base may require dust mitigation and removal techniques to maintain radiator performance over the long term.

The lunar base may include high efficiency, long life mechanical pumps. Part of the thermal control system in the lunar base is likely to be a condensing heat exchanger, which should be designed to preclude microbial growth. Small heat pumps could be used to provide cold fluid to the heat exchanger, increasing the average heat rejection temperature and reducing the size of the radiators.

Thermal management of the lunar habitat, landers, and rovers may require mechanically pumped two-phase fluid loops. Innovative design of the loops and components is needed.

Future space systems may generate large amounts of waste heat which could either be rejected or redirected to areas which require it. Novel thermal bus systems which can obtain, transport, and reject heat between various components are sought. The system should be highly configurable and adaptable to changes in equipment locations. Large diurnal temperature changes in the environment are expected. Possible systems include single and two-phase pumped fluid loops, capillary-based loops, and heat pumps.

A scaling methodology is needed to allow long term 1-g testing of two-phase systems (including pumped two-phase loops, heat pumps, and condensing heat exchangers) representative of the $1/6^{th}$ Earth-normal gravity of the Moon.

X2.02 Spacecraft Cabin Atmospheric Resource Management and Particulate Matter Removal
Lead Center: MSFC
Participating Center(s): ARC, GRC, JSC, KSC

Particulate Matter Removal and Disposal
Particulate matter suspended in the habitable cabin atmosphere is a challenge for all phases of exploration missions. Removing and disposing of particulate matter originating from sources internal to the habitable cabin and from surface dust intrusion is of interest. Process technologies and equipment that efficiently remove the range of particulate matter sizes and morphologies encountered in a crewed spacecraft cabin from the atmosphere and surfaces are sought. Candidate technology solutions should provide high efficiency and long-lived removal capacity. Successful process technologies must be tolerant of the abrasive properties of lunar surface dust. Performance should be demonstrated with appropriate lunar dust analogs or simulants. Process technologies sought must be highly efficient and promote safe disposal of accumulated particulate matter. Areas of emphasis include:

- Removal and Disposal of Fine Particulate Matter Suspended in a Cabin Atmosphere: It is hypothesized that fine particulate matter introduced into the cabin will be detrimental to crew health. Filtration technologies are sought that will limit the levels of lunar dust contaminants of less than 10 micron size in the cabin atmosphere below 0.05 mg/m^3 while providing significantly improved capture efficiency with minimal pressure drop. These may include but are not limited to mechanical filtration, inertial separation and impingement, and electrostatic and/or electrically enhanced separation solid-gas processes that are lightweight, low power and operate at reduced atmospheric pressures. Process technologies that offer both improved efficiency and are suitable for in situ regeneration as described below are preferred. Novel techniques and materials are of interest.

- Regenerative Processes and Filters: Regenerable solid-gas separations techniques and process technologies are sought that effectively handle a broad size range from >100 microns in aerodynamic diameter to <1 micron in aerodynamic diameter. These techniques and process technologies must be able to separate and dispose of accumulated particulate matter while employing minimal consumable resources. Salient features for this application include suitability for in situ regeneration, large bulk removal capacity, and high efficiency. Operational modes of continuous regeneration or long interval regeneration cycles using either single or multi-stage regeneration processes will be considered. Methods for determining and annunciating the loading and unloading status of the regenerative unit and for automated regeneration are of interest.
- Vacuum Cleaner for Planetary Surface Vehicles and Habitats: Portable crew-operated devices for removing particulate matter from a wide range of surfaces (polymer, metallic, and fabric), operating at cabin atmospheric pressures ranging from 8 to 15 psia, and minimizing electrical power and acoustic noise generation are of interest. Successful devices may employ several of the above mentioned processes or filtration systems to remove a wide range of particulate matter sizes up to 2 mm in aerodynamic diameter without contaminating the air with ultrafine particulates. The ability for the portable device to be operated as a supplemental, portable cabin air filtration unit is a plus.

Atmospheric Resource Management

Atmospheric resource management encompasses process technologies and equipment to supply, store, and condition atmospheric gases; provide gaseous oxygen at pressures at or above 3,600 psia; and achieve mass closure by recycling resources and using in situ resources. Areas of emphasis include:

- Carbon Dioxide Reduction for Recovery of Oxygen: Process technologies for reducing carbon dioxide to a carbon product via high single-pass reaction efficiency with a product yield >90% are of interest. Successful process technologies and/or process technology unit operations combinations must demonstrate efficient power use and address safety issues associated with traditional reduction processes.
- High Pressure Oxygen Gas Supply: Process technologies leading to an on-demand, in-flight renewable source of oxygen at or above 3,600-psia are of interest. Process technologies employed for achieving these needs may include mechanical compressors, temperature or pressure-swing adsorption compressors, high pressure electrolytic oxygen production or other novel means.

X2.03 Spacecraft Habitation and Waste Management Systems
Lead Center: ARC
Participating Center(s): GRC, JSC, KSC, MSFC

Waste management and habitation systems supporting critical needs for lunar mission architectures are requested. Improved technologies for recovery of water and other resources as well as safe long term stabilization and storage of residuals inside and outside the habitat are needed. Waste processes collect, process, recover resources, stabilize, and store residuals. Proposals should explicitly describe the weight, power, and volume advantages of the proposed technology.

Clothing/Laundry Systems

Clothing is a major consumable and trash source. Low mass reusable or long usage clothing options that meet flammability, out gassing, and crew comfort requirements are desired. Techniques, equipment, and clothing material that extend clothing life, facilitate clothing washing/drying, low consumable mass/volumes, low acoustic generation, and low water usage are desirable. Technologies must minimize crew time, be compatible with lunar gravity, atmospheric pressures from 8 to 15 psia, minimize electrical power, minimize acoustic noise generation, be flame resistant in 32% oxygen environments, have low outgassing, and have non-toxic cleaning agents waste products compatible with biological water processing and atmospheric trace contaminant control.

Waste Management

Wastes (trash, food packaging, feces, paper, tape, filters, water brines, clothing, hygiene wipes, etc.) must be managed to protect crew health, safety, and quality of life, to avoid harmful contamination of planetary surfaces, and to recover useful resources. Areas of emphasis include:

- Solid waste stabilization including water removal and recovery of water from wet wastes (including human fecal wastes, food packaging, brines, etc.);
- Solid waste storage and odor control (e.g., catalytic and adsorptive systems);
- Energy efficient/internal heat recycling waste pyrolysis systems for mineralization of wastes and recovery of resources.

X2.04 Spacecraft Environmental Monitoring and Control
Lead Center: JPL
Participating Center(s): ARC, GRC, JSC, KSC, MSFC

Monitoring technologies are employed to assure that the chemical, microbial and particulate content of the air and water environment of the astronaut crew habitat falls within acceptable limits, and that the chemical or biological life support system is functioning properly. The sensors may also provide data to automated control systems.

Technologies should be appropriate for a small crewed mission to the Moon, of duration no more than a few weeks. Emphasis is on airborne lunar dust and atmospheric major constituents. Extendibility of the technology to trace gas monitoring for longer missions is a plus; systems that do only trace gases are not requested. Significant improvements are sought in miniaturization, accuracy, precision, and operational reliability, as well as long life, real-time multiple measurement functions, in-line operation, self-calibration, reduction of expendables, low energy consumption, and minimal operator time/maintenance for monitoring and controlling the life-support processes. Proposals should be for either new technologies or combine existing technologies in a new way.

Lunar surface dust may be encountered during astronaut excursions and may be a mechanical or chemical threat both during the external encounter and if brought inside. Monitoring technologies are needed to assess and quantify these threats. In addition to sizing, concentration and size distribution, technologies are needed to rapidly chemically characterize the dust itself. A dust monitor for the respirable range only of less than 20 μ is also desired.

A compact sensor that measures all 3 major atmospheric constituents (O_2, H_20 and CO_2) is desired. Since it would replace a rather large unit, size and power are major drivers. While it is difficult to detect, an N_2 sensor would be a useful part of air monitoring.

For longer missions, water monitoring requires sensitive, fast response, online analytical sensors. There is an important need to for a compact total organic carbon (TOC) sensor. A major desire is that these immersible water quality sensors are reversible; i.e., they tracks analyte changes in water without having to replace any sensor chemistry element. Other water quality needs include measurement of dissolves gases, ions and polar organic compounds such as methanol, ethanol, isopropanol, butanol, and acetone in water.

Results of a Phase 1 contract should show feasibility of the technology and approach. A resulting Phase 2 contract should produce at least a prototype demonstration and test of the environmental monitor.

X2.05 Spacecraft Fire Protection
Lead Center: GRC
Participating Center(s): ARC, JPL, JSC, KSC, MSFC

NASA's fire protection strategy includes: strict control of ignition sources and flammable material, early detection and annunciation of fire signatures, and effective fire suppression and response procedures. While proposals in all of these areas are applicable, they are particularly sought in the areas of nonflammable crew clothing and fire suppression technology.

The requirements for crew clothing are balanced between comfort, durability, and flammability. Non-flammable alternatives are requested for shirts, shorts, sweaters, jackets, etc. and, ideally, would be available in a variety of colors and weights. For exploration missions, clothing should be nonflammable up to 34% O_2 by volume without being stiff and uncomfortable. The flammability characteristics of the clothing must be maintained through the recommended cleaning process.

Fire suppression technologies for exploration spacecraft and habitats must:

- Be applicable for use in a confined habitable volume having an atmosphere of up to 34% O_2 by volume and pressures as low as 7.6 psia;
- Be suitable for use in a portable fire extinguisher against fires behind panels and close-outs or the cabin open volume;
- Have minimal mass and volume requirements including consumables required for post-fire clean-up; and
- Be compatible with the spacecraft environmental control and life support system.

Results of a Phase 1 contract should show feasibility of the technology and approach. A plan for the demonstration of a prototype to be developed in Phase 2 should also be produced at the end of Phase 1. The Phase 2 contract should produce at least a prototype demonstration and test of the fire suppression system.

TOPIC: X3 Lunar 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. In particular, 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 lunar landscape for safer landing, transfer of payloads from the lander to an outpost, dust generation mitigation, and infrastructure emplacement and buildup are also extremely important for long-term lunar operations. To perform these tasks on the lunar surface, detailed knowledge of the terrain, local minerals and potential resources, and subsurface futures is important for planning and operations at the start of establishing long-term human presence on the lunar surface. Lastly, since ISRU systems and operations have never been demonstrated before in missions, it is important that ISRU concepts and technologies be evaluated under relevant conditions (1/6 g and vacuum) as well as anchored through modeling to lunar soil and environmental conditions. With this in mind, the ISRU Project within the Exploration Technology Development Program (ETDP) has initiated development and testing of hardware and systems in three main focus areas: (1) Regolith Excavation, Handling and Material Transportation; (2) Oxygen Extraction from Regolith; and (3) ISRU Development & Precursor Activities. The purpose of the following subtopics is to develop and demonstrate hardware and software technologies that can be added to on-going analysis and ISRU capability development and demonstration activities in ETDP to meet Outpost architecture and surface manipulation objectives for near and long term human exploration of the Moon.

X3.01 Lunar Regolith Excavation and Material Handling
Lead Center: JSC
Participating Center(s): GRC, KSC

The lunar regolith excavation, handling, and material transportation subtopic includes all aspects of lunar regolith handling for oxygen and other resource collection and site preparation and Outpost infrastructure emplacement, including tasks such as clearing/leveling landing areas and pathways, buildup of berms and burying of reactors or habitats for radiation protection. Excavation capabilities may involve excavation and collection of both unconsolidated and consolidated surface regolith. Hardware must be able to operable over broad temperature ranges (generally 110K to 400K) and in the presence of abrasive lunar regolith and partial-gravity environments. Expectations for maintenance by crew must be minimal and affordable. Therefore, general attributes desired for all proposed hardware include the following: lightweight, abrasion resistant, vacuum and large temperature variation compatible materials, low power, robust/low maintenance, and minimize dust generation/saltation during operation. Specific software and hardware for insertion into on-going ISRU Project development and demonstration activities include:

- Excavation hardware for oxygen production: Unconsolidated material, 17 kg/hr based on hydrogen reduction, <10 cm deep; avoid or mitigate rocks >5 cm diameter (See note on mobility platform below).
- Excavation hardware for deep digging: Consolidated material, 3 m deep and 1 meter in diameter at a minimum; (See mobility platform note below).
- Granular materials mixing and separation for reactor feedstock conditioning: remove material > 0.5 cm diameter before dumping into storage bin during excavation operation for oxygen extraction from regolith.
- Dust tolerant, lightweight mechanisms and actuators for excavation and material transport operations.
- Site preparation hardware, automation, and control for surface contouring and area clearing and leveling.
- Site preparation hardware, automation, and control for berm building; 3 meters tall; 45 degree slope minimum based on landing plume mitigation.

Phase 1 proposals should demonstrate technical feasibility of the technology and/or subsystem through laboratory validation of critical aspects of the innovation proposed, as well as the design and path toward delivering hardware/subsystems in Phase 2 for incorporation into existing development activities.

Proposers are encouraged to use the Lunar Sourcebook at a minimum for understanding lunar regolith material parameters in the design and testing of hardware proposed. To determine implement size and time required to complete tasks, proposers have three options for surface mobility: 1) part time use of NASA's large crew rover currently under development (2000 kg mass, 1.33 m wide, 4.5 m long, and 0.2 m high chasse frame, 0 to 0.67 m frame height variation capability from surface), 2) operation on a smaller dedicated ISRU rover yet to be developed, 3) optimize vehicle size to minimize total system mass and power. For option 2, interface requirements for on-going development efforts will be provided after selection. For option 3, proposers may evaluate surface mobility aspects in their proposal but cannot exceed 35% of the budget for the proposed effort.

X3.02 Oxygen Production from Lunar Regolith
Lead Center: JSC
Participating Center(s): GRC, KSC, MSFC

Oxygen (O_2) production from lunar regolith processing consists of receiving regolith from the excavation subsystem into a hopper, transferring that regolith into a chemical or an electrochemical reactor, intermediate reactions to produce O_2 and regenerate reactants if required, purification and transfer of the O_2 produced, and removal of processed regolith from the reactor to an outlet hopper. Three O_2 production from lunar regolith reaction concepts are currently under development: Hydrogen reduction, Carbothermal reduction, and Molten Oxide Electrolysis at initial lunar Outpost production scale of 1 to 2 MT per year. The production plant will utilize solar power, and two operation options are: 1) operate at polar location with solar energy available for processing to occur 70% of the year with highlands soil feedstock, and 2) operation at an equatorial location with solar energy available for processing to occur 45% of the year with mare soil feedstock. To maximize the benefits of ISRU for lunar missions,

O_2 production systems must be able to produce many times their own mass in O_2 and other products, must be able to autonomously operate in a harsh environment that can have wide temperature swings, and must operate with little or no maintenance and little or no loss of reactants and O_2 while handling and processing highly abrasive lunar regolith. Systems must also be able to sustain numerous startup and shutdown sequences when solar power is not available. Shutdown periods can vary from twenty hours to 14 days.

This subtopic is seeking hardware, subsystem, and system components and technologies for insertion and integration into on-going oxygen extraction from regolith development and demonstration efforts. Component and technology areas of particular interest are:

- Move feedstock material from hopper on ground to 2 m height for reactor inlet hopper; 40 kg/hr; material size <0.5 cm diameter.
- Inlet/outlet regolith hopper design and valve/seal concepts with no gas leakage, 1000's of operating cycles with abrasive lunar material, and minimum heat loss.
- Methods and hardware for recovering heat energy from spent regolith to pre-heat inlet regolith; 1050°C spent regolith temp, 750°C inlet regolith starting temp; 20 kg/batch.
- Molten material removal from molten electrolysis; 5 to 10 kg per batch size.
- Non-eroding cathode/anode concepts for molten oxide electrolysis; 5 to 10 kg batch size.
- Water condensers that use the space environment for water condensation/separation with minimal energy usage.
- Gas Separators that provide low pressure drop separation of the system and product gas streams from impurities (e.g. HCl, HF, H_2S, SO_2); impurities in ppm quantities.
- Microchannel methanation reactors that convert a mixture of carbon monoxide, carbon dioxide, and hydrogen to methane and water vapor with carbon monoxide and carbon dioxide consumed to the maximum extent possible.
- Advanced reactor concepts for carbothermal reduction or molten oxide electrolysis.

Phase 1 proposals should demonstrate technical feasibility of the technology or hardware concept through laboratory validation of critical aspects of the innovation proposed, as well as the design and path toward delivering hardware/subsystems in Phase 2 for incorporation into existing development activities. Interface requirements for on-going development efforts will be provided after selection. Proposers are encouraged to use the Lunar Sourcebook at a minimum for understanding lunar regolith material parameters in the design and testing of hardware proposed. It is also recommended that JSC-1a simulants be used during testing unless a more appropriate simulant can be obtained or manufactured.

X3.03 Lunar ISRU Development and Precursor Activities
Lead Center: JSC
Participating Center(s): GRC, JPL, KSC, MSFC

The ISRU Project has initiated development and testing of hardware and systems that can achieve early lunar Outpost needs with respect to oxygen (O_2) production from regolith and site preparation and outpost infrastructure emplacement. However, before ISRU hardware will be built and deployed on the lunar surface for Outpost operations, ISRU concepts and operations will need to be anchored through computer modeling, evaluated under simulated lunar environmental conditions (1/6 g and vacuum), and possibly on precursor flight missions. Secondly, before outpost emplacement occurs and O_2 production from lunar regolith begins, detailed knowledge of the terrain, local minerals, and potential resources is important for planning and operations at the start of establishing long-term Outpost capabilities. Lastly, while the other two ISRU subtopics are specifically aimed at increasing the fidelity and performance of on-going development activities at a scale appropriate for early lunar Outpost needs, it is recognized that evaluating the feasibility and benefits of other technologies and concepts not ready for insertion into these efforts should be pursued. With these objectives in mind, this subtopic is aimed at providing development support capabilities, sub-scale or precursor hardware that can be evaluated under simulated lunar environmental conditions

(1/6 g and/or vacuum), and advanced ISRU concepts not ready for incorporation into current ISRU system laboratory and field test activities. Proposals aimed at the following are of particular interest:

- Computer models to predict excavation-tool soil interaction and flow behavior of lunar regolith under vacuum conditions and 1/6 g for hardware design and performance prediction.
- Vacuum compatible geotechnical instruments to verify soil bin characteristics; instruments that can be mounted and operated from rovers for field testing are also of interest.
- Mineral beneficiation concepts to separate iron oxide-bearing material from bulk regolith; up to 20 kg/hr based on hydrogen reduction. Hardware/concepts need to be designed for compatibility with both 1/6 g flight experiments and ground vacuum experiments.
- Lunar regolith storage and granular flow devices and instruments to evaluate and characterize regolith behavior under 1/6 g flight and ground vacuum experimental conditions.
- Advanced excavation implement concepts and hardware that can utilized to evaluate implement/soil interaction characteristics under 1/6 g flight and ground vacuum conditions.
- Development of specialty lunar simulants for beneficiation and microwave processing of lunar regolith; proposals must estimate production costs per kilogram by end of Phase 1.
- Lunar surface stabilization and regolith binding methods (including but not limited to sintering and melting) for level areas and trench/berm walls; bearing strength and smoothness requirements are not currently established but should be considered in the proposal.
- Processing concepts for production of carbon monoxide, carbon dioxide, and/or water from plastic trash and dried crew solid waste using solar thermal energy; in situ produced oxygen or other reagents/consumables must be identified and quantified; recycling schemes for reagents to minimize consumables should be evaluated.

Phase 1 proposals should demonstrate technical feasibility of the technology and/or subsystem through laboratory validation of critical aspects of the innovation proposed, as well as the design and path toward delivering hardware/subsystems in Phase 2. Hardware/concepts need to be designed for compatibility with both 1/6 g flight experiments and ground vacuum experiments.

TOPIC: X4 Structures, Materials and Mechanisms

The SBIR topic area of Structures, Materials and Mechanisms centers on developing lightweight structures, advance materials technologies, and low-temperature mechanisms for enabling Exploration Vehicles and Lunar Surface Systems.

Lightweight structures and advanced materials have been identified as a critical need since the reduction of structural mass translates directly to additional up and down mass capability that would facilitate additional logistics capacity and increased science return for all mission phases. The major technology drivers of the lightweight structure technology development are to significantly enhance structural systems by 1) lowering mass and/or improving efficient volume for reduced launch costs, 2) improving performance to reduce risk and extend life, and 3) improving manufacturing and processing to reduce costs. The targeted application of the technology is the Ares V launch vehicle, Lunar Lander, and Lunar Surface Systems such as the crew habitats.

Low-temperature mechanism technology is being developed for reliable and efficient operation of mechanisms in lunar temperatures including operations in lunar shadows at -230°C and sustained surface operations thru varying lunar temperatures of -230°C to +120°C for lunar surface rovers, robotics, and mechanized operations. The technology drivers of the low temperature mechanism technology development are to significantly enhance operation of mechanized parts by 1) lowering the operating temperature for life of the component and 2) improving mechanism performance (torque output, actuation performance, lubrication state) at the lunar environment conditions of cold and vacuum over the required 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 lunar rovers and mobility systems, ISRU machinery, robotic systems mechanisms, and surface operations machinery (i.e., cranes, deployment systems, airlocks) for lunar surface operations.

This topic area is to enhance and fill gaps in technology development programs in the Exploration Technology Exploration Program Structures, Materials, and Mechanisms Project. Areas of development included in the SMM project include: low temperature drive system, motor, and gearbox system, personal kit radiation shielding materials, low density parachute material systems, expandable structural systems, Friction stir welded spun-domes, and advance composite structures. This topic area is responsible for mid-level technology research, development, and testing through experimental and/or analytical validation.

X4.01 Low Temperature Mechanisms
Lead Center: GSFC
Participating Center(s): GRC, JPL, JSC, LaRC

This subtopic focuses on the development of selected hardware and lubricants to support technologies for motors and drive systems (e.g., gear boxes) that will operate in cryogenic temperature environments such as permanently shaded craters on the Moon, and/or on the lunar surface exposed to the day/night cycle. In the former situation such mechanisms may be exposed to, and will need to operate in, sink temperatures as low as approximately 25K. In the latter situation they will need to operate over a temperature sink range of approximately 83K to 403K (-190°C to +130°C). A five year lifetime is desired. The component technologies developed in this effort will be utilized for rovers, cranes, instruments, drills, crushers, and other such facilities. The nearer term focus for this effort is for lunar missions, but these technologies should ideally be translatable to applications on Mars. These components must operate in a hard vacuum and/or planetary environment, 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 low temperature motors (in the range of 100W to 5 kWatts), gear boxes, lubricants, and closely related components that are suitable for the environments discussed above. One lubrication technology of specific interest is ionic fluids. Proposals for ionic fluid lubricant improvement should identify and/or formulate low volatility, non-corrosive extreme pressure (EP) and anti-wear additives for ionic fluid space lubricant candidate materials. Lubricant proposals should also include a sufficient quantity of the formulated end product so as to allow standard STLE 4-ball evaluation testing, comparing neat (unformulated) base ionic fluid performance to formulated ionic fluid performance.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

X4.02 Advanced Radiation Shielding Materials and Structures
Lead Center: LaRC
Participating Center(s): ARC, GSFC, MSFC

Advances in radiation shielding materials and structures technologies are needed to protect humans from the hazards of space radiation during NASA missions. The primary area of interest for this 2008 solicitation is radiation shielding materials and structures for protection from long-duration lunar surface galactic cosmic radiation (GCR). The particular radiation species of greatest concern are protons, light ions, heavy ions, and neutrons. Research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path toward a Phase 2 technology demonstration. Specific areas in which SBIR-developed technologies can contribute to NASA's overall mission requirements for advanced radiation shielding materials and structures include the following:

- Innovative lightweight radiation shielding materials and structures to shield humans in crew exploration vehicles, landers, rovers, and habitats and during lunar surface operations.
- Physical, mechanical, structural, and other relevant characterization data to validate and qualify multifunctional radiation shielding materials and structures.
- Innovative processing methods to produce quality-controlled advanced radiation shielding materials of all forms - resins, fibers, fabrics, foams, composites, light alloys, and hybrid materials.
- Innovative concepts to reuse, recycle, and reprocess materials and structures in space for use as radiation shielding materials and structures.

X4.03 Expandable Structures
Lead Center: LaRC
Participating Center(s): JPL, JSC, MSFC

This subtopic solicits innovative concepts that support repair operations for expandable structures. Primary pressurized expandable habitats for lunar surface systems (LSS) are the targeted structures. Expandable structures are desired within the Constellation Program to minimize launch mass/costs, and to obtain optimal structural performance for loads, environments, and habitation on the lunar surface. To ensure that expandable structures are viable options for LSS, several areas of risk need to be mitigated. In particular, research and technology development work needs to occur in the areas of material performance, durability in the presence of micrometeoroid impact, ground handling, dust effects, damage tolerance, and repair techniques.

Solicitations for repair techniques for expandable structures can encompass material patches, adhesives, rigidized materials, self-healing materials, stitching, and extraction and replacement of structural components. Coatings or films that enhance and improve the robustness of the parent expandable material are also being sought under this announcement. The durability of the repair technique should be considered. The primary risk of a minor material failure due to a puncture or tear needs to be directly addressed in the solicitation. Time of repair, cost, and repair components will also be reviewed. NDE of a potentially damaged area, or repaired area are not primary areas of concern for this solicitation.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration, and when possible, delivery of a demonstration package for functional and environmental testing at the completion of the Phase 2 contract.

X4.04 Composite Structures - NDE/Structures Health Monitoring
Lead Center: JSC
Participating Center(s): ARC, JSC, LaRC

Monitoring systems for advanced composite structures on the Exploration Program vehicles and systems lack sensors that are practically deployable. Monitoring is needed for improved robustness and reliability of composite structures or the mass advantage and performance of composites may not be realized. Adding sensors efficiently at any point in the vehicle lifetime is a necessity since some monitoring is needed for troubleshooting, validation of the loads, strain and thermal environment.

Sensors and their acquisition systems are needed that require a reduced wire infrastructure. Acoustic Emissions (AE) sensors have been shown to receive indications well out ahead of failure. Since propagation distance varies with each configuration and expected fault, many sensors will be needed to ensure composite health. The amount of wiring needed with standard approaches can offset much of the weight savings from composites and increase costs.

New AE sensor mounting methods and flexible sensors are needed that accommodate sometimes highly curved surfaces, don't fail or unbond at cryogenic tank temperatures and withstand high G loading. Very small sensors will need to be embedded at times to accommodate cases where attaching is impractical or the phenomenon can best be measured from within the composite structure.

Wireless sensors and wireless data acquisition systems with local processing of the composite structures events are needed to reduce the wiring and total data handling needs. Totally passive wireless sensor-tags can have advantages in certain applications.

Applications include: Advanced composite structures such as cryotanks, large area composites such as launch vehicle fairings, hard to access/inspect composite members, as well as metallic pressurized structures of all kinds. Interior as well as exterior measurements of the pressure vessel are needed.

Technologies: Flexible, highly efficient piezo materials for sensors, passive sensor-tags for communication, compact sensor data systems for modularity. Versions may be adaptable for acceleration, displacement/strain monitoring CEV parachutes as well for inflatable habitats.

TRL-3 should be achievable by the end of Phase 1.
TRL-6 should be achievable by the end of Phase 2.

X4.05 Composite Structures - Cryotanks
Lead Center: LaRC
Participating Center(s): GRC, GSFC, JSC, LaRC, MSFC

While Aluminum-lithium may be adequate for cryotanks (for immediate use and long-term storage) the use of composite materials offers the potential of significant weight savings. Composite cryotank technology would be applicable to EDS propellant tanks, Altair propellant tanks, lunar cryogenic storage tanks and Ares V tanks.

A material system (resin + fiber) which displays high resistance to microcracking at cryogenic temperatures is necessary for linerless cryotanks which provide the most weight-saving potential. This SBIR will focus on development of toughened, high strength composite materials because the literature indicates that they have the highest microcrack resistance at cryogenic temperatures.

Greatest interest is in novel approaches to increase resin strength and/or reduce resin CTE, thereby increasing resistance to microcracking at cryogenic temperature. Possible topics could include use of toughening agents, novel surface treatments for carbon fibers, reduced-temperature curing methods that reduce residual thermal stresses, etc.

Performance enhancements would be evaluated by a characterization program, which would ideally generate temperature-dependent material properties including strength, modulus, and CTE as functions of temperature. Additionally, notch sensitivity, plain strain fracture toughness, and microcracking fracture toughness as functions of temperature are desirable.

Tests will need to be performed at temperatures between -273°C and 23°C to fully characterize any nonlinearity in material properties with changes in temperature.

Initial property characterization would be done at the coupon level in Phase 1. Generation of design allowables, characterization of long-term material durability, and fabrication of larger panels would be part of follow-on efforts.

X4.06 Composite Structures - Manufacturing
Lead Center: MSFC
Participating Center(s): ARC, GRC, GSFC, LaRC

This subtopic solicits innovative research for advanced composite materials processing and characterization concepts that support the development of lightweight structures technologies that should be applicable for space transportation vehicle systems. Interests are in advanced composite structures, which can be tailored for strength, stiffness, weight and temperature capabilities with high performance at a lower cost. Reduction in structural mass translates directly to additional up-and-down mass capability that would facilitate logistics and increase science return for future missions. Advanced composites are targeted that could be implemented into launch vehicles, lunar landers, and habitats. Innovations in technology are needed for manufacturing, processing and bonded joints for structural and cryogenic applications. Manufacturing processes of interest are automated composite fiber/tape placement, non-autoclave curing, and bonding of composite joints. Development of concepts can include material system characterization, proof-of-concept demonstrations for lightweight structures, enabling performance, and affordability (including life cycle costs) enhancement.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 prototype demonstration. Demonstrate manufacturing technology that can be scaled up for very large structures.

TOPIC: X5 Lunar Operations

This call for technology development is in direct support of the Exploration Systems Mission Directorate (ESMD) Technology Development Program. The purpose of this research is to develop component level technologies to support the Constellation Program's human lunar return missions. These initial missions will be heavily engaged in construction methods, establishing self-sustaining power generation, and producing life support consumables in situ in order to establish continuous operational capability via Earth based and lunar based assets.

The objective is to produce new technology that will reduce lunar operations workloads associated with crew extra-vehicular activities (EVA) and intra-vehicular activities (IVA), and reduce the total mass-volume-power of equipment and materials required to support both short and long duration Lunar stays. The proposals must focus on component technologies to maximize the operations of exploration hardware allowing for less expensive, more productive and less risky missions.

Lunar operations are a stepping stone toward higher exploration goals. This research focuses on technology development for the critical functions that will secure an extended human presence on the Lunar surface and ultimately enable surface exploration for the advancement of scientific achievements. Surface exploration begins with short duration missions to establish extensible functional capabilities. Successive buildup missions establish a continuous operational platform from which to conduct scientific research while on the lunar surface. Reducing risk and ensuring mission success depends on the coordinated interaction of many functional systems including life support, power, communication infrastructure, and transportation. This topic addresses technology needs associated with Lunar surface systems, interaction of humans and machines, and extended operational life-cycles of resources by way of eliminating environmental contamination of mechanisms.

X5.01 Lunar Surface Systems
Lead Center: JSC
Participating Center(s): ARC, GRC, GSFC, JPL, KSC, LaRC, MSFC

The objective of this subtopic is to address projected technology needs for surface system elements supporting lunar operations. Communication integrity between lunar assets is essential during crewed translation across the lunar surface as well as during uncrewed autonomous translation of mobile assets. Navigation is essential to performing many lunar surface tasks, including exploration traverses, site surveys, material/payload transport, etc. The current lunar architecture plan for lunar surface navigation focuses on a deployed infrastructure-based solution (fixed radiometric towers, comm/nav orbiters, etc.) Although this approach is appropriate for outpost-centric operations, it is insufficient for operations in rough and steep terrain (e.g., inside deep craters) or when activity is temporarily required in regions without coverage. Commodities distribution systems (including umbilicals/connectors) will be employed to route communication and power lines to remote equipment and surface assets. These new capabilities are required to make planetary surface missions more reliable, safer, and affordable.

Maximizing the useful life of surface assets is essential to a successful lunar program. Material components must be robust and tolerate extreme temperature fluctuations and endure harsh environmental effects due to solar events, micrometeorite bombardment, and abrasive lunar dust.

Proposals are sought which address the following technology needs:

- Electrical connectors that can be repeatedly mated and de-mated (5000+ cycles) without failure in a contaminating environment consisting of regolith grain size ranging from 100um down to 10um. Capable of carrying 10kw of power transmission. Automated mating and de-mating is required.
- Lunar wireless network. Must support 15 simultaneous users with aggregate bandwidth of 80mbs at extended ranges to at least 5.6km. Must support minimum data rates of 16kbs and maximum data rates of 20mbs. Must be able to convert conventional IP stacks to SN stacks.
- Navigation and communication infrastructure technologies for use on the Lunar surface to support surface mobility and communication between lunar base, EVA astronaut and mobile rover/robotic assistant. Communication infrastructure not limited to surface-based assets but could include orbiting communication assets as well. Line of site communication must be maintained at all times. Redundant communication paths assure constant communication link and reduce the possibility of loss of communication. Data rates in excess of 200 Mbps for comm network. Less than 100W system power. Coverage area on the order of 100 km radius from a central point.
- Passive navigation sensors to improve surface vehicle operation: collision avoidance, hazard detection, relative positioning (to artificial and natural objects). Emphasis is placed on sensors that can function in a wide range of lunar conditions (illumination, temperature, etc.)
- Flight vehicle sensors repurposed for surface use. Numerous flight sensors (low light imager, star tracker, 3D flash & scanned lidar) may be suitable for lunar surface operations if modified appropriately.

X5.02 Surface System Dust Mitigation
Lead Center: GRC
Participating Center(s): GSFC, KSC, JPL, JSC, LaRC, MSFC

Lunar lander and surface systems will likely employ common hatch and airlock systems for docking, mating, and integration of spacecraft, habitat, EVA, and mobility elements. The large number of EVAs will require hatches that are safe if non-pressure assisted, and do not have to be serviced or replaced regularly.

Lunar lander will require materials and mechanisms that do not collect dust and do not abrade when in contact with lunar regolith. Technologies are also needed to remove lunar regolith, including dust, from materials and mechanisms.

Lunar Surface systems will require EVA compatible connectors for fluid, power, and other umbilicals for transfer of consumables, power, data, etc. between architecture elements that will maintain functionality in the presence of lunar regolith, including dust.

Lunar surface systems (power, mobility, etc.) will require gimbals, drives, actuators, motors, and other mechanisms with required operational life when exposed to lunar regolith, including dust.

Radiators and other thermal control surfaces for lander and surface systems must maintain performance and/or mitigate the effects of contamination from lunar regolith, including dust.

X5.03 Extravehicular Activity (EVA)
Lead Center: JSC
Participating Center(s): GRC

Proposals are sought which address the following technology needs of the advanced extravehicular activity (EVA) system:

Space suit pressure garment radiation and puncture protection technologies, dust and abrasion protection materials, flexible thermal insulation suitable for use in vacuum and low ambient pressure, and space suit low profile bearings. Technology development is needed for minimum gas loss airlocks providing quick exit and entry, suit port/suit lock systems for docking a space suit to a dust mitigating entry/hatch, and active and passive space suit and equipment dust removal technologies.

Portable life support system (PLSS) technologies that are robust, lightweight, and maintainable. PLSS technologies require a minimum of 100 EVAs x 4 life cycles (3200 hrs). High-capacity chemical oxygen storage systems for an emergency supply of oxygen, low-venting or non-venting regenerable individual life support subsystem concepts for crew member cooling, heat rejection, and removal of expired water vapor and CO_2; lightweight convection and freezable radiators for thermal control with a mass usage of water not to exceed 1.9 kg; innovative garments that provide direct thermal control to crew member.

Space suit displays, cameras, controls, and integrated systems technologies for gathering, processing, and displaying various types of information to the suited crew member, using low mass, low volume, low power, radiation hardened or tolerant equipment. Technology development is needed in the area of suit health and crew health sensors; cameras; and displays, mounted both inside and outside the space suit. Research is also needed for lightweight, low power general purpose computing platforms, such as processors or FPGAs to allow the use of on-suit software applications such as biomedical advisory algorithms, procedure displays, navigation displays, and voice recognition applications. Low computational overhead voice recognition processing systems capable of performing on lightweight radiation tolerant embedded computing platforms are also desired.

TOPIC: X6 Energy Generation and Storage

This topic includes technology development for batteries, fuel cells, regenerative fuel cells, and fission and isotopic power systems for the Altair lunar lander and surface operations on the Moon and Mars. Technologies developed must be infused into these Constellation program elements: primary fuel cells for the Altair lunar lander descent stage, secondary batteries for the Altair ascent stage, secondary batteries for extravehicular activities (EVA) suits, and regenerative fuel cells, fission and isotopic power systems on the Moon and Mars to power habitats, in situ resource production, and mobility systems. Specific technology goals and component needs are given in the subtopics. General mission priorities for energy storage and generation include:

- EVA suits require secondary batteries sufficient to power all portable life support, communications, and electronics for an 8-hour mission with minimal volume. Battery operation required for six months and 100 recharge cycles with a shelf life of at least two years. Mission priorities include human-safe operation; 8-hr duration; high specific energy; and high energy-density.
- Secondary batteries for the Altair ascent stage require nominally 10 recharge cycles with 1.7 kW nominal power and 2 kW peak power, operating for 7 hours continuously. Mission priorities include human-safe, reliable operation and high energy-density in a 0 – 30°C and 0 – 1/6 gravity environment.
- The Altair descent stage requires a fuel cell with a nominal power level of 3 kW with 5.5 kW peak, operating for 220 hours continuously. Mission priorities include human-safe reliable operation; the ability to scavenge available fuel; and high energy-density.
- Regenerative fuel cells, which combine a fuel cell with a water electrolyzer, have been baselined for lunar surface system operations. Mission priorities include reliable, long-duration maintenance-free operation;

human-safe operation; high specific-energy; and high system efficiency in a 0 – 100°C, 1/6 gravity environment.
- Architecture studies have identified nuclear power technology to effectively satisfy high power requirements for extended duration lunar surface missions. Nuclear power generation is especially attractive for missions with significant solar eclipse periods, including non-polar locations and inside lunar craters, as well as Mars outposts.
- Power systems for lunar rovers require human-safe operation; reliable, maintenance-free operation; and high specific-energy.

X6.01 Fuel Cells for Surface Systems
Lead Center: GRC
Participating Center(s): JPL, JSC

Energy storage devices are required to enable future robotic and human exploration missions. Advanced primary fuel cell and regenerative fuel cell (RFC) energy storage systems are sought for Exploration mission applications, specifically descent for power for the Altair lander and stationary power for lunar surface bases. Technology advances that reduce the weight and volume, improve the efficiency, life, safety, system simplicity and reliability of fuel cell, electrolysis, and RFC systems are desired. The specific advancements of interest are outlined below:

Regenerative Fuel Cell (RFC) Systems: Primary fuel cells, water electrolyzers, and associated balance-of-plant hardware constitute a RFC system. Performance of fuel cell and electrolysis system functions through passive means and the elimination of as many ancillary components as possible have been identified as the most direct approach to achieving mission efficiency, life, and reliability goals. Specifically, technological advances are sought in the following areas:

- Static Cathode Water Vapor Feed Electrolysis Cell: Preliminary system studies have shown that static cathode feed electrolyzers have the most potential for system simplicity and the fewest number of ancillary components. Proton-exchange-membrane (PEM) electrolysis technology is sought that electrolyzes water vapor supplied to the hydrogen evolving electrode. The electrolysis cell should operate at balanced pressures up to 2000 psi and must not require circulation of hydrogen to transport the water to the electrolysis cell cathode. The exiting hydrogen and oxygen must not contain liquid water droplets, but may contain water vapor.
- Passive Fuel Cell or Electrolysis Cell Heat Removal/ Thermal Control: Passive thermal control of individual cells within a fuel cell or electrolysis stack has the potential to eliminate actively pumped liquid coolant loops. A highly thermally conductive heat pipe plate that is also electrically conductive is sought to passively remove the heat from the individual fuel cells or electrolysis cells within a cell stack. The flat plates that are sought should have a thermal conductivity exceeding 2000 W/m/K, a thickness of <= 0.050 inches, a resistivity of <= 0.2 ohm-cm, and a bulk density of <= 3 grams/cm^3.
- Fuel Cell/ Electrolysis Cell Voltage Monitor Application Specific Integrated Circuit (ASIC): A cell voltage monitoring ASIC has the potential to eliminate a number of discreet electrical components within a fuel cell, electrolysis, or RFC electrical control system. An ASIC is sought that monitors up to 48 differential cell voltages (0-2 VDC) with <= 100 volt common mode rejection, has a multiplexed analog or <= 12 bit digital output, operates at -20 to +40°C, and is capable of being upgraded to meet a Grade-1 EEE reliability.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

X6.02 Advanced Space-Rated Batteries
Lead Center: GRC
Participating Center(s): JPL, JSC

Advanced human-rated energy rechargeable batteries are required for future robotic and human exploration missions. Advanced Li-based battery systems are sought for use on Exploration mission applications including power for landers, rovers, and Extravehicular activities (EVA). Areas of emphasis include advanced component materials with the potential to achieve weight and volume performance improvements and safety advancements in human-rated systems.

Rechargeable lithium-based batteries with advanced non-toxic anode and cathode materials and nonflammable electrolytes are of particular interest. The focus of this solicitation is on advanced cell components and materials to provide weight and volume improvements and safety advancements that contribute to the following cell level metrics:

- Specific energy of 300 Wh/kg @ C/2 discharge rate and 0°C;
- Energy density greater than 500 Wh/l;
- Calendar life of 5 years.

The cycle life requirements for these missions are relatively benign; the cycle life required at 100% Depth of Discharge (DOD) is in the range of 250 cycles.

Systems that combine all of the above characteristics and demonstrate a high degree of safety and reliability are desired. Innovative solutions that offer the cell level characteristics described above are of particular interest. Proposals are sought which address:

- Advanced cathodes with specific capacities >= 300 mAh/g at C/2 rate discharge and 0°C, and/or
- Advanced anodes with specific capacities >= 600 mAh/g at C/2 and 0°C with minimal irreversible capacity loss,
- Nonflammable electrolytes, and/or
- Electrolytes that are stable up to 5 volts.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

TOPIC: X7 Cryogenic Systems

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 Altair and Ares in the areas of storage, distribution, and low-gravity propellant management. Additionally, Earth-based and lunar surface missions will require success in storing and transferring liquid and gas commodities. Some of the technology challenges are for long-term 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 reliability, increase 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.

X7.01 Cryogenic Storage for Space Exploration Applications
Lead Center: GRC
Participating Center(s): ARC, GSFC, KSC, MSFC

This subtopic includes technologies for long-term cryogenic propellant storage applications in-space, on the lunar surface, and on the Earth. These technologies will impact cryogenic systems for space transportation orbit transfer vehicles, space power systems, spaceports, spacesuits, lunar habitation systems, robotics, in situ propellant systems, and launch site ground operations. Each of these applications has unique performance requirements that need to be met. Innovative concepts are requested for cryogenic insulation systems, fluid system components, and cryogenic conditioning systems.

Long term storage (14 days) of LO_2/ LH_2 cryogenic propellants in low-gravity with minimal propellant loss is required to support space transportation orbit transfer vehicles. The Earth Departure Stage (EDS) and the Altair (Lunar Lander) descent stage require LH_2 and LO_2 storage durations of 14 days in Low Earth Orbit (LEO). Long-term storage (224 days) of LO_2/ LCH_4 cryogenic propellants in low-gravity and reduced gravity with minimal propellant loss is required to support space transportation orbit transfer vehicles. The Altair (Lunar Lander) ascent stage requires LO_2 and LCH_4 storage durations of up to 14 days in LEO and up to an additional 210 days on the lunar surface. Long term storage (224 days) of LO_2 cryogenic propellant on the lunar surface and liquefaction of resource with minimal propellant loss is required to support space power systems, spaceports, spacesuits, lunar habitation systems, robotics, in situ propellant systems. Long term storage (6 months) of LO_2/ LH_2/ LCH_4 cryogenic propellants in 1-g on the surface of the Earth with minimal propellant loss is required to support launch site ground operations. Passive and active thermal control, and pressure control/ thermodynamic venting technologies are sought after.

In-space Storage and Lunar Surface Storage
Passive thermal control serves to limit the heat leak into the cryogenic storage system (LH_2 loss < 0.4%/day, LO_2 loss < 0.0%/day, LCH_4 loss < 0.0%/day). Propellant boil-off losses are influenced by Multi-Layer Insulation (MLI) design, MLI to tank attachment techniques and materials, tank to vehicle support structure and attachments, tank size and configuration, fluid mixing, tank and insulation penetrations, insulation venting provisions for launch and ascent, flight and surface environments, vehicle orientation in those environments, and thermal control surface coatings and materials. Passive thermal control development needs include: integration of MLI with micrometeoroid protection, tank support structure, and other insulation penetrations. Other development needs include: characterization of the potential advantages of sub-cooled propellants, investigation of options such as shading, advanced materials, mechanisms and other techniques for passive thermal control.

Active thermal control combines the passive thermal control technology element with active refrigeration (cryocoolers) to allow storage periods from a few months to years with reduced boil-off losses (LH_2 loss < 0.06%/day, LO_2 loss < 0.0%/day). Flight-type 20K (LH_2) cryocoolers of sufficient cooling capacity (20 watts) to eliminate LH_2 boil-off do not exist, and thus the development of 20K cryocoolers is a long-lead technology item. State-of-the-art cryocoolers in the 80K range (LO_2/LCH_4 temperatures) have been developed for cooling sensors and have flown on numerous satellites. However, the integration of these cryocoolers into an active thermal control system for propellant storage of LO_2 and LH_2 is a technology issue. Active thermal control development needs include: flight-type 20K, 20 watt capacity cryocoolers designed for integration into space-based LH_2 storage systems, integrated refrigeration and storage systems, innovative heat exchanger concepts, flight cryocooler to propellant tank integration techniques for large space-based storage systems, distributed cooling shields integrated with MLI, circulator development, development and testing of active cooling techniques for tank penetrations and supports is required.

Pressure control utilizes thermodynamic venting in low-gravity or direct venting in partial gravity to enable selective venting of vapor if necessary (ratio of kilograms of TVS mass per watt of heat removal from LH_2 < 0.08 kg/W, ratio of kilograms of TVS mass per watt of heat removal from LO_2 < 0.2 kg/W, ratio of kilograms of TVS mass per watt of heat removal from LCH_4 < 0.3 kg/W). Controlling cryogenic propellant tank pressure in low gravity with minimum boil-off losses without settling the propellants can be accomplished with a thermodynamic vent system

(TVS). A TVS subsystem typically consists of a pump for circulation and mixing, a Joule Thompson expansion device/heat exchanger for heat removal, valves and a vent line. Thermodynamic venting development needs include: innovative TVS configurations and applications, system integration and control and modeling of low-gravity fluid dynamics and heat transfer for specific TVS designs, and integrated system testing with LH_2, LO_2 and LCH_4 to determine the effect of internal tank hardware configuration on fluid mixing.

Earth-based Storage
Passive and active thermal control serves to limit the heat leak into the cryogenic storage system and eliminate cryogen boil-off, but not limited by mass or reliability typically associated with flight systems (LH_2 loss < 0.0%/day, LO_2 loss < 0.0%/day, LCH_4 loss < 0.0%/day). Propellant boil-off losses are influenced by cryo-tank insulation, tank support structure, tank size and configuration, fluid recirculation, and integrated cryocooler systems. Ground storage tank passive and active thermal control development needs include: advanced non-compacting insulation, fluid conditioning, and condensation/liquefaction of tank ullage, servicing needs, and enhanced pumping system.

X7.02 Cryogenic Fluid Transfer and Handling
Lead Center: KSC
Participating Center(s): GRC, JSC

Cryogenic fluid transfer and handling for spacecraft propulsion systems, launch facility ground processing, and Lunar surface systems are critical to the advancement of NASA's exploration goals. Technology development in cryogenic fluid transfer and handling directly supports the Lunar Lander, Ground Operations, Ares, and Lunar Surface Systems programs. Specifically, for Earth-based applications, propellant conditioning and cryogenic densification technologies are required. Propellant conditioning systems are needed to help control the state of the propellant that is loaded into the flight tank at the launch pad. Other technologies are primarily for active control of cryogenic propellants for densification or subcooling on the launch pad as well as liquefaction on the lunar surface.

Component technologies for cryogenic fluid transfer include regulators, valves, umbilicals, quick disconnects, pumps, distribution line insulation materials and techniques, and thermal standoffs for LH_2, LO_2, LCH_4 and cold GHe (~90K). Cryogenic components using advanced actuation technologies such as piezoelectric ceramics which demonstrates reduced heat flux into the cryogenic fluids as compared to conventional electromechanical actuators is highly desirable. Operating ranges for these components should include but are not limited to normal boiling point (NBP) LH_2 and NBP LO_2 components rated for 50 – 100 psia, NBP LO_2 and below NBP LCH_4 components rated for 100 – 400 psia, and cold GHe (~90K) components rated for 400 to 4,500 psia. The technical focus for these components are for reduced thermal mass, minimal heat leak, minimal leakage, and minimal power consumption. Analytical tools for the design and/or analysis of cryogenic fluid transfer components are also needed. These tools should focus on providing analytical capabilities, which directly correspond to cryogenic fluid component design or thermal analysis.

Advanced transfer systems capable of delivering high quality of liquid over a wide flow range between 100 GPM and 1000 GPM are sought. Liquid oxygen pumps that minimize fluid heating while allowing for a range of flowrates are also needed. Propellant subcooling or densification systems for LOX, LH_2 and LCH_4 are required, to provide for extended storage duration on orbit prior to boil off. These systems should be sized to accommodate the Altair propulsion system. Densification systems should offer reliability and efficiency benefits over past systems. Anti-stratification concepts to ensure homogeneous fluid conditions in the flight tank are needed, and better transfer line insulation to minimize heat leak are required. Connections and recirculation systems to maintain propellant state in the flight tank are also desired.

On the lunar surface, oxygen may be produced via an in situ resource utilization reactor. Efficient liquefaction of this oxygen will depend on integration of the liquefier with the gas production stream. Open cycle liquefaction systems must interface with the high-pressure electrolysis systems at the output of the reactor. Compact, low temperature radiators capable of rejecting 50-100W of heat at 140K to deep space are needed for passive cooling prior to the final liquefaction steps. High efficiency, low mass recuperative heat exchangers are needed for effective heat transfer between gas streams. Innovative heat rejection systems designed for the lunar thermal environment are needed. Heat pumps to increase the high temperature heat rejection point of the cycle can also be proposed.

Next, hydrogen cooling and/or liquefaction are required for lunar surface applications involving regenerative fuel cell systems. Efficient 20K cryocooler technology is needed. Reliquefaction systems should be capable of meeting hydrogen flowrates around 1 gram/second. Open cycle hydrogen cooling systems with low temperature isentropic expansion from 3000 psi to the desired storage pressure are needed. Heat switch technology to control energy flow during the lunar day/night cycle will also be considered.

X7.03 Cryogenic Instrumentation for Ground and Flight Systems
Lead Center: GRC
Participating Center(s): JSC, KSC, MSFC

This subtopic includes technologies for reliable, accurate cryogenic propellant instrumentation needs in-space, on the lunar surface, and on the Earth. These technologies will impact cryogenic systems for space transportation orbit transfer vehicles, space power systems, spaceports, lunar habitation systems, in situ propellant systems, and launch site ground operations. Innovative concepts are requested to enable accurate measurement of cryogenic liquid mass in low-gravity storage tanks with and without propellant settling, to enable the ability to detect in-space and on-pad leaks from the storage system, and address other cryogenic instrumentation needs. Cryogenic propellants such as hydrogen, methane, and oxygen are required for many current and future space missions. Operating efficiency and reliability of these cryogenic systems must be improved considering the launch environment, operations in a space environment, and system life, cost, and safety. Proposed technologies should offer enhanced safety, reliability, or economic efficiency over current state-of-the-art, or should feature enabling technologies to allow NASA to meet future space exploration goals.

Mass Gauging technologies will principally impact cryogenic systems for space transportation orbit transfer vehicles. Mass gauging provides accurate measurement of cryogenic liquid mass (LH_2, LO_2, and LCH_4) in low gravity storage tanks, and is critical to allowance of smaller propellant tank residuals in assuring mission success. Both low-gravity mass-gauging (measurement uncertainty < 1% over fill levels from 2% to 98%) and low-thrust level settled mass gauging (measurement uncertainty < 0.5% over fill levels from 2% to 98%) technologies are being solicited for these applications.

Leak detection technologies impact cryogenic systems for space transportation orbit transfer vehicles, lunar surface, and launch site ground operations. These systems will be operational both in atmospheric conditions and in vacuum with multiple sensor systems distributed across the vehicle or a region of interest to isolate leak location. Methane and hydrogen leak detection sensors with milli-second response times and 1 ppm detection sensitivity in air are desired for ground and launch operations.

Other cryogenic instrumentation needs include minimally invasive cryogenic liquid flow measurement sensors for rocket engine feed lines, and sensors to detect and quantify two-phase flow (bubbles) within the feed lines.

TOPIC: X8 Protection Systems

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 CEV missions, e.g., Mars Landing with 8 km/s entry and Mars Sample Return with 12-15 km/s entry.

X8.01 Detachable, Human-Rated, Ablative Environmentally Compliant TPS
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, LaRC

The technologies described below support the goal of developing higher performance TPS materials and integrated entry systems architectures for higher performance CEV as well as future Exploration missions.

Development of TPS materials for maximum reliability and survivability with minimized mass requirements, under severe combined convective and radiative heating, including development of acreage materials, adhesives, joints, penetrations, deployables, inflatables and seals.

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. This leads to higher fidelity design tools, risk reduction, decreased heat shield mass and a direct payload increase.

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 themselves have the proper integrity and are free of voids or defects.

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 density charring ablators.

Advances in Multidisciplinary Design Optimization (MDO) are sought specifically in application to address combined aerothermal environments, material response, vehicle shape, vehicle size, aerodynamic stability, mass, and cross-range, characterizing the entry vehicle design problem.

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

TOPIC: X9 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. Although aerobic capacity has not been formally measured in returning ISS crew, short duration Space Shuttle crewmembers have been shown to undergo a 22% reduction in VO2max in response to space flight. 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 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. Exercise systems is seeking technologies or devices to provide resistive and aerobic exercise in flight, monitor a crewmember inflight fitness state or simulate an Extra Vehicular Activity (EVA) suit on the ground.

X9.01 Crew Exercise System
Lead Center: GRC
Participating Center(s): JSC

Compact, reliable, multi-function exercise devices/systems are required to protect bone, muscle, and cardiovascular health during lunar outpost missions (missions with total duration less than 6 months). This device should be easily configured and stowed, require minimal power to operate, include instrumentation to document exercise session parameters including portable electronic media, and require minimum periodic calibration (no more than 2 times per year). The device must be capable of providing whole body axial loading and individual joint resistive loading that ideally simulates free weights. If unable to match the inertial properties of free weights, then the device must provide near constant loading at any given load setting and achieve an eccentric to concentric load ratio greater than 90%. The load must be adjustable in increments no greater than 2.5 kgs and provide adequate loading to protect muscle strength and bone health such that post-mission muscle strength is maintained at or above 80% of baseline values; bone mass DEXA T score must not exceed – 2.0 S.D. below the mean bone mineral density at mission's end. The same device must be capable of providing whole-body aerobic exercise levels necessary to maintain aerobic capacity at or above 75% of baseline VO2max. Finally, the ideal device should also stimulate the sensory-motor system which controls balance and coordination.

A small, lightweight, sensor-based fitness monitoring system that can be used to assess periodic fitness during lunar outpost missions and transit to Mars is also desired. Devices should be small, employ re-usable elements (versus requiring consumables), and be minimally invasive to measure heart rate and rhythm, oxygen consumption and lactic acid threshold. The ideal system would also include other medical monitoring capabilities such that it could be utilized to assess other crew health variables (e.g., imaging capabilities, respiration rate, blood parameters, etc.).

The Exercise Systems subtopic is also seeking a wearable suit or system that simulates the mechanical properties of the current extravehicular space suit. System should be lightweight (less than 30 pounds), easy to don/doff (especially in the supine position), replicate the mechanical properties of a space suit (in terms of resistance to motion and mass and inertia), and able to be worn during conduct of simulated lunar tasks that last up to 4 hours. Suit system must be adjustable to accommodate individuals of different height and weight. Joints of primary interest to simulate in this system are the shoulder, elbow, trunk, hip, and knee.

Phase 1 Requirements: Phase 1 expectations would be a fully developed concept, complete with feasibility analyses and top-level drawings. A breadboard or prototype is highly desired.

TOPIC: X10 Exploration Medical Capability

The Exploration Medical Capability Topic is soliciting research and technology development for key areas of crew health maintenance, including injury/illness treatment scenarios. The Vision for Space Exploration presents significant new challenges to crew health care capabilities. These challenges include the hazards created by the terrain of lunar or planetary surfaces that may be difficult to traverse during exploration, the effects of gravity transitions, low gravity environments, and limited communications with ground-based personnel for diagnosis and consultation. Each challenge has associated medical implications and medical requirements and technologies to ensure safety and success. The areas of concern for the ExMC that are targeted in this solicitation include: Non-toxic In-flight Sprain/Strain Therapeutic Treatment; Through-suit Medication Delivery in a Reduced Pressure Environment; Reusable Diagnostic Lab Analysis Technology; Biosensors for Lunar EVA Suits; and a Lightweight/compact Oxygen Concentrator. Proposals may respond to one or more of these areas.

X10.01 In-Flight Diagnosis and Treatment
Lead Center: JSC
Participating Center(s): ARC, GRC

Proposals may respond to one or more of the following areas:

Non-Toxic Sprain/Strain Treatment
With longer missions and more labor intensive tasks expected in the Constellation Program, the likelihood of musculoskeletal injuries such as sprains and strains are expected to increase. Standard terrestrial therapeutic response to treating sprains and strains is to provide cold compress or heat treatment to the affected area. The focus of this subtopic is to develop a reusable cold compress and/or heat treatment that can be stowed in its inactive state in the vehicle's ambient environment, activated to provide the desired therapeutic relief, recharged using available vehicle resources, and restowed in its inactive state for future use. This capability is desired on the International Space Station and all Constellation Program vehicles that support missions involving labor intensive tasks or exercise countermeasures. Efforts should be made to minimize the volume and mass footprint of the deployed system so that when activated and treating the patient, the patient will have mobility and free movement to continue with mission tasks and objectives. The cold compress and heat treatment capability can be provided through separate systems and does not necessarily have to be the same piece of hardware. The materials used shall be non-toxic in the quantities provided. Current terrestrial solutions are undesirable due to the chemicals involved, onetime use designs or requirement for pre-cooling (e.g., freezer) or pre-heating (e.g., microwave) devices.

Phase 1 Requirements: Phase 1 would include trade studies with reports and down select recommendation. A prototype is preferable.

Phase 2 Requirements: Phase 2 would deliver a working prototype and documentation packages for NASA safety and design reviews.

Reusable Diagnostic Lab Technology
On-board clinical diagnostics to monitor crew member physiology must be available for both mid-term lunar and long-term Mars exploration missions. As in terrestrial medicine, devices with which to measure multiple constituents of small volume samples of bodily fluids are crucial components in assessing astronaut health. Nevertheless, mass, space, and power requirements of such devices are an obvious concern in an environment with scarce resources. Miniaturized laboratory analysis sensors represent a potential solution, given that these devices and supporting hardware are designed to be small, lightweight, and require little power. However, current sensor cartridges are typically single-use with limited shelf life. In order to satisfy the needs of longer duration exploration missions, reusable laboratory analysis sensors with increased shelf life must be designed without compromising accuracy or sensitivity. NASA seeks proposals for developing such reusable laboratory analysis sensors for analysis of bodily fluids, including blood, urine and saliva. The ability to analyze whole blood for a complete blood count with differential and hemoglobin is essential. Priority will be given to designs which also incorporate onboard

detection capabilities for other analytes, such as electrolytes, lipids, proteins and hormones. Multiplexed systems providing runtime selection of the assay suite are also desirable. The detection system should minimize the use of electrical power, external optics or other infrastructure, and the use of reagents and additives. The device can rely on a PC or PDA for signal processing and display if desired, but the footprint of all other components should be tightly controlled. The best design will require minimal user interaction for processing or maintenance.

Phase 1 Requirements: During Phase 1, research should be conducted to demonstrate technical feasibility with a draft end item functional requirements document. Phase 1 will also produce documentation showing a viable path to a Phase 2 breadboard demonstration.

Lightweight/Compact Oxygen Concentrator
Concentrated oxygen for medical use is a consumable that when used cannot be replenished. Due to relatively low metabolic consumption, a large percentage of the concentrated oxygen is not consumed but is instead released into the vehicle's cabin where it offers minimal medical use and is essentially wasted. This release of concentrated oxygen leads to increased ambient oxygen levels to the point where the vehicle oxygen fire limit will be exceeded. An effective solution to both these issues involves use of an oxygen concentrator that can take ambient air and re-concentrate the oxygen providing medical grade oxygen and removing excess oxygen from the vehicle cabin. However, oxygen concentrator technology to date is mostly large, massive, and power intensive. The focus of this subtopic is to develop a small, lightweight, portable oxygen concentrator that can produce concentrated medical oxygen using ambient vehicle cabin air. Of particular interest is oxygen concentration technology that can produce at minimum 60% oxygen at 4-6 liters per minute. Efforts should be made to minimize the volume, mass, and power draw of the system. The oxygen concentrator will use vehicle power as its primary source of power; however there is a brief need for battery power for when the patient is transported between vehicles. This technology is desired on ISS and future exploration vehicles supporting long duration missions.

Phase 1 Requirements: Phase 1 deliverables should include trade studies with down select criteria and recommendations for which technology will best meet the O_2 concentrator figures of merit. A requirements document for a Phase 2 prototyping effort should also be included.

X10.02 EVA Suit Monitoring and Treatment
Lead Center: JSC
Participating Center(s): ARC, GRC

Proposals may respond to one or more of the following areas:

Through-Suit Medication Delivery
NASA operations concepts envision contingencies where astronauts may be required to wear Extra Vehicular Activity (EVA) suits for up to 120 hours. If a crewmember requires medication while in a suit, a method of administration must be developed that does not compromise the integrity of the suit, nor the environment it provides. Current concepts for the EVA suit include a self-sealing diaphragm through which injections could be given. However, fluid management in microgravity presents problems with filling a syringe and delivering medication in such an environment. The three main concerns are preventing bubbles from being injected, appropriate fluid management, and excessive volume requirements for pre-loaded syringes. Due to uncertainties about when such an event might occur, the system would have to function in the range of gravity levels between 0 to 1G, as well as pressure levels from vacuum to 1 atmosphere, and require very little volume and no power. Accordingly, NASA seeks proposals detailing concepts for such a system.

Phase 1 Requirements: Phase 1 would include appropriate trade studies, design concepts, and any limited laboratory proof-of-concept testing required to support Phase 2 development.

Phase 2 Requirements: Phase 2 would include fabrication, testing, and validation of breadboard hardware that could be delivered to NASA for evaluation at the conclusion of Phase 2. Phase 2 would be a commercial system that NASA or a prime contractor could integrate within the Exploration Medical Kit.

Biosensors for Lunar EVA Suits
During surface Extravehicular Activities (EVAs), it is anticipated that the flight surgeons will need the ability to monitor heart rate, heart rhythm (ECG), derived core body temperature, and calculated metabolic rate to ensure the health and safety of the crewmember. Of particular interest are technologies that would allow data to be collected, with minimal crew time or effort required to don/doff the measurement hardware, while also maintaining crew comfort (i.e., sensors NOT involving skin preparation, gels, or taping). Also of interest are technologies/systems that would allow the collection of robust, diagnostic quality signals even during periods of strenuous lunar surface operations (lifting, climbing ladders, recovering from falls, and assembling structures).

Phase 1 Requirements: Phase 1 should deliver prototype functioning sensors, but not necessarily in their final form. A report showing prototype function versus a benchmark system's function will be provided. Also a roadmap to getting to the final sensor will be provided.

Phase 2 Requirements: Phase 2 should deliver sensors in their spaceflight-friendly, miniaturized form. Data from spaceflight analog testing using protocols delivered from NASA will also be expected.

TOPIC: X11 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 2008, the Behavioral Health and Performance topic is interested in the following technologies: Crew Cohesion Monitoring Technologies; Behavioral Assessment Tools; and an Individualized Fatigue Meter. Proposals may respond to one or more of these areas.

X11.01 Behavioral Assessment Tools
Lead Center: JSC

During Exploration Missions, and especially during a Mars Mission, real time communication between the crew and flight surgeons and crew and mission control will not be available as it is now on ISS and the Shuttle. Flight surgeons have stated the need for unobtrusive monitoring tools that are transparent to crews, require minimal crew time or effort, and that help detect if crews are having difficulties with coping with the spaceflight environment. The aim of this subtask is to provide tools that will automatically generate feedback for astronauts and flight surgeons, regarding team cohesion and behavioral health status of crews in-flight.

Requirements for Behavioral Assessment Tools:

- Be unobtrusive;
- Be transparent to crews;
- Require minimal crew time or effort.

Proposals may respond to one or more of the following areas:

Crew Cohesion Monitoring Technology
Detect if crews are having difficulty with team cohesion within the spaceflight environment.

Phase 1 Requirements: Phase 1 will involve an assessment of current methods through which to monitor/measure cohesion within the military and other agencies will be provided. Recommendations regarding enhancements to current technology or the development of a new technology will be presented. The spaceflight environment (current and future) and models related to team cohesion will be assessed in order to determine the optimal requirements for developing a Crew Cohesion Technology suitable for NASA human space exploration. The resulting deliverable will be requirements for a Crew Cohesion Monitoring Technology.

Phase 2 Requirements: Phase 2 requires the development of a prototype Crew Cohesion Monitoring Technology based on accurate models and Phase 1 findings. The prototype will include the hardware, manual and trouble-shooting guide, and results from evaluation and testing the functionality of the prototype device.

Behavioral Health Assessment Tool
Detect if crews are facing increased risk related to interpersonal and psychosocial issues, or other behavioral health problems, and provide feedback to the crewmember and flight surgeon.

Phase 1 Requirements: During Phase 1, the current and future spaceflight environment will be assessed in order to determine the optimal requirements for providing Behavioral Health Assessment tools suitable for NASA human space exploration. An analysis of current methods through which to assess behavioral health status will be provided. Recommendations regarding enhancements to current technology (and how these enhancements will be implemented), or the development of a new technology will be presented. These recommendations will be documented along with a plan to take to Phase 2.

Phase 2 Requirements: Phase 2 requires the development of a prototype Behavioral Health Assessment Technology based on accurate models and Phase 1 findings. The prototype will include the hardware, manual and trouble-shooting guide, and results from evaluation and testing the functionality of the prototype device.

Individualized Fatigue Meter
Design and/or enhance a fatigue meter that would provide immediate feedback to the individual regarding their specific alertness or fatigue levels. Specifically, the feedback from the Fatigue Meter shall be based at a minimum, on the following factors, but other relevant factors can be included:

- A clear, concise method for indicating alertness or fatigue state to the user;
- Length and restfulness of sleep;
- Quantity and quality of physical activity;
- Wavelength and timing of light exposure;
- Heart rate;
- Body temperature.

Phase 1 Requirements: Fatigue Meter Evaluation – A market analysis and a literature review of the state of the art current tools will be conducted. Recommendations regarding enhancements to current technology (and how those enhancements will be implemented), or the development of a new technology will be presented. The spaceflight environment (current and future) and mathematical models related to sleep and performance will be assessed in order to determine the optimal requirements for developing a Fatigue Meter suitable for human space exploration. These recommendations will be documented along with a plan to take to Phase 2.

Phase 2 Requirements: Fatigue Meter Prototype developed based on accurate models and Phase 1 findings. Develop prototype hardware. Develop manual and trouble-shooting guide. Evaluate and test the functionality of the prototype device.

TOPIC: X12 Space Human Factors and Food Systems

The new Vision for Space Exploration encompasses needs for innovative technologies 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 the Space Human Factors and Food Systems topic address challenges that are fundamental to design and development of the next generation crewed space vehicles. These challenges include: 1) understanding the requirements for information feedback to the crew and developing technologies to ensure these requirements are met, 2) building tasks and tools that are compatible with humans and that enable human performance consistent with mission success, and 3) providing extended shelf life foods with improved nutritional content, quality and reduced packaging mass. This Topic seeks methods for monitoring, modeling, and predicting human performance in the spaceflight environment. The Space Human Factors and Food Systems is seeking new Space Human Factors Assessment Tools and Advanced Food Technologies that utilize non-foil barriers and allow food processing or preparation in a reduced gravity and pressure environment.

X12.01 Space Human Factors Assessment Tools
Lead Center: JSC

Operations in confined, isolated, and foreign environments can lead to impairments of human performance. This subtopic seeks methods for monitoring, modeling, and predicting human performance in the spaceflight environment for accurate and valid human system integration into vehicle design and operations. In particular, the Space Human Factors Engineering Project within the Human Research Program is interested in obtaining timely and context-specific Human Factors (HF) incident data. Currently, space HF data come from crew debriefs. Such debriefs rely on retrospective recall, which could suffer delays of up to six months. Furthermore, opportunities to discuss HF issues in detail during these debriefs are limited. Consequently, the HRP sees the need to develop an automated human factors incident reporting tool.

Objective: Development of tool that assists the gathering and reporting HF incidents for long-duration space missions.

Requirements: In general, the tool will be used to help detect areas where HF can contribute to mission success, assess the effects of operational and hardware changes, and complement existing HF data sources for operations. Specifically, the tool shall meet the following requirements:

1) The crew shall have easy access to the tool at any time to eliminate the need for the crew to recall information retrospectively.
2) An easy-to-use data gathering protocol with the following functionalities: Allow data to be entered either as text, audio, and/or video inputs,
3) It is desirable for tool to detect a system anomaly automatically and immediately record system status. At a minimum, however, the tool should provide an easily accessible event marker for the crew to mark the context and take a snapshot of the system and operator system status.
4) Provide a user-friendly automated data search engine for extracting meaningful incident information from the raw data. Examples of desirable search schemes include natural language, spatial, temporal searches, etc.

Phase 1 Requirements: The technical merit of the tool will be explored to evaluate feasibility. The Phase 1 report will include results of the evaluation/research/ or development of automated data mining technologies, definition of optimal data gathering protocol(s), and recommendations for optimal hardware/software design. Development of hardware and software algorithms is highly desirable.

Phase 2 Requirements: Development of a working tool prototype, with documentation of functionality and usability evaluation and testing.

X12.02 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 to the Moon, Mars, and beyond. Safe, nutritious, acceptable, and varied shelf-stable foods with a shelf life of 3 - 5 years will be required to support the crew during future exploration missions to the Moon or Mars. Concurrently, the food system must efficiently balance appropriate vehicle resources such as mass, volume, water, air, waste, power, and crew time. One of the objectives during the lunar outpost missions is to test technologies that can be used during the Mars missions. This subtopic will concentrate on two specific areas; food packaging and lunar outpost food preparation and food processing.

Non-Foil High Barrier Materials
Development of shelf-stable food items that use high-quality ingredients is important to maintaining a healthy diet and the psychosocial well being of the crew. Shelf-life extension may be attained through new food preservation methods and/or packaging. New food packaging technologies are needed that have adequate oxygen and water barrier properties to maintain the foods' quality over a 3 - 5 year shelf life. The packaging must also minimize waste by using high barrier packaging with less mass and volume. The current flexible pouch packaging used for the thermostabilized and irradiated food items contains a layer of foil. Although the foil provides excellent oxygen and water barrier properties, it also contributes to added waste. Food packaging will be a major contributor to the trash on the lunar or Mars surface. One of the proposed methods to dispose of trash on the lunar or Mars surface is incineration. However, the foil layer will not incinerate completely and there will be ash formed. Two emerging food preservation technologies, high pressure processing and microwave processing, are being considered for future NASA missions. However, the current high barrier packaging material cannot be used for these processes. The material delaminates during high pressure processing and cannot be used in microwave processing. Hence, any food packaging material developed in response to this subtopic should be compatible with one or more of the following food preservation technologies: retort processing, microwave processing, and/or high pressure processing. In addition, the material should have an oxygen transmission rate that shall not exceed 0.06 $cc/m^2/24$ hrs/atm and a water vapor transmission rate that shall not exceed 0.01 $gm/m^2/24$ hrs as stated in the MIL-PRF 33073F specification.

Effect of Partial Gravity and Reduced Atmospheric Pressure
It will require approximately 10,000 kg of packaged food for a 6-crew, 1000 day mission to Mars. For that reason, 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 food processing and food preparation equipment. The equipment should be miniaturized, multipurpose and efficiently use vehicle resources such as mass, volume, water, and power. Food preparation may include gourmet kitchen appliances such as food processors or bread makers in addition to the standard stove and oven. Proposed food processing equipment may include a mill to produce wheat and soy flour, a soy milk/tofu processor, and a concentrator. The Moon's gravity is 1/6 of Earth's gravity. In addition, it is being proposed that the habitat will have a reduced atmospheric pressure of 8 psia which is equivalent to a 16,000 foot mountain top. These two factors will affect the heat and mass transfer during food processing and food preparation of the food. Heat transfer is required for proper microbial kill and to produce the desired texture and appearance of the food prior to consumption. At this pressure, the boiling temperature of water will be 181°F which has significant implications for preventing microbial contamination and to acceptable food quality. Prior to any design of food processing or preparation equipment, the effects of partial gravity and partial atmospheric pressure as it relates to fluid management, heat and mass transfer and chemical reactions must be determined. Once the effects are determined, methods to overcome these effects must be developed. All of this needs to happen prior to any fabrication of actual food processing or food preparation equipment that can be used in the Lunar Habitat.

The response to this subtopic should include a plan to either (1) develop food packaging technologies that respond the above requirements, or (2) develop a technology which will aid in determining the effects of reduced cabin pressure and reduced gravity and/or (3) develop a technology that will enable safe and timely food processing and food preparation in reduced cabin pressure and reduced gravity.

Phase 1 Requirements: Phase 1 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.

TOPIC: X13 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 pass through spacecraft shielding and human tissue. The Space Radiation Program Element, within the Human Research Program uses the NASA Research Announcement as a primary means of soliciting research to understand the health risks and reduce the uncertainties in risk projection; however, there are areas where the SBIR program contributes. Specific areas where SBIR technologies can contribute to NASA's overall goal include: reliable radiation monitoring for manned and unmanned spaceflight; and radiation damage imaging.

X13.01 Active Charged Particle and Neutron Radiation Measurement Technologies
Lead Center: ARC
Participating Center(s): JSC

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 particles created when the protons and heavy ions pass through spacecraft and human tissue.

Areas of Interest: Charged particles (protons and heavy ions) and secondary radiations, such as neutrons, contribute the most significant fraction to the total dose-equivalent received by astronauts. At present, NASA has active detectors on International Space Station (ISS) that measure the microdosimetric quantities and the charge and energy spectra of the space radiation field. Neutron specific data are included as part of the microdosimetric measurements. For Exploration class missions, however, more compact and reliable active detection systems will be needed to make microdosimetric, charge, and energy measurements of the total space radiation environment. Advanced technologies (up to technology readiness level 4) are requested.

Subtopic Requirements/Needs:

Tissue Equivalent Microdosimeter
NASA has a need for small/low-mass/low-power microdosimeter to support Exploration class missions. The microdosimeter should be capable of performing single event microdosimetric measurements of tissue equivalent volumes with simulated diameters of 1-2 micrometers. The microdosimeter should be sensitive to lineal energies of 0.2 – 1000 keV/micron. Design goals for mass and volume should be 2 kg and 2000 cm^3, respectively. The microdosimeter should be able to measure charged particles and neutrons in ambient conditions in space (0.01 mGy/hr) and during a large solar particle event (100 mGy/hr). The time resolution of the lineal energy measurements should be less than or equal to 1 minute.

Charged Particle Spectrometer
Of particular interest are compact real-time detection systems that can measure charge and energy spectra of protons and other ions (Z = 2 to 26) and be sensitive to charged particles with LET of 0.2 to 1000 keV/mm. 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 and volume should be 2 kg and

3000 cm^3, respectively. 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
Systems are needed specifically to measure the neutron component of the dose and provide the neutron dose-equivalent in real time. Of interest would be compact active monitoring devices that could measure neutron energy spectra. The principal energies of interest are neutrons from 0.5 MeV to 150 MeV. The spectrometer should be able to measure neutrons at ambient conditions such that proton/ion veto capability should be approaching 100% at solar minimum galactic cosmic radiation (GCR) rates. The spectrometer should be able to measure ambient dose equivalent of 0.02 mSv in a 1 hour measurement period, using ICRP 74 (1997) conversion factors. Design goals for mass and volume should be 5 kg and 6000 cm^3, respectively. The spectrometer shall store all necessary science data and unfolding/processing algorithms shall be determined and provided for post measurement data evaluation.

Phase 1 Requirements: Expected deliverable for Phase 1 is a detailed report that (1) establishes proof of concept; (2) addresses the scientific, technical and commercial merit and feasibility of the proposed technology and its relevance and significance to one or more NASA needs within the Solicitation; and (3) provides a preliminary strategy that addresses key technical, market, business factors, demonstration of the proposed innovation, and its transition into products for NASA mission programs and other potential customers.

X13.02 Technology/Technique for Imaging Radiation Damage at the Cellular Level
Lead Center: JSC

New quantitative techniques need to be developed in order to assess astronauts' exposure to space radiation. Charged particles (protons and heavy ions) are of major concern for health risks because they cause chromosome damage. Current methods for measuring space radiation chromosome damage are time consuming and have limitations in sensitivity and accuracy. The Space Radiation Element within the Human Research Program seeks a sensitive, accurate method for assessing chromosome damage, while at the same time being less time consuming than current mFISH and mBand techniques.

Subtopic Requirements/Needs: Of particular interest are ground laboratory techniques using fluorescence in situ hybridization to detect various types of chromosome damage. The technique should be able to measure charged particle exposure at both ambient conditions in space (0.005 mGy/hr) and during a large solar particle event (1000 mGy/hr). The technique should be able to detect various types of chromosome damage such as inversions and deletions in various regions of chromosomes. The technique must be able to quantify chromosome abnormalities that persist after space flight.

Phase 1 Requirements: Phase 1 expectations include a report describing the fully developed concept with feasibility analyses and comparisons to existing methods.

TOPIC: X14 In-Flight Biological Sample Preservation and Analysis

Flight resources such as the International Space Station and the Lunar outpost 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 a means for in-flight sample analysis or unique sample processing techniques that minimize the need to return conditioned human samples for analysis. The In-flight Biological Sample Preservation and Analysis topic is seeking innovative technologies or techniques to: provide an On Orbit Cell Counting and Analysis capability; and On Orbit Ambient Biological Sample Preservation Techniques.

X14.01 On Orbit Ambient Biological Sample Preservation Techniques
Lead Center: JSC

Measurement of blood 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. Diagnosis, treatment and research of health-related issues in human crewmembers during their confinement in the remote spaceflight environment depend on the ability to maintain the analytical integrity of biological samples. 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 Dried Chemistry Technology developed at NASA/JSC represents one approach to the collection and preservation of in-flight blood and urine samples. Briefly, whole blood collected by venipuncture into flight-certified tubes is applied either directly to special filter cards, or alternatively, serum or plasma separated from the red cells by means of the ISS refrigerated centrifuge is applied to the filter cards. Urine samples can also be applied directly to the filter cards. The whole blood, plasma, serum, or urine filter cards are then dried and stored at ambient temperature pending analyses which may require that they be returned to Earth. Many analytes in blood and urine samples prepared and stored by means of the NASA/JSC Dried Chemistry Technology are stable for several months. 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 1 Requirements: Phase 1 expectations include at a minimum a fully developed concept with feasibility analyses and top-level drawings. A breadboard or prototype is highly desirable.

X14.02 On Orbit Cell Counting and Analysis Capability
Lead Center: JSC

Cell counting and analysis within the clinical hematology/immunology area generally refers to identification and enumeration of various populations of white blood cells in the peripheral blood. This capability has direct clinical relevance, as peripheral cell populations may expand (proliferation in response to pathogen, hematological malignancy) or contract (sequestered at localized site of inflammation) related to specific disease states. In medicine, the complete blood count, white blood count and CD4+ T cell counts are examples of routinely used cell counting assays. Instrumentation typically used for automated analysis includes hematology analyzers and flow cytometers. Hematology instruments generally accept unstained cells for analysis and differentiate the subpopulations based on scatter properties alone. Flow cytometers require pre-staining of specific cell surface proteins with fluorescent dyes, the emission of which will be optically detected by the cytometer upon excitation with an onboard laser. Flow cytometers may range from large, multi-laser/multi-color instruments with sorting capability, to miniaturized bench top instruments with diode lasers and less capability. NASA is interested in developing a microgravity-compatible instrument capable of on-orbit cell counting. This instrument could support medical testing of crewmembers as well as various research activities. The instrument technology is not constrained, and might range from typical cytometer fluidics, a micro fluidics approach, or some other novel method for resolving and counting cells. It is generally believed that typical sheath-fluid based cell focusing, used in standard flow cytometers, is not desirable due to microgravity incompatibility and operational constraints (fluid volume, mass and waste constraints). Extremely miniaturized and lightweight instrumentation, without high-energy lasers, and requiring minimal sample volume or exogenous (sheath) fluid to operate, and generating minimal biohazardous waste would have the greatest chance for success. An associated sample processing system may be required, that would stain, lyse or otherwise process the whole blood or cell sample is anticipated. The instrument should be capable of deriving absolute counts, in addition to the relevant percentage of various cell subpopulations.

Phase 1 Requirements: Phase 1 expectations would be at a minimum a fully developed concept, complete with feasibility analyses and top-level drawings. A breadboard or prototype is highly desired.

9.1.3 SCIENCE

The Science Mission Directorate (SMD) engages the Nation's science community, sponsors scientific research, and develops and deploys satellites and probes in collaboration with NASA's partners around the world to answer fundamental questions requiring the view from and into space. SMD seeks to understand the origins, evolution, and destiny of the universe and to understand the nature of the strange phenomena that shape it. SMD also seeks to understand:

- The nature of life in the universe and what kinds of life may exist beyond Earth;
- The solar system, both scientifically and in preparation for human exploration; and
- The Sun and Earth, changes in the Earth-Sun system, and the consequences of the Earth-Sun relationship for life on Earth.

The Science Mission Directorate also sponsors research that both enables, and is enabled by, NASA's exploration activities. The SMD portfolio is contributing to NASA's achievement of the Vision for Space Exploration by striving to:

- Understand the history of Mars and the formation of the solar system. By understanding the formation of diverse terrestrial planets (with atmospheres) in the solar system, researchers learn more about Earth's future and the most promising opportunities for habitation beyond our planet. For example, differences in the impacts of collisional processes on Earth, the Moon, and Mars can provide clues about differences in origin and evolution of each of these bodies.
- Search for Earth-like planets and habitable environments around other stars. SMD pursues multiple research strategies with the goal of developing effective astronomically-detectable signatures of biological processes. The study of the Earth-Sun system may help researchers identify atmospheric biosignatures that distinguish Earth-like (and potentially habitable) planets around nearby stars. An understanding of the origin of life and the time evolution of the atmosphere on Earth may reveal likely signatures of life on extrasolar planets.
- Explore the solar system for scientific purposes while supporting safe robotic and human exploration of space. For example, large-scale coronal mass ejections from the Sun can cause potentially lethal consequences for improperly shielded human flight systems, as well as some types of robotic systems. SMD's pursuit of interdisciplinary scientific research focus areas will help predict potentially harmful conditions in space and protect NASA's robotic and human explorers.

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

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TOPIC: S1 Sensors, Detectors, and Instruments

NASA's Science Mission Directorate (SMD) (http://nasascience.nasa.gov/) encompasses research in the areas of Astrophysics (http://nasascience.nasa.gov/astrophysics), Earth Science (http://nasascience.nasa.gov/earth-science), Heliophysics (http://nasascience.nasa.gov/heliophysics), and Planetary Science (http://nasascience.nasa.gov/planetary-science). A major objective of SMD instrument development programs is to implement science measurement capabilities with smaller or more affordable spacecraft so development programs can meet multiple mission needs and therefore make the best use of limited resources. The rapid development of small, low-cost remote sensing and in situ instruments is essential to achieving this objective. For Earth Science needs, in particular, the subtopics reflect a focus on instrument development for airborne and Unmanned Aerial Vehicle (UAV) platforms. Astrophysics has a critical need for sensitive detector arrays with imaging, spectroscopy, and polarimetric capabilities which can be demonstrated on ground, airborne, balloon, or suborbital rocket instruments. Heliophysics, which focuses on measurements of the sun and its interaction with the Earth and the other planets in the solar system, needs a significant reduction in the size, mass, power, and cost for instruments to fly on smaller spacecraft. Planetary Science has a critical need for miniaturized instruments with in situ sensors that can be deployed on surface landers, rovers, and airborne platforms. For the 2008 program year, two new subtopics have been added. One subtopic solicits technology for geodetic instruments and instruments to enable global navigation and very long baseline interferometry. A second new subtopic requests proposals for technology to enable new lunar science instruments. A key objective of this SBIR topic is to develop and demonstrate instrument component and subsystem technologies that reduce the risk, cost, size, and development time of SMD observing instruments and to enable new measurements. Proposals are sought for development components that can be used in planned missions or a current technology program. Research should be conducted to demonstrate feasibility during Phase 1 and show a path towards a Phase 2 prototype demonstration. The following subtopics are concomitant with these objectives and are organized by technology.

S1.01 Lidar System Components
Lead Center: LaRC
Participating Center(s): ARC, GSFC

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. 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 program is highly encouraged. Examples of planned missions and technology programs are: Ice, Cloud and land Elevation Satellite (ICESat, http://icesat.gsfc.nasa.gov), Laser Interferometer Space Antenna (LISA, http://lisa.nasa.gov/index.html), Doppler Wind Lidar, Lidar for Surface Topography (LIST), and Earth and planetary atmospheric composition (ASCENDS).

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 prototype demonstration. For this Program year, we are soliciting only the specific component technologies described below.

- High speed fiber multiplexers for multimode fiber (200 micron core, 0.22 NA) operating at 1064 nm wavelength. We require an N by M multiplexer (where N is 1 or more and M is 10 to 100 or more) capable of switching at speeds on the order of 10 microseconds with low insertion loss (<2 dB). The unit must be small, lightweight, capable of long life, and low power consumption.
- Space-qualifiable high reliability frequency-stabilized CW laser source with 1 W output power. A master oscillator power amplifier (MOPA) configuration is desirable since the source must be phase-modulated.

- Development of polarization-maintaining Er and/or Yb doped optical fiber amplifiers that are optimized for suppression of stimulated Brillouin scattering (SBS). Resulting fiber amplifier must be capable of single frequency (< 1MHz linewidth), peak power of > 1 kW, and M2 beam quality < 1.3.
- Efficient and compact single frequency, near diffraction limited fiber lasers operating in near infrared (1.0 – 1.7 µm) and mid-infrared (3 – 4 µm). Requirements include: polarization maintaining output (better than 100:1), M2 beam quality < 1.5, wavelength stability <50 pm over one hour. Both pulsed lasers with repetition rates of the order of 10 KHz and pulse energies greater than 0.5 mJ, and CW lasers in multiwatts regimes are applicable. Wavelength tunability over 10s of nanometers is desirable for certain applications.
- Efficient and compact single mode solid state or fiber lasers operating at 1.5 and 2.0 micron wavelength regimes suitable for 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 approximately 200 nsec.
- Single frequency semiconductor or fiber laser generating CW power in 1.5 or 2.0 micron wavelength regions with less than 50 kHz linewidth. Frequency modulation with about 5 GHz bandwidth and wavelength tuning over several nanometers are desirable.
- Development of efficient, compact, and space qualifiable laser absorption spectrometry-related technologies for measuring atmospheric pressure and density. Components of interest include but not limited to fiber based Raman amplifier-based transmitter architecture. Remote sensing of oxygen in the 1.26-micron spectral region for measuring atmospheric pressure is of particular interest.

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

NASA employs active sensors (radars) for a wide range of remote sensing applications (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. The areas of interest for this call are listed below (with applications and/or mission concept names):

- Lightweight deployable L-band antenna structures and deployment mechanisms suitable for large aperture (reflectors or phased array of $50m^2$ and larger) systems. (Solid Earth Science [SES], http://solidearth.jpl.nasa.gov/)
- Compact wide bandwidth L-band and S-band (200 MHz) array antennas for airborne real aperture and synthetic aperture radar remote sensing applications.
- Rad-hard, high-efficiency, low-cost, lightweight L- and P-band Transmit/Receive (TR) modules (~250 W peak RF output power at ~100 us pulsewidth and 20% duty cycle) with respective energy storage units to provide pulsed DC power to the power amplifier while minimizing ripple on the primary DC power source. (DESDynI, http://desdyni.jpl.nasa.gov/; SES, hydrology http://www.nasa.gov/topics/earth/features/decadal_missions.html)
- Low Power 10-bit, 1.5 GHz analog bandwidth ADCs and digital filtering with an emphasis on rad-tolerance and space-qualification. (Ice Topography (GLISTIN), planetary landing)
- Lightweight deployable reflectors (Ku-band and Ka-band) and active feed electronics.
- High efficiency Ka-band (34-36GHz) TR modules with output power of 5-10W. The Low Noise Amplifiers (LNAs) should have a NF less than 3dB and gain better than 30dB. Included in the TR module is a low loss phase shifter. (GPM, Clouds and precipitation, planetary landing)
- Power amplifier and associated LNA for a Ka-band (34-36GHz) radar system with a peak output power of 2KW to 10KW (duty cycle of 10%) and system bandwidth of up to 1 GHz and LNA NF of less than 1.5dB. The LNA needs to have enough isolation and power handling capability to operate in this high power transmission environment. (SWOT, GLISTIN, clouds and precipitation)

- 140-160 GHz planar frequency-scanned antenna with scan range +/- 16 degrees, beamwidth 0.5 degrees, and bandwidth 400 MHz per beam. (planetary landing, atmospheric radar)
- Dual or tri-frequency (Ku/Ka/W band), matched beam antennas with high cross-polarization isolation (>32 dB). (Cloud and precipitation)
- Innovative approaches to realizing a low-cost instrument (sub-system).

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.

S1.03 Passive Microwave Technologies
Lead Center: GSFC
Participating Center(s): JPL, MSFC

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://universe.nasa.gov/program/probes/inflation.html)

- 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.
- 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 10 K) for 10^8 or more cycles. Technology applies to Beyond Einstein Probe.
- 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.
- 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.
- Low loss, low RF power waveguide SPDT diode switches and active noise sources for frequencies above 90 GHz to support calibration of SWOT and other atmospheric temperature and humidity measurements.

In addition to the technologies listed above, proposals for innovative passive microwave instruments for a wide range of remote sensing applications from measurements of the Earth's surface and atmosphere to cosmic background emission would also be welcome.

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

S1.04 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter
Lead Center: JPL
Participating Center(s): ARC, GSFC, 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 & astrophysics (http://www.nap.edu/books/0309070317/html/).

The following technologies are of interest for Earth and planetary science instrument concepts such as Scanning Microwave Limb Sounder (http://mls.jpl.nasa.gov/index-cameo.php) on the Global Atmospheric Chemistry Mission, Climate Absolute Radiance and Refractivity Observatory (http://science.hq.nasa.gov/earth-sun/docs/Volz4_CLARREO.pdf), Methane Trace Gas Sounder, and Lunar Atmosphere Dust Environment Explorer:

- New or improved technologies leading to measurement of trace atmospheric species (e.g., CO, CH4, N_2O) from geostationary and low-Earth orbital platforms. Of particular interest are new techniques in gas filter correlation spectroscopy, Fabry-Perot spectroscopy, or improved component technologies.
- Uncooled or passively cooled detectors with specific detectivity (D*) $\geq 10^{10}$ cm $Hz^{1/2}$/W in the operating wavelength ranges 6-14 μm and 10-100 μm.
- Efficient, flight qualifiable, spur free, local oscillators for SIS mixers operating in low Earth orbit. Two bands: (1) tunable from 200 to 250 GHz, and (2) tunable from 610 to 650 GHz, phase-locked to or derived from an ultra-stable 5 MHz reference.
- Technologies for calibrating millimeter wave spectrometers for spaceborne missions, including low power, flight qualifiable comb generators for gain, linearity, and sideband calibration of microwave spectrometers covering the bands from 180 to 270 GHz and from 600 to 660 GHz; flight qualifiable low noise diodes for the bands from 180 to 270 and 600 to 660 GHz; very low return loss (70 dB or better) calibration targets and techniques for quantifying and calibrating out the impact of standing waves in broadband heterodyne submillimeter spectrometers.
- Low power, stable, linear, spectrometers capable of measuring the band from 6-18 GHz with ~120 100 MHz wide channels.
- Digital spectrometers with ~4 GHz bandwidth and 10 MHz resolution. Components for these digital spectrometers including high speed digitizers, efficient spectrometer firmware, and ASIC implementations.

Detector technologies for future astrophysics mission concepts, such as the Single Aperture Far Infrared (SAFIR) Observatory (http://safir.jpl.nasa.gov/technologies.shtml), the Space Infrared Telescope for Cosmology and Astrophysics (SPICA) (http://www.ir.isas.ac.jp/SPICA/), and Inflation Probe (cosmic microwave background, http://universe.nasa.gov/program/probes/inflation.html).

- Innovative detector designs, readout electronics, or new sensor materials (e.g. novel dopants for extrinsic Si detectors) are of interest, as is development of a photo-definable version of parylene to aid the fabrication of thermally isolated structures of bolometers (and x-ray microcalorimeters).
- Spatial Filter Array (SFA) consisting of a monolithic array of up to 1200 coherent, polarization preserving, single mode fibers that operate over a large fraction of the spectral range from 0.4 - 1.0 microns and such that each input and output lenslet is mapped to a single fiber. Uniformity of output intensity and high throughput is desired and fiber-to-fiber placement accuracies of < 2.0 microns are required with < 1.0 microns desired. Applications include active and passive wavefront and amplitude control, and relevant missions include Terrestial Planet Finder (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) and Stellar Imager (http://hires.gsfc.nasa.gov/si/).

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.

S1.05 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. As would be expected, requirements across the board are for greater numbers of readout pixels, lower power, faster readout rates, greater quantum efficiency, and enhanced energy resolution. Typical semiconductor devices in this energy range are based on silicon or germanium. However, proposals for other detector materials are welcomed if a compelling case is made.

The proposed efforts must be directly linked to a requirement for a NASA mission. Details of these can be found at the following URLs:

- General Information on Future NASA Missions: http://nasascience.nasa.gov/missions
- Specific Mission pages:
  - ConX: http://constellation.gsfc.nasa.gov/
  - LBTI: http://planetquest.jpl.nasa.gov/lbti/lbti_index.cfm
- Future Mars Programs: http://marsprogram.jpl.nasa.gov/missions/future/futureMissions.html
- Solar Probes: http://science.hq.nasa.gov/missions/sun.html

Specific technologies are listed below. Highly desirable are developments that satisfy multiple requested parameters:

- Large-format focal plane detectors for use in UV and X-ray imaging and spectrometry:
  - UV-sensitive CCD and active pixel sensors with large formats: to 6k x 6k abuttable; extended UV response below 0.2 nm;
  - X-ray-sensitive CCD and active pixel sensors: up to 4k x 4k formats, 4-side abuttable; power levels of 0.1 W / megapixel; resolutions less than 120 eV; readout rates of at least 30 Hz; extended x-ray response above 6 keV.

- Very-large-area X-ray detectors for survey instruments: square-meter area capability; response from 3-30 keV; ultra-low power (10 microW/channel).
- Significant improvements in wide band gap materials, individual detectors, and detector arrays for UV and X-ray applications.
- Photon counting detectors with capability to resolve single photon arrival for use in space applications.
- Mega-to-giga-channel analogue electronic systems for very-large-area X- and gamma-ray detectors as follows: up to 10^8 channel capability; less than 10 microW/channel power requirement; less than 100 electron rms noise level with interconnects.
- Technology to accomplish X-ray and gamma-ray imaging spectroscopy and polarimetry at the arcsecond level in the energy range from 1 keV to 20 MeV.

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.

S1.06 Particles and Field Sensors and Instrument Enabling Technologies
Lead Center: GSFC
Participating Center(s): ARC, JPL, 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 by charge exchange, and electric and magnetic fields in space are needed to achieve NASA's transformational science advancements in Heliophysics. The Heliophysics discipline 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 to 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 (http://solarprobe.gsfc.nasa.gov/), Solar Orbiter (http://www.rssd.esa.int/index.php?project=SOLARORBITER), Solar Sentinels (http://www.lws.nasa.gov/missions/sentinels/solar_sentinels_orbiter.htm), GEC, Magnetospheric Constellation (http://stp.gsfc.nasa.gov/missions/mc/mc.htm), IT-SP (http://www.lws.nasa.gov/missions/geospace/geospace.htm) and some 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 magnetometers, fast high voltage stepping power supplies for charged particle analyzers, electric field booms 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).
- Self-calibrating scalar-vector magnetometer for future Earth and space science missions. Performance goals: dynamic range: +/-100,000 nT, accuracy with self-calibration: 1 nT, sensitivity: 5 pT / sqrtHz, 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".
- Strong, lightweight, thin, compactly-stowed electric field booms possibly using composite materials that deploy sensors to distances of 10 m or more and/or long wire boom (> 50 m) deployment systems for the deployment of very lightweight tethers or antennae on spinning spacecraft.
- Low power charge sensitive preamplifiers on a chip.
- Radiation hardened ASIC spectrum analyzer module that determines mass spectra using fast algorithm deconvolution to produce ion counts for specific ion species.

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.

S1.07 Cryogenic Systems for Sensors and Detectors
Lead Center: GSFC
Participating Center(s): ARC, JPL, MSFC

Cryogenic cooling systems are often enabling technologies for cutting edge science from infrared imaging and spectroscopy to x-ray calorimetry. Improvements in cryogenic technologies enable further scientific advancement at lower cost, lower risk, reduced volume, and/or reduced mass. Lifetime, reliability, and power requirements of the cryogenic systems are critical performance concerns. Of interest are cryogenic technologies for cooling detectors for scientific instruments and sensors on advanced telescopes and observatories (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20070018750_2007018830.pdf) as well as on instruments for lunar and planetary exploration such as missions to Europa, Titan, or Enceladus (http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=42337). Active coolers should have long life, low vibration, low mass, low cost, and high efficiency. Specific areas of interest include:

- Essentially vibration-free cooling systems such as Pulse Tube or reverse Brayton cycle cooler technologies with cooling capability of 20 mW at 4K.
- Low temperature cooling systems, operating and rejecting heat at 150K, providing 0.3W of cooling at 35K with input power on the order of 10W.
- Distributed cooling systems using circulators for larger systems including helium circulators. The temperature range is 20-100K, with flowrates of up to 1 gram/sec and a maximum pressure drop of 50 psi.
- Heat switches for redundant cryocoolers with a temperature range of 20-100K and a capacity of 20W.
- Highly efficient magnetic and dilution cooling technologies under 1 Kelvin.

- Components for advanced magnetic coolers (adiabatic demagnetization refrigerators) including:
    - Small (few cm bore), lightweight, low current (under 10A, goal under 5A) superconducting magnets capable of producing at least 3 Tesla central field while operating at least 10 Kelvin. Higher temperature superconductor (HTS) magnets operating at significantly higher temperatures are of particular interest.
    - Lightweight (relative to standard ferromagnetic flux guides) active and/or passive magnetic shielding for 3 to 4 Tesla magnets that reduces the stray field to tens of microTesla at a distance of several cm from the outside of the shield.
    - Large (>1 cubic cm) single crystal or polycrystalline magnetocaloric materials.
    - Superconducting current leads operating between 90 Kelvin down to 10 Kelvin, capable of carrying up to 10 amperes while allowing only approximately 1 mW of heat to be conducted.
    - Compact, accurate, easy to use thermometers that operate down to 10 milliKelvin.

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.

S1.08 In Situ Airborne, Surface, and Submersible Instruments for Earth Science
Lead Center: GSFC
Participating Center(s): ARC, JPL, MSFC, SSC

There are new platform systems that have the potential to benefit Earth science research activities. To capitalize on these emerging capabilities, proposals are sought for the development of in situ instruments for use on radiosondes, dropsondes, tethered balloons, kites, Unmanned Aerial Vehicles (UAVs), Unmanned Surface Vehicles (USVs), or Unmanned Underwater Vehicles (UUVs). Both miniaturization of current techniques, as well as innovative new methods that lead to compact and lightweight systems are important. Details of complete instrument systems are desired, including data acquisition, power, and platform integration. Instrument performance goals such as resolution, accuracy, and response time should be discussed, as well as maintenance and reliability considerations. An outline of potential use by NASA and a plan for commercial production and marketing should be included as well. Technology innovation areas of interest include:

- Atmospheric measurements including aerosol properties, temperature, humidity, solar radiation, clouds, liquid water, ice, precipitation, and chemical composition (carbon dioxide, methane, reactive gases and radicals, dynamical tracer species).
- Three-dimensional wind measurements near the Earth's surface, and within the troposphere and lower stratosphere.
- Oceanic and coastal measurements including inherent and apparent optical properties, temperature, salinity, chemical composition, nutrient distribution, and currents.

Instrument systems to support field studies of fundamental processes are of interest, as well as for satellite measurement calibration and validation. Applicability to NASA's Airborne Science, Ocean Biology and Biogeochemistry, and Applied Sciences programs, including support of the Integrated Ocean Observing System (IOOS), is a priority.

S1.09 In Situ Sensors and Sensor Systems for Planetary Science
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC, LaRC, MSFC

This subtopic solicits development of advanced instruments and instrument components that are tailored to the demands of planetary instrument deployment on a variety of space platforms (orbiters, flyby spacecraft, landers, rovers, balloon or other aerial vehicles, subsurface penetrators or impactors, etc.) accessing the wide variety of bodies in our solar system (inner and outer planets and their moons, comets, asteroids, etc.). For example missions see: http://science.hq.nasa.gov/missions/solar_system.html.

Specifically, this subtopic solicits instrument development that provides significant advances in the following areas:

- Reduced mass, power, volume, data rates for instruments or instrument components that could be achieved in optomechanical components (e.g., room temperature lasers, detectors, mixers, microvalves, optical components and structures, gas and liquid pumps, ion sources, light sources from UV to microwave, seismometers, etc.) or electronics (e.g., FPGA, ASIC implementations, advanced array readouts);
- Improved g-force survivability for rough landings on Mars, Moon, or comet/asteroid bodies;
- Mitigation strategies for tolerance to high-radiation environments like that around Europa;
- High temperature and/or high pressure lifetime improvement for instruments landed on Venus;
- Low temperature survivability or lifetime improvement for instruments landed on cryogenic outer planet bodies or deployed to the subsurface;
- Advanced sample handling and manipulation technologies for challenging environments and planetary protection.

Proposers are strongly encouraged to relate their proposed development to (a) future planetary exploration goals of NASA; and (b) existing flight instrument capability to provide a comparison metric for assessing proposed improvements.

Instruments for both remote sensing and in situ investigations are required for NASA's planned and potential solar system exploration missions. Instruments are required for the characterization of the atmosphere, surface, and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed for remote sensing, on orbital or flyby spacecraft, or for in situ measurements, on surface landers and rovers, subsurface penetrators, and airborne platforms. In situ instruments cover spatial scales from surface reconnaissance to microscopic investigations. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses.

Proposals should show an understanding of one or more 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, LaRC

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 (http://science.hq.nasa.gov/strategy/roadmaps/surface.html). 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 (2 – 14 GHz) feeds capable of receiving GNSS signals, Ka-band (32 – 36 GHz) 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, and frequency standards / distribution systems 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.
- Geodetic GNSS software receivers and antenna systems capable of receiving all signals from the GPS, GLONASS, Galileo and Beidou/Compass GNSS.
- 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.

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

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 (hwttp://ww.nap.edu/catalog.php?record_id=11954). Future missions will characterize the lunar exosphere and surface environment; field test new equipment, technologies, and approaches for performing lunar science; identify landing sites and emplace infrastructure to support robotic and human exploration; demonstrate and validate heritage systems for exploration missions; and provide operational experience in the harsh lunar environment.

Space-qualified instruments are required to perform remote and in situ lunar science investigations, to include measurements of 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.

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.

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, and Laser Induced Breakdown Spectroscopy (LIBS). Instruments shall have the potential to provide isotope ratio measurements and/or hydrogen distributions to ±10 ppm locally. 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: the plasma environment, surface electric field, 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.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 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://constellation.gsfc.nasa.gov/, http://lisa.gsfc.nasa.gov/). 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 10,000 - 100,000 km 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 through-put, 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 polarime-try. 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;
- Pupil plane masks for interferometry;
- 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 in homogeneity, 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;
- Single mode fiber filtering from visible to 20 µm wavelength;
- 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.

Wavefront Control Technologies

- Development of small stroke, high precision, deformable mirrors (DM) and associated driving electronics scalable to 10^4 or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple DM 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;
- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance; and
- Highly reflecting broadband coatings.

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): LaRC, GSFC

Planned future NASA Missions in astrophysics, such as the Single Aperture Far-IR (SAFIR) telescope, James Webb Space Telescope (JWST, http://www.jwst.nasa.gov/), Terrestrial Planet Finder (TPF, http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) missions: Coronagraph, External Occulter and Interferometer, 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 topic 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; and innovative systems which minimize complexity, mass, power and cost. The goal for this effort is to mature technologies that can be used to fabricate 20 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 2 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 Optical Devices for Starlight Detection and Wavefront Analysis
Lead Center: MSFC
Participating Center(s): GSFC, JPL

The planned Ares V vehicle will enable the launch of 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. UV/optical telescopes require 1 to 3 meter class mirrors with < 5 nm rms surface figures. IR telescopes require 2 to 3 meter class mirrors with cryo-deformations < 100 nm rms. X-ray telescopes 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 lenses.

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 $3M to $4M per square meter of optical surface area. This research effort seeks a cost reduction for precision optical components by 20X to 100X to less than $100K per square meter.

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 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).

An additional key enabling technology for UV/optical telescopes is a 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 mirrors.

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.

The Phase 1 deliverable will be at least a 0.25 meter near UV, visible or x-ray precision mirror or lens or replicating mandrel, its optical performance assessment and all data on the processing and properties of its substrate materials. This effort will allow technology to advance to TRL 3-4.

The Phase 2 deliverable will be at least a 0.50 meter near UV, visible or x-ray space-qualifiable precision mirror or lens system with supporting documentation, optical performance assessment, all data on materials and processing, and thermal and mechanical stability analysis. Effort will advance technology to TRL 4-5.

The proposal must address the technical need of a recognized future NASA space science mission, science measurement objective or science sensor for a Discovery, Explorer, Beyond Einstein, Origins, GOESS, New Millennium, Landmark-Discovery, or Vision mission. Missions of interest include the following: Constellation-X (http://constellation.gsfc.nasa.gov/); Generation-X (http://www.cfa.harvard.edu/hea/genx.html); Single Aperture Far-Infrared (http://safir.jpl.nasa.gov/technologies.shtml); Terrestrial Planet Finder (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm); Orbiting Wide Angle Light Collector (http://owl.gsfc.nasa.gov/); Extreme Universe Space Observatory (http://hena.lbl.gov/EUSO/).

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 year's 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://universe.nasa.gov/program/probes/jdem.html), Constellation-X (http://constellation.gsfc.nasa.gov/), TPF (http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm) and SAFIR (http://safir.jpl.nasa.gov/technologies.shtml). Optical systems currently being researched for these missions are large area aspheres, requiring accurate figuring and polishing across six orders of magnitude in period (i.e., 1st and 2nd order errors through micro-roughness). 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 (i.e., 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.

By the end of a Phase 2 program, technologies must be developed to the point where the technique or instrument can dovetail into an existing optics manufacturing facility producing optics at the R&D stage. Metrology instruments should have 10 nm or better surface height resolution and span at least 3 orders of magnitude in lateral spatial frequency.

Examples of technologies and instruments of interest include:

- 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; chart the best route of discovery; and reap the benefits of Earth and space exploration for society. A major objective of the NASA science spacecraft systems development programs is to implement science measurement capabilities using small, affordable spacecraft enabling a single spacecraft to meet multiple mission requirements thus making the best use of our limited resources. To accomplish this objective, NASA is fostering innovations in propulsion, power, and guidance and navigation systems (including advanced avionics for low cost small spacecraft and technology) that significantly reduce the mass and cost while maximizing the scientific return for future NASA missions. Innovations are sought in the areas of power generation, energy storage, guidance, navigation, command/control, on-board propulsion (electric propulsion, advanced chemical and propellantless propulsion), propulsion technologies related to sample return missions, and on-board power management and distribution (power electronics and packaging). Also sought for NASA Science Missions are thermal control technologies for spacecraft, piloted and unpiloted aircraft, and terrestrial and planetary balloons.

S3.01 Avionics and Electronics
Lead Center: GSFC
Participating Center(s): ARC, GRC, 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 guidance, navigation, command and data handling are sought to support NASA's goals and several missions and projects under development (http://nasascience.nasa.gov/search?SearchableText=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, (3) develop precision line-of-sight sensing for large telescopes and spacecraft formations, and (4) mass and technology improvements in guidance, navigation and control for low cost small spacecraft use. 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 vision of the Science Mission Directorate.

Successful proposal concepts will significantly exceed the present state-of-the-art. Proposals will clearly (1) state what the product is; (2) describe how it targets the technical priorities listed below; and (3) outline the feasibility of the technical and programmatic approach. If a Phase 2 proposal is awarded, the combined Phase 1 and Phase 2 developments shall produce a prototype that is testable by NASA. The technology priorities sought are listed below.

Command and Data Handling

- 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 (>500 MIPS at >100 MIPS/W for general purpose processing platforms, >5 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 and Ethernet physical layer components.
- Tunable, scalable, reconfigurable, adaptive fault-tolerant avionics.

Guidance, Navigation and Control

- 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.

The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) of the solicitation participates in this subtopic. Offerors are encouraged to take this in consideration as a possible flight opportunity when proposing work to this subtopic.

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 (http://nasascience.nasa.gov/search?SearchableText=missions+under+development, http://www.nap.edu/catalog.php?record_id=10432). Some of these requirements include:

- Optical systems, lasers (ICESAT 2), and detectors which require tight temperature control, often to better than +/- 1°C. Some new missions such as CON-X and LISA, and upcoming Earth Science missions require thermal gradients held to even tighter micro-degree levels.
- Exploration science missions to the Moon and Mars present engineering challenges requiring systems which are more self-sufficient and reliable.
- The introduction of low-cost, small, rapidly configured spacecraft as described in Topic S4 requires the development of new thermal technologies to reduce the time and costs typically required for analysis, design, integration, and testing of the spacecraft. The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) participates in this subtopic and offerors are encouraged to take this in consideration as a possible flight opportunity when proposing work to this subtopic.

Innovative proposals for the cross-cutting thermal control discipline are sought in the following areas:

- Methods of precise temperature measurement and control to tight temperature levels.
- High conductivity, vacuum-compatible interface materials to minimize losses across make/break interfaces.
- High conductivity materials to minimize temperature gradients and provide high efficiency light-weight radiators, including interfaces to heat pipes and fluid loops that overcomes issues with CTE mismatch.
- Advanced more efficient thermoelectric coolers capable of providing cooling at ambient and cryogenic temperatures.
- Advanced thermal control coatings or process technologies including variable emittance surfaces applicable to small spacecraft.
- Single and two-phase mechanically pumped fluid loop systems which accommodate multiple heat sources and sinks, and long life, lightweight pumps for these systems. Also includes advanced fluid system components such as accumulators, valves, pumps, flow rate sensors, etc. optimized for improved reliability, long life, and low resource needs.
- Efficient, lightweight, oil-less, high lift vapor compression systems for cooling up to 2 KW.

- Advanced thermal modeling techniques that can be easily integrated into existing codes, emphasizing inclusion of two-phase systems and mechanically pumped system models.
- Integration of standardized formats into existing codes for the representation and exchange of Thermal Network Models and Thermal Geometric Models and results.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration. Phase 2 should deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

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.

S3.03 Power Generation and Storage
Lead Center: GRC
Participating Center(s): 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.
(http://nasascience.nasa.gov/search?SearchableText=missions+under+development,
http://www.nap.edu/catalog.php?record_id=10432)

Proposals are solicited to develop advanced power conversion, energy storage, and power electronics to enable or enhance the capabilities of future science missions. The requirements for the power systems for these missions are varied and include long life capability, high reliability, significantly lower mass and volume, higher mass specific power, and improved efficiency over the state of practice (SOP) components/systems. Other desired capabilities are high radiation tolerance, and ability to operate in extreme environments (high and low temperatures and over wide temperature ranges).

Advanced Photovoltaic Energy Conversion
Photovoltaic cell, blanket, and array technologies that lead to significant improvements in overall solar array performance (i.e. efficiency (>30%), mass specific power (>300W/kg), 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):

- Photovoltaic cell and blanket technologies capable of low intensity, low-temperature (LILT) operation applicable to the Outer Planets Mission;
- Photovoltaic cell, blanket and array technologies for high intensity high-temperature operation applicable to the Solar Probe mission;
- Thermophotovoltaic technologies applicable to the Outer Planets Mission;
- Component technologies of interest include advanced solar cell designs, space-durable coatings, designs capable of high voltage operation within the space environment, and technologies that reduce fabrication/testing costs while maintaining high reliability;
- Array technologies of interest include concentrators, large reliably-deployable arrays, ultra-lightweight arrays for use with flexible, lightweight cells. Of particular interest are lightweight array technologies that are electrostatically-clean and can operate at voltages up to 1000 volts, enabling direct drive electric propulsion for deep space missions.

Stirling Power Conversion
Novel methods or approaches for radiation-tolerant, sensorless, autonomous control of the Stirling converters with very low vibration and having low mass, size, and electromagnetic interference (EMI). Other technologies of interest include:

- High-temperature, high-performance regenerators;
- High-temperature, lightweight, high-efficiency, low EMI, linear alternators;

- High-temperature heater heads (> 850°C) and joining techniques and regenerators applicable to Venus surface missions (~1200°C);
- Combined electrical power generation and cooling systems applicable to Venus surface missions (~1200°C).

Energy Storage
Future science missions will require lithium-based or other advanced rechargeable electrochemical battery systems that offer greater than 40,000 charge/discharge cycles (7 year operating life) for low-Earth-orbiting (LEO) spacecraft, 20 year life for geosynchronous (GEO) spacecraft, and as low as -80°C storage and operation temperatures for planetary missions. Energy storage technologies that enable one or more of the above requirements combined with very high specific energy and energy density are of interest.

Power Management and Distribution
Advanced electrical power technologies are required for the electrical components and systems on future platforms to address the size, mass, efficiency, capacity, durability, and reliability requirements. In addition to the above requirements, proposals must address the expected improvements in energy density, speed, efficiency, or wide-temperature operation (-125°C to 200°C) with a high number of thermal cycles. Advancements are sought in power electronic devices, components, and packaging. Technologies of interest include:

- Power electronic components and subsystems;
- Power distribution;
- Fault protection;
- Advanced electronic packaging for thermal control and electromagnetic shielding.

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.

S3.04 Propulsion Systems
Lead Center: GRC
Participating Center(s): ARC, JPL, JSC, MSFC

The Science Mission Directorate (SMD) needs spacecraft with ever-increasing propulsive performance and flexibility for ambitious missions requiring high duty cycles and years of operation. Planetary spacecraft need the ability to rendezvous with, orbit, and conduct in situ exploration of planets, satellites and other solar system bodies (http://www.nap.edu/catalog.php?record_id=10432). Platforms, satellites, and satellite constellations have high-precision propulsion requirements, usually in volume- and power-limited envelopes. This subtopic seeks innovations to meet SMD propulsion requirements, reflecting the goals of NASA's In-Space Propulsion Technology program to reduce the travel time, mass, and cost of SMD spacecraft. Propulsion areas include chemical and electric propulsion systems, propulsion technologies related to sample return missions to asteroids, comets, and other small bodies, propellantless options (such as aerocapture and solar sails), and less developed but emerging propulsion concepts such as advanced plasma thrusters and momentum exchange/electrodynamic reboost (MXER) tethers.

Specific sample return propulsion technologies include, but are not limited to, ascent vehicle propulsion, pumps for pressure-fed propulsion systems, long-term storage capable solid rocket propulsion technologies, lightweight propulsion components, Earth-return propulsion systems, Earth-EDL systems, and Earth Entry Vehicle heat shield materials.

This subtopic also seeks proposals that explore uses of technologies that will provide superior performance in attitude control and overall orbit control. The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) of the solicitation participates in this subtopic. Offerors are encouraged to consider this possible flight opportunity when proposing work to this subtopic.

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.

S3.05 Balloon Technology, Terrestrial and Planetary
Lead Center: GSFC
Participating Center(s): JPL

Innovations to advance terrestrial (http://sites.wff.nasa.gov/code820/) and planetary balloons and aerobots are being solicited. The technologies proposed shall have a clear path for infusion into the current flight systems within the next few years.

Currently, NASA is developing a superpressure terrestrial vehicle targeting 100 day duration missions in mid-latitude. This added capability will greatly enable new science investigations. The design of the current pumpkin shape vehicle utilizes light weight polyethylene film and high strength tendons made of twisted Zylon® yarn. The in-flight performance and health of the vehicle relies on accurate information on a number of environmental and design parameters. Therefore, NASA is seeking innovations in the following specific areas:

Devices or methods to accurately and continuously measure individual axial loading on an array of up to 200 separate tendons during a superpressure balloon mission. Tendons are the load carrying member in the pumpkin design. During a typical mission, loading on individual tendons should not exceed a critical design limit to insure structural integrity and survival. Tendons are typically captured at the fitting via individual pins. Loading levels on the tendons can range from ~20 N to ~8,000 N and temperature can vary from room temperature to the troposphere temperatures of -90°C or colder. The devices of interest shall be easily integrated with the tendons or fittings during balloon fabrication and shall have minimal impact on the overall mass of the balloon system. Support telemetry and instrumentation is not part of the this initiative; however, data from any sensors (devices) that are selected from this initiative must be able to be telemetered in-flight using single-channel (two-wire) interface into existing NASA balloon flight support systems.

Devices or methods to accurately and continuously measure ambient air, helium gas, and balloon film temperature. The measurements are needed to accurately model the balloon performance during a typical flight at altitudes of approximately 120,000 feet. The measurement must compensate for the effects of direct solar radiation through shielding or calculation. Minimal mass and volume are highly desired. For film measurement, a non-invasive and non-contact approach is highly desired for the thin polyethylene film, with film thickness ranging from 0.8 to 1.5 mil, used as the balloon envelope. Devices for measurement of helium gas and balloon film temperature must be compatible with existing NASA balloon packaging, inflation and launch methods. Devices and/or methods must be able to interface with existing NASA balloon flight support systems or alternatively, a definition of a telemetry solution be provided.

Innovations in materials, structures, and systems concepts have also 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 on Mars, Venus, and Titan in order to investigate their atmospheres in situ and their surfaces from close proximity. Their envelopes will be subject to extreme environments and must support missions with a range of durations. Proposals are sought in the following areas:

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 m^3 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. (http://newfrontiers.nasa.gov/program_plan.html)

Cryogenic Testing of Titan Aerobots (http://www.nap.edu/catalog.php?record_id=10432)
Aerobots at Titan must operate at cryogenic temperatures in the range of 85 to 95 K. There is a need for inexpensive test facilities to conduct experiments on sub-scale and full scale prototype balloons ranging in size from 1 to 15 m in their largest dimension. Proposals are sought for the development and validation of innovative, low cost test facilities that can be used to conduct light gas and Montgolfiere balloon experiments with time scales ranging from hours to weeks.

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.

Ground-launched Mars Balloons
NASA is interested in small balloons with very light payloads (< 1 kg) that can be autonomously launched on the Martian surface from a lander or large rover. Proposals are sought for balloon designs and systems concepts to enable this. It is important that proposals directly address the difficult problem of not damaging the balloon despite proximity to landed equipment and surface rocks. Preference will be given to proposals that include proof-of-concept experiments addressing key feasibility questions for the proposed approach.

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: S4 Low-Cost Small Spacecraft and Technologies

The Low-Cost Small Spacecraft and Technologies Topic focuses on the technologies, subsystems, methodologies, and mission concepts for space missions which lower the over-all cost for scientific exploration. The "Small" of spacecraft and missions refers to small spacecraft that have "wet" masses below 500 Kg. (compared to micro satellites 10-100kg, nano satellite 1-10kg, or pico satellite <1kg), are substantially less expensive, and will require different approaches to solve traditional problems in development, operations and capability. The goal of these low-cost missions is not to replace the major missions, but rather to reduce the risks to, as well as the costs of, future major missions. Low-Cost Small Spacecraft and Technologies Missions will be used as test beds for new technologies, provide flight "heritage" for new instruments and components. Increasing the number of flight opportunities per year enables missions to be designed and flown during typical graduate and post-doctoral tenures, provide training for a new generation of scientists and engineers. These small spacecraft missions can also accomplish specific scientific investigations that would be too narrow for a major mission but still scientifically important. This topic is divided into two categories of subtopics: Small Spacecraft Technologies and Enablers and Small Spacecraft Build.

Small Spacecraft Technologies and Enablers: These subtopics will lower the barrier to entry for small spacecraft missions by encouraging launch opportunities and creating open design and spacecraft management tools. These subtopics include: 1. Nanosat launch vehicles and technologies, 2. Rapid End-to-end Mission Design and Simulation 3. Cost modeling.

Small Spacecraft Build: When used together, SBIR subtopics could create a small spacecraft mission. The subtopics required to accomplish this effort extend beyond the Low-cost Small Spacecraft and Technologies topic, and definition for such an effort is in progress (see 2.0, Mission Concept). In FY08, there will be multiple subtopics across the topic portfolio participating toward this mission concept.

Mission Concept: NASA announced a mission concept at a Mission Concept Review (MCR) held February 8, 2008. The spacecraft is a modular spacecraft that operates using standard protocols (high speed: Ethernet, SpacewireTM; low speed: RS-422, I2C) and at 28V +/- 6V. With this modularity, a requirement for the Low-Cost Small Spacecraft and Technologies, components can be interchanged from a basic spacecraft design to tailor for specific missions.

The Low-Cost Small Spacecraft and Technologies topic will invite to subsequent reviews those awardees current at the time of the review; review titles and respective tentative dates follow: a) System Requirements Review (SRR), tentatively August 2008; b) Mission Definition Review (MDR), tentatively November 2008; c) Preliminary Design Review (PDR), tentatively August 2009; Critical Design Review (CDR), tentatively September 2010. NASA intends to make SBIR Phase 1 and Phase 2 awards to this effort, which NASA understands are a best effort by the SBIR awardees and NASA alike. By 1QFY11, all Phase 2 and Phase 3 SBIR teams are encouraged to deliver to NASA the hardware to be integrated and ready for launch in 4QFY11. The Low-Cost Small Spacecraft and Technologies topic is envisioned to launch one satellite per year or every other year, starting in FY11, kicking off a new team at each cycle. NASA cannot direct SBIR awardees to conform to the provisional schedule outlined above, however when brought together this could create the opportunity for a spacecraft build. This topic will give significant priority to offerors that take full advantage of standard interfaces, protocols, methodologies, open source software and Commercial off the Shelf (COTS)-derivative hardware.

S4.01 NanoSat Launch Vehicle Technologies
Lead Center: ARC

The space transportation industry is in need of low-cost, reliable, on-demand, routine space access. Both government and private entities are pursuing various launch systems and architectures aimed at addressing this market need. Significant technical risk and cost exists in new system development and operations - reducing incentive for private capital investment in this still-nascent industry. Public and private sector goals are aligned in reducing these risks and enabling the development of launch systems capable of reliably delivering payloads to low Earth orbit. The NanoSat Launch Vehicle Technology subtopic will particularly focus on higher risk entrepreneurial projects for dedicated nano and small spacecraft launch vehicles. This subtopic is seeking proposals in the following, but not limited, areas:

- Conceptual designs of system/architectures capable of reducing the mission costs associated with small payload delivery to LEO.
- Maturation of hypersonic and small launch vehicle design and analysis tools or tool-sets aimed at increasing the state-of-the-art while reducing the required design cycle time and human interaction.
- Maturation of key technologies/processes for hypersonic and small launch vehicles including, but not limited to:
    - Thermal protection systems;
    - Airframe and subsystem structures that increase system performance and propellant mass fraction;
    - Vehicle sensor networks.
- Novel, low-cost modular adapters and release mechanisms.
- Lightweight interstage designs.

Applications of wireless networking technologies for small launch vehicles are also specifically of interest to this subtopic. This technology could be used for vehicle to ground communications (spread-spectrum and non-licensed technologies), as well as within the vehicle itself. We desire new architectures for intelligent on-board communications as well as satellite-to-satellite communication using machine-to-machine (M2M) solutions. The traditional wire harness architecture could be replaced by the wireless technology for command and control, which would reduce vehicle mass and improve reliability. Also stage-to-stage interfaces and vehicle-payload interfaces are of interest. These wireless technologies can include but are not limited to WIMAXTM and ZIGBEETM.

Non-propulsive approaches and architectures for new launch vehicles can also achieve increases in launch vehicle payload mass delivered to orbit for small spacecraft missions. Offerors should consider development, test, and operational factors to show improvements in development and operational costs, payload mass fraction, and mission assurance. Special attention should be given to improved integration between the launch vehicle and payloads to further reduce operational costs. Furthermore, non-propulsive launch vehicle technologies have a dramatic impact on launch vehicle performance and constitute a large percentage of development and operational costs.

They include, but are not limited to:

- Robust on-board Guidance, Navigation and Control (GN&C) avionics. GN&C should be modular (including modular software architectures) and make use of modern architectures, including high-performance low-weight avionics hardware, and modern software tools. Emphasis is on low-weight architecture to allow maximum payload capacity.
- Range safety solutions and operational concepts to lower costs. These may include alternative solutions to expensive explosive destruct packages, including, but not limited to propulsion-cutoff systems, autonomous flight-abort systems, etc.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 2 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 space-worthy systems.

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

S4.02 Rapid End-to-End Mission Design and Simulation
Lead Center: ARC
Participating Center(s): GSFC

This subtopic addresses the need to rapidly and efficiently analyze, design, simulate, and evaluate competing mission concepts.

The traditional mission design process involves multiple tools and trades, resulting in design data being generated and stored in various proprietary formats, making iterative trades cumbersome. Current mission design and simulation environments require dedicated personnel that execute mission simulations for mission projects, but at a significant cost to project budgets. For efficient mission design and simulation activities, particularly for small satellites and other missions with small budgets and cost margins, there is a need for user-friendly tools that will provide seamless data flow between simulation environments with little overhead.

This subtopic seeks proposals for a toolset that shall integrate legacy engineering software with user-generated design and simulation tools into a single, user-friendly environment. The toolset shall automate the flow of data between analysis, design, and simulation applications with minimal user manipulation. The data shall also be preserved through the various design phases from initial concept to execution.

Data resources to be linked include cost tracking spreadsheets, task plans, risk management databases, requirements databases, technical performance metrics and margins sheets, top level and WBS element schedules, and standard monthly status reports from WBS elements. The tool should be easily scalable for large or small projects and the number of WBS elements and features included or excluded for a given project should be user-selectable. User and group permission and access controls are required.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration, and when possible, deliver a demonstration application for NASA testing at the completion of the Phase 2 contract.

Phase 2 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.

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

S4.03 Cost Modeling
Lead Center: ARC
Participating Center(s): GSFC, JPL

An integrated cost-design model is required, one that incorporates the regression analysis and statistical validity of historical parametric cost models with the flexibility and relevance of a ground-up, or grassroots, cost model. By explicitly focusing on the prime cost determinant, labor, as opposed to the spacecraft parameters, and determining the historic relationships between the tasks on the WBS and cost for a given institution/firm, as opposed to space industry in general, a cost model can be produced that is specific to the production process used by an institution. Such a cost model would predict the cost of individual tasks at sub-system and component levels within a given institution, enabling cost to be included as an endogenously determined variable in the design process.

Such an integrated cost-design model is currently embodied only as human capital in individual managers who have, through their personal experience, accumulated knowledge of cost-design relationships. When these experienced managers leave, the institution loses the understanding of the relationship between cost and design choices that the manager had built up through years of experience. Without this experience, ground-up cost models can be wildly inaccurate and as a result, only parametric cost models such as the NASA/Air Force Cost Model (NAFCOM) and the Small Satellite Cost Model (SSCM) are accepted for Technical Management and Cost (TMC) reviews. This is particularly problematic for small low-cost spacecraft where designs are rapidly evolving, management structures are more varied, and the entire purpose is to provide spacecraft at costs lower than what has historically been considered possible.

This subtopic seeks proposals to define management system requirements and develop software that would enable cost (and schedule) data at the task-level to be collected and centralized creating a base dataset for institution-based cost models and cost management research. The system would codify cost information of projects ensuring it is preserved beyond the careers of individual managers and would, over time, accumulate long time-series of task-level cost information that would enable ground-up institution-based cost models to stand on a rigorous statistical framework. This would enable the development of a generic institution-based design-cost model that can then be tailored for individual institutions and used across the industry.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

In Phase 1, research should provide examples of proven cost benefits and project successes based on the use of integrated management tools for management of multiple simultaneous distributed projects. Architectures should be proposed for implementation of an integrated multi-project management tool.

In Phase 2, a management tool set will be implemented and demonstrated as part of an actual small satellite management project. The tool will be evaluated for ease of use, effectiveness as a NASA project set-up tool, management information tool, and reporting tool. Feasibility for a single manager to effectively manage and report on multiple simultaneous projects will be assessed. Project users from the WBS elements of the satellite project will evaluate ease of use of uploading data.

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

S4.04 Reusable Flight Software
Lead Center: ARC
Participating Center(s): GSFC

There is a need to rapidly develop and deploy small satellites and easily adapt new payloads in a cost effective manner. The cost of flight software, including algorithms and data management, is continuing to increase and multiply in complexity.

Spacecraft software applications are typically customized, however, development costs can be driven down and a plug-and-play capability can be fostered through repeated use of reusable software and functional libraries that are developed once and updated only to enhance performance or correct deficiencies.

Small satellites can be effectively designed for multiple uses of the same nominal hardware set to perform multiple missions. Interfaces between differing payloads are anticipated to be “plug-and-play”, where the interface between hardware elements is transparent across the interface. This implies that and allows the software to be reusable from mission to mission. An analogy would be a reusable core executive operating system that controls central satellite functions. Each payload or special hardware element will have subservient applications, written by the element developed that provides special needs. In order to be most economical, the subservient applications should be capable of utilizing an extensive library of modules.

This subtopic calls for the definition and development of a common core executive software and library modules that can be utilized repeatedly for many small satellite missions. The software shall be portable between several types of core processors. The executive and libraries shall provide robust functionality, based on open standards that can be utilized by specialized payload and component developers. In this manner, a minimum amount of custom software, limited to basic functional control of certain hardware elements, will be required. Library functions within the reusable core executive shall be capable of performing computation intense work. The intent is to not modify the reusable core executive except as experience dictates from previous missions.

The Reusable Flight Software subtopic encourages offerors to utilize open source software and hardware solutions to be utilized for other actors, including entrepreneurial and university teams, for reusability.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration, and when possible, deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 2 emphasis should be placed on developing and demonstrating the software technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems.

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: 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://marstech.jpl.nasa.gov/ for additional information on Mars Exploration technologies.

S5.01 Planetary Entry, Descent, Ascent, Rendezvous and Landing Technology
Lead Center: JPL
Participating Center(s): ARC, JSC, LaRC

NASA seeks innovative sensor technologies to enhance success for entry, descent and landing (EDL) operations on missions to Mars. This call is not for sensor processing algorithms. Sensing technologies are desired 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, altitudes, orientation, localization);
- Extending the range over which such measurements are collected (e.g., providing a method of imaging through the aeroshell, or terrain-relative navigation that does not require imaging through the aeroshell);
- Enhancing the situational awareness during landing by identifying hazards (rocks, craters, slopes), or providing indications of approach velocities and touchdown;
- Substantially reducing the amount of external processing needed to calculate the measurements; and
- Significantly reducing the impact of incorporating such sensors on the spacecraft in terms of volume, mass, placement, or cost.

For a sample return mission, rendezvous technologies for capture of an Orbiting Sample (OS) with the return spacecraft:

- Remotely actuated mechanisms for automated OS capture;
- Optical and contact sensors.

For a sample return mission, monitoring local environmental (weather) conditions on the surface just prior to Planetary Ascent Vehicle (PAV) launch, via appropriate low-mass sensors.

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

S5.02 Sample Collection, Processing, and Handling
Lead Center: JPL
Participating Center(s): ARC, GSFC, JSC

Robust systems for sample acquisition, handling and processing are critical to the next generation of robotic explorers for investigation of planetary bodies (http://books.nap.edu/openbook.php?record_id=10432&page=R1). Limited spacecraft resources (power, volume, mass, computational capabilities, and telemetry bandwidth) demand innovative, integrated sampling systems that can survive and operate in challenging environments (extremes in temperature, pressure, gravity, vibration and thermal cycling). 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. Other sample types of interest are unconsolidated regolith, dust, and atmospheric gas.

Sample Manipulation (core management, sub-sampling/sorting)
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 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.

System Robustness and Reliability
Consideration should be given to potential failure scenarios for integrated systems. For example, recovery and mitigation techniques for platform slip and borehole misalignment should be addressed. Significant attention should be given to the sensing and automation required for real-time control, fault diagnosis and recovery. In the case of rover-mounted subsurface sampling systems, the ability to release under load will be critical to mitigate risk of losing mobility if unexpected subsurface conditions are encountered.

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 (PAV)

- Automated payload transfer mechanisms;
- 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

Technologies are needed to enable access and sample acquisition at surface and subsurface sampling sites of scientific interest on Mars (http://books.nap.edu/openbook.php?record_id=10432&page=R1). Mobility technology is needed to enable access to difficult-to-reach sites such as access through steep terrain. Many scientifically valuable sites are accessible only via terrain that is too steep for state-of-the-art planetary rovers to traverse. Sites include crater walls, canyons, and gullies. Tethered systems, non-wheeled systems, and marsupial systems are examples of mobility technologies that are of interest. Tether technology could enable new approaches for deployment, retrieval and mobility. Innovative marsupial systems could allow a pair of vehicles with different mobility characteristics to collaborate to enable access to challenging terrain. 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.

Technologies to enable acquisition of subsurface samples are also needed. Technologies are needed to acquire core samples in the shallow subsurface to about 10cm and to enable subsurface sampling in multiple holes at least 1 - 3 meters deep through rock, regolith or ice compositions. 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. 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 low-mass, low-power, and modular systems and subsystems are of particular interest. Technical feasibility should be demonstrated during Phase 1 and a full capability unit of at least TRL level 4-6 should be delivered in Phase 2. 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, and boring systems for subsurface sampling to 10cm or 1 to 3 meters.

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.

S5.04 Technologies for Low Mass Mars Ascent Vehicles (PAV)
Lead Center: JPL
Participating Center(s): ARC, DFRC, MSFC

NASA aims to design, build and test vehicles that will be launched from the surface of other planets and place a payload, Orbiting Sample (OS), into orbit (http://marsprogram.jpl.nasa.gov/missions/future/futureMissions.html).

We are seeking proposals for the development of innovative technologies to support future Payload Ascent Vehicles (PAVs) and associated sample operations. Technology innovations should either enhance vehicle capabilities (e.g., increased payload, launch success probability, mission success) or ease implementation in spaceborne missions (e.g., reduce size, weight, power, improve reliability, or lower cost). The areas of interest for this call are listed below.

Alternate propellants, thrusters and propulsion feed system technologies for the PAV:

- Higher performing monopropellants with specific impulse >240 secs;
- High chamber pressure thrusters > 500 psia;
- Pressurization component technologies to reduce system mass (filters, solenoid valves, latch valves, tanks, fill & drain and check valves);
- Small lightweight pump technologies to operate at >500 psi output pressure;
- Non-pyrotechnic isolation valves.

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: S6 Information Technologies

Modeling and simulation are being used more pervasively and more effectively 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. Examples of past simulation successes include simulations of entry conditions for man-rated space flight vehicles, visualizations of distant planet topography via simulated fly-over and three-dimensional visualizations of coupled ocean and weather systems. In many of these situations, assimilation of real data into a highly sophisticated physics model is needed. Also use NASA missions and other activities to inspire and motivate the nation's students and teachers, to engage and educate the public, and to advance the scientific and technological capabilities of the nation.

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 Earth and astrophysical systems, as well as to conduct high-fidelity engineering analyses (http://nasascience.nasa.gov/earth-science/water-and-energy-cycle/research/?searchterm=large%20scale%20 simulation). The goal of this subtopic is to make NASA's supercomputing systems and associated resources easier to use, thereby broadening NASA's supercomputing user base and increasing user productivity. Specific objectives are to:

- Reduce the learning curve for using supercomputing resources;
- Minimize total time-to-solution (i.e., time to discovery, understanding, or prediction);
- Increase the scale and complexity of computational analysis and data assimilation;
- Accelerate advancement of system models and designs.

The approach of this subtopic is to develop intuitive, high-level tools, interfaces, and environments for users, and to infuse them into NASA supercomputing operations. Successful technology development efforts under this subtopic would be considered for follow-on funding by, and infusion into either of the NASA high-end computing (HEC) projects, including the High End Computing Capability (HECC) project at Ames and the NASA Center for Computational Sciences (NCCS) at Goddard. SBIR projects should be informed by direct interactions with one or both

HEC projects. Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 prototype demonstration. Open Source software and open standards are strongly preferred.

Specific areas of interest include:

Application Development Environments
With the increasing scale and complexity of supercomputers, users must often expend a tremendous effort to translate their physical system model or algorithm into a correct and efficient supercomputer application code. This subtopic element seeks intuitive, high-level application development environments, ideally leveraging high-level programming languages to enable rapid supercomputer application development, even for novice users. This environment should dramatically simplify application development activities such as porting, parallelization, debugging, scaling, performance analysis, and optimization.

Results V&V
A primary barrier to effective use of supercomputing by novices, and often experts, is understanding the accuracy of their computational results. Errors in the input data, domain definition, grids, algorithms, and application code can individually or in combination produce non-physical results that a user may not detect. This subtopic element seeks tools and environments to help users with verification and validation (V&V) of simulation results. This could be accomplished by enabling comparison of results from similar applications or with known accurate results, access to results analysis tools and domain experts, or access to error estimation tools and training.

Data Analysis and Visualization
Supercomputing computations almost invariably result in tremendous amounts of data, measuring in the gigabytes or terabytes, and with many dimensions and other complexity aspects. This subtopic element seeks user-friendly tools and environments for analysis and visualization of large-scale, complex data sets typically resulting from supercomputing computations.

Ensemble Management
Conducting and fusing the results from an ensemble of related computations is an increasingly common use of supercomputers. However, ensemble computing and analysis introduces a new set of challenges for deriving full value from using supercomputing. This subtopic element seeks tools and environments for managing and automating ensemble supercomputing-based simulation, analysis, and discovery. Functions could include managing and automating the computations, model or design optimization, interactive computational steering, input and output data handling, data analysis, visualization, progress monitoring, and completion assurance.

Integrated Environments
The user interface to a supercomputer is typically a command line or text window, where users may struggle to understand resources and services available, locate or develop applications, understand the job queue structure, develop scripts to submit jobs to the queue, manage input and output files, archive data, monitor resource allocations, collaborate and share data and codes, and many other essential supercomputing tasks. This subtopic element seeks more intuitive, intelligent, and integrated interfaces to supercomputing resources. This integrated environment could include access to user training (e.g., tutorials, case studies, experts), application development tools, standard (e.g., production, commercial, and Open Source) supercomputing applications, results V&V tools, computing and storage resources, ensemble management tools, workflow management, data analysis and visualization tools, and remote collaboration.

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.

S6.02 Sensor and Platform Data Processing and Control
Lead Center: ARC
Participating Center(s): GSFC, JPL

This subtopic seeks proposals for software-based advances in data collection quality and/or coverage of scientific instruments that support NASA Science Mission Directorate objectives across any of the Earth, Solar, Lunar, Space, or Planetary sciences.

Algorithmic based approaches expressed in software or reconfigurable hardware can improve measurement quality and coverage of existing scientific instrument technologies. Software or reconfigurable hardware based computing can enable design trades to reduce cost and or mass of instruments by implementing needed sensor or platform capabilities in software. Limited computing resources can require innovative approaches to specific problems or use of FPGA hardware.

Target platforms or instruments can be designed to fly on any of the broadest range of NASA platforms ranging from airborne (e.g., Aircraft, UAVs and SOFIA), small, micro, and nano-satellites that support current and anticipated NASA science mission to NASA's flagship mission platforms. The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) of this solicitation participates in this subtopic. Offerors are encouraged to take this relationship in consideration as a possible flight opportunity when proposing work to this subtopic.

New approaches to software frameworks or APIs are discouraged. Technological advances should leverage or extend existing standards or capabilities within the respective science communities (i.e., Sensor Mark-up Language, Virtual Observatory, Earth Science Federation standards, Planetary data standards). Proposals can develop instrument specific software if demonstrated how the software can improve instrument performance (such as improving sensor calibration and correction of data in a tightly closed loop without human intervention). Other examples would show how on-board data processing enables rapid analysis or data sharing between instruments/platforms (e.g., perform level 0, level 1 or level 2 processing on-board the sensor or platform to support decision making based on data results).

Proposers are encouraged to plan on making contact with existing sensor development or prototype development teams or NASA relevant platform developers to understand the computation services available on the sensor, platform and the information flow expected between the sensor and human controller.

- Novel approaches that can leverage specialized, space qualified computing resources such as FPGAs that return order of magnitude reduction in data volume or screening capabilities are desirable.
- Improvements in measurement quality include system models of specific instruments (developed other SBIR subtopics or elsewhere) that account for more of the underlying instrument physics, improved data calibration and data correction capabilities and instrument "intelligence".
- Improved coverage can be achieved by data compression and/or data prioritization for transmission and closing the collection loop; also by the rapid assessment of data content for re-tasking the platform and sensor as the data are collected.

For data compression, aggressive metrics for compression and data volume have the following requirements:

RADAR Missions	SMAP (RADAR)	DESDynI (RADAR)	SWOT (RADAR)
OBP Input data rate (MHz)	32	400	500
Processor Throughput (GFLOPS)	7	20	90
Data Compression Ratio	80:1	10:1	90:1

Where raw data sample spacing is 0.75 m x 1.5 m (16 bits per sample), and the output data sample spacing is 10 m x 10 m (16 bits per sample).

For Hyper-spectral imaging instruments, here is an exemplar requirement on data compression and on-board feature detection.

Data Rate:	660 gigabits per orbit, 220 megabits per second
Data Compression Ratio:	> 3.0
On-Board Detection Capability:	A quick look at the data for presence of cloud cover.

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.

S6.03 Data Analyzing and Processing Algorithms
Lead Center: GSFC
Participating Center(s): ARC, MSFC, SSC

This subtopic seeks technical innovation and unique approaches for the processing and the analysis of data from NASA's space and Earth science missions (http://nasascience.nasa.gov/earth-science/atmospheric-composition/research/). Analysis of NASA science data is used to understand dynamic systems such as the sun, oceans, and Earth's climate as well as to look back in time to explore the origins of the universe. Complex algorithms and intensive data processing are needed to understand and make use of this data. Advances in such algorithms will support science data analysis related to current and future missions and mission concepts such as the Landsat Data Continuity Mission (LDCM) (http://science.hq.nasa.gov/missions/satellite_56.htm), the NPOES Preparatory Project (NPP) (http://science.hq.nasa.gov/missions/satellite_58.htm), the Orbiting Carbon Observatory (OCO) (http://science.hq.nasa.gov/missions/satellite_61.htm), the Lunar Reconnaissance Orbiter (LRO), (http://nssdc.gsfc.nasa.gov/nmc/spacecraftDisplay.do?id=LUNARRO), the Lunar Atmosphere and Dust Environment Explorer (LADEE) satellite (http://nssdc.gsfc.nasa.gov/planetary/), and the James Webb Space Telescope (JWST) (http://www.jwst.nasa.gov/).

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 prototype demonstration. Innovations are sought in data processing and analysis algorithms in the following areas:

NASA seeks tools that increase the utility of scientific research data, models, simulations, and visualizations. Of particular interest are innovative computational methods that will dramatically increase algorithm efficiency and thus performance of scientific applications such as assimilation/fusion of multiple source data, mining of large data holdings, reduction of telescope data and decision support systems for Lunar and planetary science.

Tools to improve predictive capabilities, to optimize data collection by identifying gaps in real-time, and to derive information through synthesis of data from multiple sources are also needed. The ultimate goal is to increase the value of data collected in terms of scientific discovery and application. Data analysis and processing must relate to advancement of NASA's scientific objectives.

NASA is soliciting proposals for software tools which access, fuse, process, and analyze image and vector data for the purpose of analyzing NASA's space and Earth science mission data. Tools and products might be used for broad public dissemination or for communicating within a narrower scientific community. These tools can be plug-ins or enhancements to existing software or on-line 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, popular applications. It is highly desirable that the project development leads to software that is infused into NASA programs and projects.

To promote interoperability, tools shall use industry standard protocols, formats, and APIs, including compliance with the ISO, FDGC, and OGC standards as appropriate.

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.

S6.04 Data Management - Storage, Mining and Visualization
Lead Center: GSFC
Participating Center(s): JPL, LaRC

This subtopic focuses on supporting science analysis through innovative approaches for managing and visualizing collections of science data which are extremely large, complicated, and are highly distributed in a networked environment that encompasses large geographic areas. There are specific areas for which proposals are being sought:

Distributed Scientific Collaboration

- Social networking tools that enable high bandwidth scientific collaboration among scientists distributed worldwide in a large number of different organization. These tools should allow scientists to share data and computational resources, allow collaborative visualization of data, promote the development of online communities for sharing thoughts and ideas, and address issues of data and system security.
- Novel software tools for data viewing, real-time data browse that will enable users to 'fly' through the data space to locate specific areas of interest, and general purpose rendering of multivariate geospatial scientific data sets that use geo-rectification, data overlays, data reduction, and data encoding across widely differing data types and formats.
- Novel 3D hardware virtual reality environments for scientific data visualization that make use of 3D presentation techniques that minimize or eliminate the need for special user devices like goggles or helmets.

Distributed Data Management and Access

- Metadata catalog environments to locate very large and diverse science data sets that are distributed over large geographic areas.
- Dynamically configurable high speed access to data distributed and shared over wide area high speed network environments.
- Object based storage systems, file systems, and data management systems that promote the long term preservation of data in a distributed online (i.e. disk based) storage environment, and provide for recovery from system and user errors.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware/software demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

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.

S6.05 Software as a Service to Large Scale Modeling
Lead Center: GSFC
Participating Center(s): ARC

Currently there are notable obstacles in making NASA's Earth and space science research models useful to new investigators. Much of the software, upwards of hundreds of thousands of lines of code per model, has evolved gradually over the past three decades. At their inceptions the individual numerical models were intricate elements of independent research projects, intended to be mostly internal products rather than tools contributing to a larger, collaborative effort in Earth and space sciences. Hence today when investigators from outside the developers' organizations choose to begin a collaboration, or merely want to use the model for their own benefit, they are often required to adhere to the unfamiliar development environment of the host institution. This environment typically includes the regulation and management of the software repository, the data management system, and the high-end computing platforms. Problems that arise from this type of a work arrangement include:

- IT security policies that restrict certain individuals from obtaining access to Government facilities (especially with providing foreign national graduate students access to the institutional high-end computers that host a particular model);
- Knowledge of running a model residing "in the heads" of support programmers, often too busy to assist outsiders;
- Interface components residing in individuals' directories unknown to others who might take advantage of them;
- User administration practices (userids, passwords, filesystem/data management, other IT security rules) that are specific to one agency's computing center;
- A lack of front-end tools available to other model developers to set up and run collaborative experiments.

The Agency seeks a computational "service layer" to enhance NASA's scientific numerical modeling efforts. The goal is to improve the accessibility of the models to universities and other Government institutions for research and operations. Proposals are sought that develop methods for hosting NASA's Earth and space science models under a "Software As A Service (SaaS)" paradigm. Proposal are also sought which couple model components and ancillary programs under a service-oriented architecture. A feasibility study should be conducted during Phase 1 that will lead to a Phase 2 prototype that makes use of a NASA Earth or space science numerical model. Under such a scenario the back-end supercomputing environment should be segregated from the user's work environment while providing an interface to specific, secure services that will allow (1) execution of the model as a "black box" and (2) the ability to edit model elements, upload, recompile, and execute.

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.

9.1.4 SPACE OPERATIONS

The Space Operations Mission Directorate 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 role of the directorate is to provide the operational capabilities for the agency. These capabilities must continue to evolve synergistically with the directorate guiding the development and enhancement of operational systems (e.g., communications and navigation, space transportation, launch range safety, processing and on-board operations). Also as the Exploration Program provides new capabilities, operation of future spacecraft and new missions that must be integrated into the evolving operational capability and have the potential to vary in size and complexity from micro satellites to manned missions. 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 the Vision for Space Exploration, the Space Operations Mission Directorate will marshal its SBIR efforts around a key enabling transformational technology: Affordable communications and navigation for exploration, human operation in space, science and space access services and operations. We go forward as explorers and as scientists to understand the universe in which we live.

http://www.hq.nasa.gov/osf

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TOPIC: O1 Space Communications

NASA's communications capability is based on the premise that communications shall enable and not constrain missions. Communications must be robust to support the numerous missions for space science, Earth science and exploration of the universe. Technologies such as optical communications, RF including antennas and ground based Earth stations, surface networks, access links, reprogrammable communications systems, communications systems for EVAs, 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 around operational issues associated with the communications capability are needed. Communications that enable the range safety data from sensitive instruments is imperative. These technologies are to be aligned with the Space Communications and Navigation Architecture as being developed by the Agency. See https://www.spacecomm.nasa.gov/spacecomm/ for more details. A typical approach for flight hardware would include: Phase 1 - 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 required. Phase 2 - 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 2 contract. 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.

O1.01 Coding, Modulation, and Compression
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC

This subtopic aims to develop components in digital communication systems that offer both spectrum and power efficient solutions to NASA's future near-Earth, deep-space science and exploration applications. This area comprises technology in three key areas: forward error-correction (FEC) coding, data compression, and modulation. The state-of-the-art in flight for coding is (1) Reed-Solomon code concatenated with a convolutional codes, (2) turbo codes, and just emerging, (3) Low Density Parity Check (LDPC) codes. The first two have flown many times, and the initial designs for (3) are just being begun now. The state-of-the-art in compression is the CCSDS standard http://public.ccsds.org/publications/archive/122x0b1c1_e1.pdf. The state-of-the-art for modulation is BPSK and QPSK for deep space, and BPSK, QPSK, SQPSK, and 8-PSK for near Earth (TDRS) applications. Technology development is needed and required in the following areas:

Coding
The need is to handle signal degradation due to weather impact in Ka-band, RFI interference, and multi-path fading in NASA's future missions. A major challenge is developing coding schemes to handle long bursts of errors, up to 100,000 symbols long, at high processing rate. FEC coding technology to protect against long bursts of erasures due to radio frequency interference (RFI), weather conditions, fading, etc. An entirely new protection mechanism is needed for this long-outage scenario -- existing FEC codes of up to 16,000 are insufficient for this purpose. This technology would be needed in time for a first Ka-band-only mission in the 2015 time-frame. The target is a finished product at TRL 5.

Data Compression
The need is for a real-time high-speed hardware decoder for CCSDS 122.0-B-1 (http://public.ccsds.org/publications/archive/122x0b1c1_e1.pdf). (A CCSDS 122.0-B-1 compliant encoder is already inserted into NASA's mission.) This hardware development effort would be a reference implementation of this standard, that could be used either as the basis for a flight unit, or as an independent validation test module for a flight unit or engineering model. The target is a finished product at TRL 6.

Modulation
Bandwidth efficiency is becoming increasingly important; missions desire simultaneous telemetry and ranging. Modulations and multiple access schemes for multiple spacecraft downlinking to a single antenna; expansion of

SNIP code library – find more good PN spreading codes compatible with SNIP library; bandwidth efficient ranging – how to combine ranging with higher order modulations. Technology target is a demonstration at TRL 5.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration and deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.02 Antenna Technology
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC, LaRC

NASA seeks advanced antenna systems in the following areas: phased array antennas; ground-based uplink antenna array designs; high-efficiency, miniature antennas; smart, reconfigurable antennas; large aperture inflatable/deployable antennas; and antenna adaptive beam correction with pointing control.

Phased Array Antennas
Low cost phased array antennas are needed to enable communication capabilities in the following areas: lunar and planetary exploration, including links between astronauts, landers, habitats, probes, orbiters, suborbital vehicles such as sounding rockets, balloons, unmanned aerial vehicles (UAV's), and expendable launch vehicles (ELV's). The frequencies of interest are S-, X-, Ku-, and Ka-band.

The arrays are required to be aerodynamic or conformal in shape for sounding rockets, UAV's, and expendable platforms. They must also be able to withstand the launch environment. The balloon vehicles communicate primarily with TDRS and can tolerate a wide range of mechanical dimensions. The main challenges to be addressed are low mass, low cost, high power efficiency (i.e., > 40%), and coverage area (i.e., highly steerable). A significant cost reduction for MMIC based arrays is highly desirable. (Typical NRE is ~ $1000.00/element.) Advances in digital beam-forming techniques, including those based on superconducting digital signal processing methods, are also desirable. The expected exit technology readiness level (TRL) is 4.

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. Some concepts currently under consideration are the development of medium-size (12-m class) antennas (hundreds of them are expected to be required) for transmit/receive (Tx/Rx) ground-based arrays. 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. The uplink frequency will be in the 7.1-8.6 GHz range (X-band) in the near term, and may be higher frequencies in in the future; it will likely carry digital modulation at rates from 10 kbps to 30 Mbps. An EIRP of at least 500 GW is required, and some applications contemplate an EIRP as high as 10 TW. A major challenges in the uplink array design is minimizing the life-cycle cost of an array.

Other challenges for ground-based antennas include the development of low cost, reliable components for critical antenna systems; advanced, ultra-phase-stable electronics, and phase calibration techniques; improved understanding of atmospheric effects on signal coherence; and integrated low-noise receiver-transmitter technology. Phase calibration techniques needed to ensure coherent addition of the signals from individual antennas at the spacecraft are also required. It is important to understand whether space-based techniques are required or ground-based techniques are adequate. In general, a target spacecraft in deep space cannot be used for calibration because of the long round-trip communication delay.

Design of ultra-phase-stable electronics to maintain the relative phase among antennas is also needed . These will minimize the need for continuous, extensive and/or disruptive calibrations. A primary related effort currently underway is understanding the effect of the medium (primarily the Earth's troposphere) on the coherence of the signals at the target spacecraft. Generally, turbulence in the medium tends to disrupt the coherence in a way that is time-dependent and site-dependent. A quantitative understanding of these effects is needed. Consequently, techniques for integrating a very low-noise, cryogenically cooled receiver with a medium power (1-200 W) transmitter, are desired . If transmitters and receivers are combined on the same antenna, the performance of each should be compromised as little as possible, and the low cost and high reliability should be maintained.

Under the ground-based antenna area, the exit TRL should be greater than or equal to 4.

High-Efficiency, Miniature Antennas
High efficiency, low-cost, low-weight, miniaturized antennas that are wearable antennas or can be highly integrated into the structure. Example of EVA's space suits made with textile antennas or visor mounted antennas. The antennas may be fractal antennas but also multi-directional to support astronaut mobility, multiband operation and/or broad bandwidth. Antennas should be low/self-powered, small, and efficient, and compatible with communication equipment that can provide high data rate coverage at short ranges (~1.5-3 km, horizon for the Moon for EVA). In-situ low-gain antenna (UHF or X-band) that provide circular polarization with full hemispherical coverage (zenith as well as over the horizon) are desirable.

Smart, Reconfigurable Antennas
NASA is interested in smart, reconfigurable antennas for applications in lunar and planetary operations. 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 lunar and planetary surface exploration (e.g., rovers, pressurized surface vehicles, habitats, etc.). Desirable features include multibeam operation to support connectivity to different communication nodes on lunar and planetary surfaces or in support of communication links for satellite relays around planetary orbits. Also the antenna shall be highly directive, multi-frequency and compatible with Multiple Input Multiple Output (MIMO) concept.
The exit TRL should be 4.

Large Aperture Inflatable/Deployable Antennas
Large deployable or inflatable membrane antennas to significantly reduce stowage volume (packaging efficiencies as high as 50:1), provide high deployment reliability, and significantly reduced mass density (i.e., < 1kg/square meter) are needed. These large Gossamer-like antennas are required to provide high-capacity communication links with low fabrication costs from the Moon/Mars surface to relay satellites or Earth. These membrane antennas are deployed from a small package via some inflation mechanism. Techniques for rigidizing these membrane antennas without the use of gases (e.g., ultraviolet curing), as well as thin-membrane tensioning and support techniques to achieve precision and wrinkle-free surfaces, in particular for applications at Ka-band or higher frequencies is desirable.

Novel materials (including memory matrix materials), low fabrication costs and deployment and construction methods using low emissivity materials to enable passive microwave instrument application are also beneficial. Structural health monitoring systems, needed to support pre-flight integration / test activities and determine health of system in-flight, are of interest. The challenge is to generate designs incorporating structural considerations (e.g., aero-braking for deep space planetary missions).

Antenna Adaptive Beam Correction with Pointing Control
Antenna adaptive beam correction with pointing control that can provide spacecraft knowledge with fine beam pointing with sub-milliradian precision (e.g., < 250 micro-radians) in order to point large spacecraft antennas (e.g., 10-m diameter) in Mars' vicinity is also desirable under this subtopic. The challenges include reduced antenna reflector surface distortions in a space environment; compensation techniques to optimize antenna beam patterns; ground- and space-based methods to monitor spacecraft antenna distortions; and advanced technologies that enable antenna pointing accuracies in the sub-milliradian range for Ka-band spacecraft applications. Methods of dealing with extreme latency (e.g., 20 minutes) in beacon and monopulse systems are of interest. Advances would lead to enhanced space communication links. The resulting developments should be at TRL 4. Size weight and power requirements are of concern.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Development Timeline: After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2014. Therefore a TRL progression from an entry TRL of 1-2 for Phase 1 in January 2009 followed by an exit TRL of 3 - 4 after Phase 2 is reasonable.

Phase 1 Deliverables: A final report containing optimal design for the technology concept including feasibility of concept, a detailed path towards Phase 2 hardware and/or software demonstration. The report shall also provide options for potential Phase 3 funding from other government agencies (OGA).

Phase 2 Deliverables: A working proof-of-concept demonstrated and delivered to NASA for testing and verification.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.03 Reconfigurable/Reprogrammable Communication Systems
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC

NASA seeks novel approaches in reconfigurable, reprogrammable communication systems to enable the vision of Space, Exploration, Science, and Aeronautical Systems. Exploration of Martian and Lunar environments will require advancements in communication systems to manage the demands of the harsh space environment on space electronics, maintain flexibility and adaptability to changing needs and requirements, and provide flexibility and survivability due to increased mission durations. NASA missions can have vastly different transceiver requirements (e.g., 1's to 10's Mbps at UHF and S-band frequency bands up to 10's to 1000's Mbps at X, and Ka-band frequency bands.) and available resources depending on the science objective, operating environment, and spacecraft resources. For example, deep space missions are often power constrained; operating over large distances, and subsequently have lower data transmission rates when compared to near-Earth or near planetary satellites. These requirements and resource limitations are known prior to launch; therefore, the scalability feature can be used to maximize transceiver efficiency while minimizing resources consumed. Larger platforms such as vehicles or relay spacecraft may provide more resources but may also be expected to perform more complex functions or support multiple and simultaneous communication links to a diverse set of assets.

This solicitation seeks advancements in reconfigurable transceiver and associated component technology. The goal of the subtopic is to provide flexible, reconfigurable communications capability while minimizing on-board resources and cost. Topics of interest include the development of software defined radios or radio subsystems which demonstrate reconfigurability, flexibility, reduced power consumption of digital signal processing systems, increased performance and bandwidth, reduced software qualification cost, and error detection and mitigation technologies. Complex reconfigurable systems will provide multiple channel and multiple and simultaneous waveforms. Areas of interest to develop and/or demonstrate are as follows:

- Advancements in bandwidth capacity, reduced resource consumption, or adherence to the Space Telecommunications Radio System (STRS) standard and open hardware and software interfaces. Techniques should include fault tolerant, reliable software execution, reprogrammable digital signal processing devices.
- Reconfigurable software and firmware which provide access control, authentication, and data integrity checks of the reconfiguration process including partial reconfiguration which allows simultaneous operation and upload of new waveforms or functions.
- Operator or automated reconfiguration or waveform load detection failure and the ability to provide access back to a known, reliable operational state. An automated restore capability ensures the system can revert

to a baseline configuration, thereby avoiding permanent communications loss do to an errant reconfiguration process or logic upset.

- Dynamic or distributed on-board processing architectures to provide reconfigurability and processing capacity. For example, demonstrate technologies to enable a common processing system capacity for communications, science, and health monitoring.
- Adaptive modulation and waveform recognition techniques are desired to enable transceivers to exchange waveforms with other assets automatically or through ground control.
- Low overhead, low complexity hardware and software architectures to enable hardware or software component or design reuse (e.g., software portability) that demonstrates cost or time savings. Emphasis should be on the application of open standards architecture to facilitate interoperability among different vendors to minimize the operational impact of upgrading hardware and software components.
- Software tools or tool chain methodologies to enable both design and software modeling and code reuse and advancements in optimized code generation for digital signal processing systems.
- The use of reconfigurable logic devices in software defined radios is expected to increase in the future to provide reconfigurability and on-orbit flexibility for waveforms and applications. As the densities of these devices continue to increase and feature size decreases, the susceptibility of the electronics to single event effects also increases. Novel approaches to mitigate single event effects in reconfigurable logic caused by charged particles are sought to improve reliability. New methods should show advancements in reduced cost, power consumption or complexity compared to traditional approaches (i.e., voting schemes and constant updates (i.e., scrubbing)).
- Techniques and implementations to provide a core capability within the software defined radio in the event of failure or disruption of the primary waveform and/or system hardware. Communication loss should be detected and core capability (e.g., “gold” waveform code) automatically executed to provide access control and restore operation.
- Innovative solutions to software defined radio implementations that reduce power consumption and mass. Solutions should enable future hardware scalability among different mission classes (e.g., low rate deep space to moderate or high rate near planetary, or relay spacecraft) and should promote modularity and common, open interfaces.
- In component technology, advancements in analog-to-digital converters or digital-to-analog converters to increase sampling and resolution capabilities, novel techniques to increase memory densities, and advancements in processing and reconfigurable logic technology each reducing power consumption and improving performance in harsh environments.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.04 Miniaturized Digital EVA Radio
Lead Center: JSC
Participating Center(s): GRC

Lunar outpost surface operations pose unique challenges that demand a compact, power-efficient, and adaptive S-band EVA digital radio with built-in navigation capability. High-performance criteria, tight power constraints, and multi-mode functionality are making mobile terminals increasingly complex. Therefore, NASA needs to advance next-generation digital radio technologies to meet the stringent demands of ultra low power, high reliability, and small form factor. More than a conventional system, the EVA radio infrastructure supports relative navigation, high resolution image processing, voice encoding, networked based IP communications, and dynamic quality of service. By leveraging RF micro-electromechanical system (MEM) components, intelligent middleware, and location aided networking, this solicitation aims to reach TRL 5 by 2012 with breakthrough radio metrics- less than four watts of total power consumption and cell-phone sized form factor.

Operating at 2.4-2.483 GHz (S-band), the digital radio must support multiple bandwidth and data transmissions of voice, telemetry, and video- standard as well as high definition- to fixed and mobile assets, including lunar base station, landers, habitat, rovers, and other astronauts.

To extend battery life, the EVA digital radio must incorporate middleware that optimizes power needed to maintain link quality. Under harsh lunar environmental conditions, the cognitive middleware must optimally match the QoS requirement, the channel condition, and the interference environment as well as select the mode with the least energy profile for power efficiency. As a result, this EVA radio must dynamically and adaptively conserve power on a packet-by-packet basis.

During contingency mode, EVA digital radio will transmit voice and data in half-duplex mode. With novel wireless communication network concepts, the offeror should propose solutions to enable position determination and relative navigation out to a distance of 10km with accuracy of 100 meters (3 sigma).

The Phase 1 effort defines an ultra low-power, high-performance, compact digital radio that incorporates innovative components and novel approaches to meet the above requirements for a single fault tolerant architecture. To achieve dramatic reductions in power and volume, solutions must exploit MEMS for cell phones and handheld (e.g., MEM filters, tunable matching elements, etc.) and other advanced analog/digital components, advanced digital signal processing, as well as next-generation processing elements such as FPGAs and multi-core processors.

Moreover, one must select a promising modular candidate architecture for the above requirements, exploiting emerging commercial wireless network technologies such as WLAN and WWAN. This encompasses identifying transceiver hardware, firmware, and all platform integration issues.

For this solicitation, one can assume EVA digital radio will be part of a mobile ad hoc network infrastructure that is self-configuring, self-discovering, and self-healing. Where all nodes can act as routers for other low power mobile nodes and network coverage has no limit for wireless communications. In other words, the diameter of the network can be increased by adding more nodes.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 1 Deliverables:

Conduct design tradeoffs between power, performance, and flexibility. Estimate mass, volume, power, max/min range, and data rates for dynamic quality of service (voice, telemetry, video) standard and high definition TV at S-band (2.4 - 2.483 GHz), backed with analyses including lunar propagation effects and comprehensive simulations to ensure achievable performance and power goals. Consider IP voice as an optional feature.

As a prerequisite to Phase 2, one must select a promising architecture that balances ultra low power, mass, size, performance, functionality, and reliability. In fact, the offeror must demonstrate the ability to achieve significant advantages in compactness over a non-MEMS approach and address power efficiency and reliability. Special interests include single-chip design/packaging and integrated circuit-level implemenation of RF MEMS.

Propose a preliminary design approach for the next-generation digital EVA radio, leveraging commercial multimedia cellular and WLAN technology. Operating at S-band (2.4- 2.483 GHz), MEM filters should be considered to achieve low power consumption and compact, cell-phone sized form factor. Determine the suitability and usage of ultra low power digital devices, compact RF systems, and novel configurations when recommending candidate architectures.

For the middleware, conduct trade-offs and identify the set of required parameters for the ideal radio. Quantify performance in terms of energy savings and the ability to maximize connectivity and throughput in an ad hoc network.

Develop communications and 3D navigation tracking ad hoc network concepts and algorithms that validate the feasibility of the approach. Without GPS, integrated low-power communication and navigation surface assets must track, locate, and identify tagging assets with multiple routes over an operational range of 10 km, even if astronauts descend into craters. Assume the availability of digital terrain maps. Consider low-power approaches that exploit bread crumbs, active/passive RFID systems for ID, position, sensing, etc and expand investigation to modulated retroreflectors based upon MEMS technology or solar-powered beacons.

Simulate the performance of a robust integrated communications and navigation network architecture and conduct preliminary sensitivity analysis for parameterization of the selected implementation strategy. Specifically, describe the division of functionalities between the various components (fixed and mobile) as well as segments (inter-vehicle and mobile-to-fixed node on planetary surface as well as surface-to-orbit (lunar relay satellites).

Phase 2 Deliverables:

Demonstrate RF performance and total power consumption of less than four watts, delivering voice, telemetry, and standard and high-definition video motion imagery at 2.4- 2.483 GHz (S-band). Within power budget allocation, verify performance and reliability for multiple bandwidth and data transmissions of telemetry, voice, and high-rate video.

Develop a reliable, intelligent, and power-efficient EVA digital radio prototype unit and demonstrate robust power management and optimization feasibility of the Phase 2 middleware and ad hoc network approach.

Explore radiometric tracking techniques and benefits from location-aided networking to support (limited) relative navigation using an ad hoc network infrastructure during EVA walkback. Moreover, a simulation capability must demonstrate node discovery, location awareness, and route re-configurability as nodes enter and leave the network. Testing will be conducted at an approved site and should comprise of a variety of nodes (fixed and mobile) as well as a suite of applications (non-real time data as well as real-time voice and video).

Develop and demonstrate a working ad hoc network prototype that allows characterization of the following metrics in a static deployment: a) network range, b) aggregate throughput and throughput per user, and c) node and network lifetime.

Deliver open middleware and supporting IP solutions.

Where costs preclude full implementation of all component technologies, provide analysis to extrapolate the performance of a complete design.

Commercial Potential:

Adaptive radios potentially offer significant cost savings to a wide spectrum of commercial markets including telecommunications and consumer electronics. They also provide for enhanced interoperability and spectrum reuse for Homeland Security applications. New component technologies and radio infrastructures are needed to extend the programmable capabilities into long battery life handsets.

O1.05 Communication for Space-Based Range
Lead Center: GSFC
Participating Center(s): ARC, GRC

Space-Based Telemetry Transceivers may replace Line-of-Sight (LOS) and RADAR based Tracking, Telemetry, and Command (TT&C) flight and ground systems for sub-orbital platforms and orbit-insertion launch vehicles. In order to do so, the transceivers must be capable of providing real-time or near real-time return (data) and forward (command) links of varying bandwidths with industry accepted Quality of Service (QoS) levels. Some applications require the coupling of embedded GPS receivers and attitude determination units, while others require high bandwidth links with common interfaces (i.e., Ethernet). In all cases it is desired to utilize an existing commercial satellite provider with fee-for-service to reduce operating and overhead expenses.

Note: The proposer should be aware of subtopic O4.01, which seeks advancements in GPS metric tracking. This proposal primarily focuses on space-based transceivers. However, advancements made under O4.01 could be incorporated with space-based transceivers in the future.

Purpose

The vision of Space-Based Range architecture is to assure public safety, reduce the costs of launch operations, enable multiple simultaneous launch operations, decrease response time, and improve geographic and temporal flexibility. It is desired to reduce or eliminate the need for redundant range assets and deployed down-range assets that are currently used to provide for LOS TT&C with sub-orbital platforms and orbit-insertion launch vehicles. This solicitation seeks to achieve this by focusing on specific needed advancements in TT&C.

There are varying applications for space-based transceivers, each necessitating a different set of requirements. Low data rate and very low cost transceivers coupled with highly accurate GPS receivers may be used to measure wind velocities to determine flight conditions and accurate trajectory predictions. These could also be used to track low risk payload or vehicle components for recovery purposes. Higher dynamic vehicles require a more robust transceiver with embedded position and attitude determination units to track vehicle trajectories through space insertion or for recovery purposes. High data rate transceivers with a commonly used interface could be used across multiple platforms for primary or redundant data dispersion and command control.

The proposer should address one of the following three need areas below:

Low Cost and Low SWAP Transceiver with Integrated GPS Receiver

Core Capabilities should include:

- Utilize existing commercial satellite provider with fee for service. Limit the user burden to provide adequate effective isotropic radiated power (EIRP) for providing acceptable link margins.
- Low Cost: several hundred dollars or less (throw-away).
- Low size, weight, and power (SWAP): 10 cubic inches or less, weigh less than 0.25 lbs, consume less than 1W (on avg).
- Ability to operate up to +/- 70 deg latitude (all latitudes preferred).
- Ability to sample time, position (x, y, z), and velocity (x., y., z.) solutions at a min of 10Hz.
- Ability to downlink the 10Hz or better sampled data with low latency (several seconds or better) and little to no loss (not to include ground infrastructure latency, i.e., internet latency).
- Ability to receive data and send commands from one location anywhere in the world via IP. However, an RF link could be used as a backup for remote locations.
- Ability to accept near real-time commands (latency of several seconds or better) and provide firmware level actions/responses (e.g.: to select alternate downlink data format).
- Highly accurate GPS solutions. Commercial-off-the-Shelf (COTS) embedded units may be utilized but repackaging may be needed to provide a single, integrated Over-the-Horizon (OTH) tracker. Independent Kalman Filtering techniques may need to be developed. Velocity jitter is highly undesirable. The ability to lift altitude and velocity (COCOM) restrictions is needed.
- Environmental considerations: Operability from sea level to 160,000 ft with operating temperatures of -20°C to +60°C. Vehicle dynamics are relatively benign. Duration of mission operation is several hours.
- Ground Software to view the telemetered data.

Optional Capabilities: The ability to operate at all latitudes. The ability to interface a small number of sensors (TTL, Analog-to-Digital, and/or serial interfaces) for sampling and transmit. Operating temperatures of -40°C to +85°C. The ability to allow uplink commands to change the state of on-board TTL level outputs. Ability to receive data and send commands from multiple locations via IP. Open source or factory customizable firmware.

Highly Dynamic Transceiver with Integrated GPS Receiver and Attitude Determination
Core Capabilities should include:

- Utilize existing commercial satellite provider with fee for service. Limit the user burden to provide adequate EIRP for providing acceptable link margins.
- Low cost, size and weight commensurate with materials and techniques used. Power consumption less than 5W (on avg).
- Ability to operate up to +/- 70 deg latitude (all latitudes preferred).
- Ability to sample time, position (x, y, z), velocity (x., y., z.), and vehicle dynamics (accelerations, pitch, and roll) at a min of 20Hz.
- Ability to downlink the 20Hz or better sampled data with very low latency (preferably sub-second) and little to no loss (not to include internet latency).
- Ability to accept commands on a real-time basis (preferably sub-second latency) and provide firmware level responses to those commands.
- Ability to receive data and send commands from one location anywhere in the world via IP. However, an RF link could be used as a backup for remote locations.
- Highly accurate integrated position and solid-state attitude solutions. COTS units may be utilized but repackaging may be needed to provide a single integrated OTH tracker. The ability to lift altitude and velocity (COCOM) restrictions is needed.
- Environmental considerations: Operability from sea level up to space insertion is desired (note that radiation hardening is not required). Operating temperatures of -20°C to +60°C are needed. Ability to operate on spin stabilized rockets (up to 7 rps), under sudden acceleration, and under high jerk environments (e.g., launch conditions and separation / jettison events). Duration of mission operation is several hours.
- Ground Software to view the telemetered data.

Optional Capabilities: The ability to operate at all latitudes. The ability to interface a small number of sensors (TTL, A to D, and/or serial interfaces) for sampling and transmit. Operating temperatures of -40°C to +85°C. The ability to allow uplink commands to change the state of on-board TTL level outputs. Ability to receive data and send commands from multiple locations via IP. Open source or factory customizable firmware.

High Data Rate Transceiver
Core Capabilities should include:

- Utilize existing commercial satellite provider with fee for service. Limit the user burden to provide adequate EIRP for providing acceptable link margins.
- Cost and SWAP commensurate with performance, but all should be kept minimal.
- Ability to operate up to +/- 70 deg latitude (all latitudes preferred).
- The minimum return bandwidth (data) is 50 kbps but several hundred kbps is desired. The minimum forward bandwidth (command) is 1 kbps but several kbps is desired.
- Ability to downlink data with very low latency (preferably sub-second) and little to no loss (not to include ground infrastructure latency, i.e., internet latency).
- Ability to receive commands with very low latency (preferably sub-second) and little to no loss from an IP based ground terminal.
- Ability to receive data and send commands from one location anywhere in the world via IP. However, an RF link could be used as a backup for remote locations.
- The transceiver I/O interface should allow for easy interfacing to multiple platforms. An Ethernet interface is preferred, but lower data rates may allow for an asynchronous serial interface. Depending on the satellite platform chosen, the proposer may have to provide internal buffering and clocking mechanisms to smooth an asynchronous input for proper ground receipt.
- Environmental considerations: Operability from sea level up to space insertion is desired (note that radiation hardening is not required). Operating temperatures of -20°C to +60°C are needed. The initial prototype could be tested on low dynamics vehicles, thereby concentrating the focus on performance. However, the ultimate goal is the ability to operate on spin stabilized rockets (up to 7 rps), under sudden acceleration, and under high jerk environments (e.g., launch conditions and separation / jettison events). Duration of mission operation is several minutes to several months.

- Ground Software to view the telemetered data.

Optional Capabilities: The ability to operate at all latitudes. Operating temperatures of -40C to +85C. Ability to receive data at multiple locations simultaneously via IP. Open source or factory customizable firmware.

In all cases, research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.06 Long Range Optical Telecommunications
Lead Center: JPL
Participating Center(s): ARC, 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-microradian pointing of the optical communications beam under typical deep-space ranges (to 40 AU) and spacecraft micro-vibration environments.
- Small lightweight (< 1-Kg), 2-axis gimbals with < 30-μrad rms error and blind-pointing accuracy of < 35-μrad. Must be able to actuate payload mass of approximately 6-Kg at rates up to 5-deg/sec. Assume that the payload is shaped as an 8-cm diameter cylinder, 30-cm long, with uniformly distributed mass. Proposals should come up with innovative pragmatic designs that can be flown in space.
- Light-weighted afocal optical telescopes with diameters varying from 10-50-cm diameter with an average areal density of < 45 Kg/m^2 (Areal density is average over large and small optics used to gather and focus light on to sensors/detectors). The telescopes should be capable of operating in the near-infrared spectral range (1.0 – 1.6 micrometers) with less than a tenth wave root-sum squared wavefront error.
- Uncooled photon counting imagers with >1024 x 1024 formats, ultra low dark count rates and 400 - 2000 nm sensitivity.
- Ultra-low (<0.1%) fixed pattern non-uniformity NIR imagers with large format (1024 x 1024), low noise (<1 e- read, <1ke/pix/sec dark) and high QE (>0.7).
- Nutating fiber pointing mechanisms with high precision (<0.01 urad) and high bandwidth (> 3 kHz).
- Compact, lightweight, low power, broad bandwidth (0 - 3 kHz) disturbance rejection and/or isolation platforms.
- Space-qualifiable, > 20% wall plug efficiency, lightweight, 20-500 psec pulse-width (10 to > 100 MHz PRF), tunable (± 0.1 nm) pulsed 1064-nm or 1550-nm laser transmitter fiber MOPA sources with >1 kW of peak power per pulse (over the entire pulse-repetition rate), with Stimulated Brillouin Scattering (SBS) suppression and > 10 W of average power, near transform limited spectral width, and <10 psec 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.Description of approaches to achieve the stated efficiency is a must.
- > 2-m diameter, <30-nm bandpass optical filters on a membrane substrate to pass center. Wavelengths in the 1000 to 1600 nm band with >90% transmission.
- > 2-m diameter f/1.1 primary mirror and Cassegrain focus of ~f/6 optical communication receiver telescopes. Maximum RMS surface figure error of 1-wave at 1000 nm wavelength. Telescope is positioned with a 2-axis gimbal capable of 0.25 mrad pointing. Combined telescope and gimbal shall be manufacturable in quantity (tens) for <$400k 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 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.
- Ground-based, relatively low-cost diode-pumped laser technology capable of reaching 100 kW average power levels in a TEM00 mode, for uplink to spacecraft.
- Photon counting Si, InGaAs, and HgCdTe detectors and arrays for the 1000 to 1600 nm wavelength range with single photon detection efficiencies > 60% and output jitters less than 20 psec, active areas > 20 microns/pixel, and 1 dB saturation rates of at least 100 megaphotons (detected) per pixel and dark count rates of < 1 MHz / mm^2.
- Radiation hard (100 Mrad level) photon counting detectors and arrays for the 1000 to 1600 nm wavelength range with single photon detection efficiencies > 40% and 1 dB saturation rates of at least 30 megaphotons/pixel and operational temperatures above 220 K and dark count rates of < 10 MHz / mm.
- Single-photon-sensitive, high-bandwidth (1 GHz), linear mode, high gain (> 1000), low-noise (< 1 kcps), large diameter (200 micron), HgCdTe avalanche photodiode and/or (small diameter) arrays for optical detection at 1060 nm or 1550 nm.

Research should be conducted to convincingly prove technical feasibility during Phase 1, with clear pathways to demonstrating and delivering functional hardware, meeting all objectives and specifications, in Phase 2.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.07 Long Range Space RF Telecommunications
Lead Center: JPL
Participating Center(s): ARC, GRC

This solicitation seeks to develop innovative technologies for long-range RF telecommunications supporting the needs of space missions.

Purpose (based on NASA needs) and current state-of-the-art: 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 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 communications is about 2 Mbps from Mars using microwave communications systems (X-Band and Ka-Band) with output power levels in the low tens of Watts end DC-to-RF efficiencies in the range of 10-25%.

Specifications and Requirements:
- 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 large linear phase modulation (above 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%) 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 techniques and/or wide band-gap semiconductor devices at X-band (8.4 GHz) and Ka-band (26 GHz, 32 GHz and 38 GHz);
- Epitaxial GaN films with threading dislocations less than 106 per cm^2 for use in wide band-gap semiconductor devices at X- and Ka-Band;
- 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);
- SSPAs, modulators and MMICs for 26 GHz Ka-band (lunar communication);
- TWTAs operating at millimeter wave frequencies (e.g., W-Band) and at data rates of 10 Gbps or higher;
- Ultra low-noise amplifiers (MMICs or hybrid) for RF front-ends (< 50 K noise temperature); and

- MEMS-based RF switches and photonic control devices needed for use in reconfigurable antennas, phase shifters, amplifiers, oscillators, and in-flight reconfigurable filters. Frequencies of interest include VHF, UHF, L-, S-, X-, Ka-, V-band (60 GHz) and W-band (94 GHz). Of particular interest is Ka-band from 25.5 - 27 GHz and 31.5 - 34 GHz.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 1 Deliverables: Feasibility study, including simulations and measurements, proving the proposed approach to develop a given product. Verification matrix of measurements to be performed at the end of Phase 2, along with specific quantitative pass-fail ranges for each quantity listed.

Phase 2 Deliverables: Working engineering model of proposed product, along with full report of on development and measurements, including populated verification matrix from Phase 1.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.08 Lunar Surface Communication Networks and Orbit Access Links
Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC

This solicitation seeks to develop a highly robust, bidirectional, and disruption-tolerant communications network for the lunar surface and lunar orbital access links. Exploration of lunar and planetary surfaces will require short-range (~1.6 km line-of sight, ~5.6 km non-line-of-sight) bi-directional, and robust multiple point links to provide on-demand, disruption and delay-tolerant, and autonomous interconnection among surface-based assets. Some of the nodes will be fixed, such as base stations and relays to orbital assets, and some transportable, such as rovers and humans. The ability to meet the demanding environment presented by lunar and planetary surfaces will encompass the development and integration of a number of communication and networking technologies and protocols. NASA lunar surface networks will be dynamic in nature, and required to deliver multiple data flows with different priorities (operational voice, command/control, telemetry, various qualities of video flows, and others). Bandwidth and power efficient approaches to mobile ad hoc networks are desired. Quality of Service (QoS) algorithms in a Mobile Ad hoc NETwork (MANET) setting will need to be developed and tailored to NASA mission specific needs and for the lunar surface environment.

These lunar and planetary surface networks will need to seamlessly interface with communications access terminals and orbiting relays that also can provide autonomous connectivity to Earth based assets. The access link communications system will encompass the development and integration of a number of communications and networking technologies and protocols to meet the stringent demands of continuous interoperable communications. Human exploration, therefore, requires the development of innovative communication protocols that exploit persistent storage on mobile and stationary nodes to ensure timely and reliable delivery of data even when no stable end-to-end paths exist. Solutions must exploit stability when it exists to nearly approximate the performance of conventional MANET protocols. The lunar surface communications network must support 15 simultaneous users with aggregate bandwidth of 80 Mbps. It must also support minimum data rates of 16 kbps and maximum data rates of 20 Mbps and be IP compatible with a BER of 10e-8 or less, and graceful degradation. Frequency bands of interest are UHF (401 - 402 MHz, 25 kHz bandwidth), S-band (2.4 - 2.483 GHz), and Ka-band (22.55 - 23.55 GHz).

Core capabilities:

- Short range access point, base stations, and wireless router bridges for extending surface network coverage;
- Non-line-of-sight communication between stationary and moving assets, outside or inside lunar craters without using orbiting assets;

- Analog voice-only radio service to the lunar outpost and the lunar relay satellite at the highest network priority for HF, UHF, or S-band for reliability;
- Support multiple bandwidths for telemetry, voice, and high-rate video;
- Ability to determine the QoS, channel, and interference information;
- Autonomously reconfigurable receivers capable of automatic link configuration and management;

Proposals should address the following areas:

- Disruptive and delay-tolerant networking (DTN);
- Networking algorithms and adaptive routing;
- Extra-Vehicular Activity (EVA) radio.

The following technologies are addressed under other SBIR Subtopic solicitations:

- Antennas for surface and orbital access communications required for the aforementioned goals shall be developed under subtopic O1.02;
- Radios for surface and orbital communications required for the aforementioned goals shall be developed under subtopic O1.03;
- Optical transceivers required for the aforementioned goals shall be developed under subtopic O1.06;
- Any high rate, low power, efficient amplifiers or transponders required for the aforementioned goals shall be developed under subtopic O1.07.

Development Timeline: After a possible Phase 3 development activity, these technologies are expected to ready for insertion at TRL 6 by 2014. To meet the schedule for NASA's Vision for Space Exploration (VSE), a TRL progression from an entry TRL of 1-2 for Phase 1 in January 2009 followed by an exit TRL of 3 - 4 after Phase 2 is required.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 1 Deliverables:

Propose a robust lunar surface and orbit access communications network suitable for the applications and environment. Address all technical challenges, pitfalls, and tradeoffs of the network size, assets, and power as well as reliability, complexity, and performance. Solutions should encompass a notional architecture, functional requirements, and building block concepts, demonstrating a reliable and simultaneous voice, telemetry, and video transmission as well as reconfigurability across multiple applications and frequency bands.

Develop suitable communication algorithms capable of demonstrating the feasibility of the approach. Based on a minimum of three (3) nodes, simulate the performance of the proposed integrated communications network architecture and analyze the selected implementation strategy. Identify required parameters for the network architecture and quantify performance in terms of energy savings, connectivity, and throughput in a mobile ad hoc network.

Phase 2 Deliverables:

Develop a communications network with multi-functional capabilities described in above. Further enhance the concepts investigated in Phase 1 and demonstrate the feasibility of the approach on an actual platform.

Fabricate and test a prototype communications network with a minimum of three (3) nodes using an active integrated communication network. Simulate and refine power software algorithms for real time robust operations and characterize system performance in compliance with the design goals outlined in Phase 1.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O1.09 Software for Space Communications Infrastructure Operations
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC

New technology is sought to improve resource optimization and the user interface of planning and scheduling tools for NASA's Space Communications Infrastructure. The software created should have a commercialization approach with the new modules fitting into an existing or in development planning and scheduling tool.

Purpose (based on NASA needs) and the current state of the art: 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). Recent planning for the Vision for Space Exploration (VSE) for human exploration to the Moon and beyond as well as maintaining vibrant space and Earth science programs resulted in a new concept of the communications architecture. The future communications architecture will evolve from the present legacy assets and with addition of new assets.

NASA seeks automation technologies that will facilitate scheduling of oversubscribed communications resources to support: (1) Increased numbers of missions and customers; (2) Increased number and complexity of constraints (as required by new antenna types); and (3) decreased operations budgets (both core communications network operations and mission side operations budgets.

Core Capabilities:

Intelligent Assistants
In order to automate the user's provision of requirements and refinement of the schedule, "intelligent assistant" software should manage the user interface. Assistants should streamline access and modification of requirement and schedule information. By modeling the user, this software can adjust the level of autonomy enabling decisions to be made by the user or the automated system. Assistants should try to minimize user involvement without making decisions the user would prefer to make. The assistants should adapt to the user by learning their control preferences. This technology should apply to local/centralized and collaborative scheduling.

In a conflict-aware scheduling system (especially in a collaborative scheduling environment), conflicts are prevalent. With the concept of one big schedule from the beginning of time, real time, to the end of time, resolving conflicts become a difficult task especially since resolving conflicts in a local sense may affect the global schedule. Therefore, an intelligent assistant may provide decision support to the system or the users to assist conflict resolution. This may involve a set of rules combining with certain local/global optimization to generate a list of options for the system or users to choose from.

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.

Optional Capabilities:

Multiple Agents
In an environment where all system variables can be controlled by a single controller, an optimal solution for the objective function can be achieved by finding the right set of variables. In a collaborative environment with multiple decision makers where each decision maker can only control a subset of the variables, modeling and optimization become a very complex issue. In the proposed collaborative scheduling approach, there are many users/agents that will control their own allocations with interaction with the others. How we model their interactions and define system policy so the interaction can achieve the overall system goal is an important topic. The approach for multiple decision-maker collaboration has been studied in the area of Game Theory. The applications cover many areas including economics and engineering. The major solutions include Pareto, Nash, and Stackelberg. There are many new research areas including incentive control, collaborative control, Ordinal Games, etc. Note that intelligent assistants and multiple agents represent different points on the spectrum of automation. Current operations utilize primarily manual collaborative scheduling, intelligent assistants would enhance users ability to participate in this process and intelligent agents could more automate individual customers scheduling. Ideally, proposed intelligent assistants and distributed agents would also be able to represent customers who do not wish to expose their general preferences and constraints.

A start for reference material on this subtopic may be found at the following:

http://ai.jpl.nasa.gov in the publications area;
http://scp.gsfc.nasa.gov/gn/gnusersguide3.pdf, NASA Ground Network User’s Guide, Chapter 9 Scheduling; and
http://scp.gsfc.nasa.gov/tdrss/guide.html, Space Network User?s Guide, SpaceOps Conference Proceedings.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract

Phase 1 Deliverables: Propose demonstration of Intelligent Assistants, Resource Optimization, or Multiple Agents on a number of communication asset allocation problem sets (involving dozens of missions, communications assets, and operational constraints). End Phase deliverable would include a detailed rationale for ROI in usage of said technology to communications asset allocation based on knowledge of current and future operations flows.

Phase 2 Deliverables: Demonstrate Intelligent Assistants, Resource Optimization, or Multiple Agents on actual or surrogate communication asset scheduling datasets. Deliverables would include use cases and some evidence of utility of deployment of developed technology.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

TOPIC: O2 Space Transportation

Achieving space flight can be astonishing. 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 that states that the U.S. maintains robust transportation capabilities to assure access to space. Given this backdrop, this topic is designed to address technologies to enable a safer and more reliable space transportation capability. Automated collection of range data, and instrumentation for space transportation system testing are all required. The following subtopics are required to secure technologies for these capabilities.

O2.01 Automated Collection and Transfer of Launch Range Surveillance/Intrusion Data
Lead Center: KSC
Participating Center(s): MSFC, GSFC

NASA is seeking innovative technologies for sensors and instrumentation technologies which expedite range clearance by providing real-time situational awareness for safe Range operations from processing to launch and recovery. These sensors and instruments are expected to operate, as a payload, on mobile or deployable Unmanned Aerial Systems (UAS), High Altitude Airships (HAA), buoys, etc.

Purpose: NASA is embarking on a new era of space exploration with new launch vehicles and demands for availability to support launch times within hours of one another to ensure mission success. This availability requirement is allocated across the entire launch operations which includes the Range that provides clear corridor of land, air and sea for the vehicles to transit through, as they ascent or return. The current Range infrastructure is aging, labor intensive and independent, and would benefit from new sensors and instrumentation that improve the situational awareness to those that are responsible for ensuring public safety, mission assurance and efficient operations.

To aid in this situational awareness the new sensors and instrumentation must be able to operate in the environment that takes advantage of mobile or deployable Unmanned Aerial Systems (UAS), High Altitude Airships (HAA), buoys, etc. Use of these vehicles as a platform is intended to increase the Ranges availability while reducing the cost of operations. Size, power, weight and stability of these systems, that operate on these platforms, will be a major constraint their use.

These sensors and instrumentation provide for the remote detection, recognition, and identification of persons and objects that have intruded into areas of the range that must be cleared in order to conduct safe launch operations. This would include a wide spectrum of optical, infrared, Radio Frequency (RF), and millimeter wave sensors for this purpose. In order to achieve accurate identification, time and position of intruding entities multiple sensors and instruments may be used, or combined through the use of neural networks and data fusion techniques. This will require the use of standards for communications, so that, data from individual sensors or instruments can be combined on a platform and processed on-board, or communicated to central location where a fused solution is processed.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

O2.02 Ground Test Facility Instrumentation
Lead Center: SSC
Participating Center(s): GRC, MSFC

Ground testing of propulsion systems continues to be critical in meeting NASA's strategic goals. Advanced ground testing technologies and capabilities are crucial to the development, qualification, and flight certification of rockets engines. The ability to quickly and efficiently perform ground system certification greatly impacts all space programs. Proposals are sought in the following areas:

Instrumentation and Smart Sensors
Innovative network enabled sensors/instruments capable of providing data, a measure of the quality of the data, and a measure of their health are needed. Sensors may be wired or wireless. Smart instruments/sensors that enable improved rocket test operations must provide many of the following characteristics: simplify and standardize the configuration and maintenance of sensor systems; reduce integration time and errors; expedite fault identification, isolation, assessment, and recovery; facilitate reuse; contribute to improved system integration, decrease cabling mass; decrease costs associated with cable/connector fabrication; distribute computing resources; improve reliability and availability; reduce mean-time to recovery after a failure.

Current challenges include: computational power within the sensor to extract features of interest; full implementation of IEEE 1451 family of Smart Sensors and Actuators Standards (plug & play functionality); miniaturization; ease of adding/modifying software for continued evolution of the "smart/intelligent" capabilities.

Integrated Failure Detection, Isolation, and Recovery (IFDIR)
Innovative technologies are needed to enable implementation of affordable, modular, and evolvable IFDIR, including architectures, taxonomies, and ontologies; standards for interoperability; integration software environments; algorithms, approaches, and strategies for anomaly detection, diagnosis, prognosis; user interfaces for integrated awareness of system health and readiness for operations. IFDR must be achieved in the context of comprehensive and continuous vigilance.

Major challenges include software environments for integration, adherence to standards for interoperability, and validated algorithms/approaches/strategies for anomaly detection.

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 the Space Shuttle, to assembling 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 for these tasks that ensures they are accomplished efficiently and accurately enables successful missions and healthy crew.

O3.01 Crew Health and Safety Including Medical Operations
Lead Center: JSC
Participating Center(s): ARC, GRC

Determining the probability of certain types of events (such as medical conditions) can be tricky. Often there is not enough space-flight data to make a good determination and so other types of evidence are used such as expert opinion, analog data, controlled studies, etc. Each source of evidence must be documented (e.g., as a publication citation, or as a data pull against some data source along with the query parameters used). The source is also characterized as to its "level of evidence" using the Cochrane methodology as documented in the National Guideline Clearinghouse (http://www.guideline.gov/summary/summary.aspx?doc_id4913). There are many methods for combining these evidence pieces. A software system is sought that can be used to collect the evidence (references to evidence sources such as journal publications, population statistics, analog study, etc.) and which facilitates the evidence level assignment (providing a place to record the evidence level and definitions of each level). Furthermore the system should provide a model for combining these evidence sources in a principled manner that characterizes the certainty of the conclusion reached, e.g., a weighted equation where the weights may be adjusted by the users of the system.

Relevance: Evidence of events drives risk assessment. Depending on the risks identified, decisions can be made as to whether to mitigate the risk via pre-flight activities or in-flight capabilities. Such a system supports "what would happen if" type reasoning that enables exploration of different mission options.

Challenge Addressed: Capturing the evidence base in one place along with additional categorization (level of evidence, uncertainty, quality of evidence, etc.) is invaluable in preserving decision-making rationale such that the decisions can be revisited if additional evidence/information is added later. Determining where to spend limited resources wisely is supported – e.g., balance funding between development of pre-flight mitigation strategies, in-flight capability development, investigation of knowledge gaps (uncertainties), and risk acceptance decisions.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

O3.02 Human Interface Systems and Technologies for Spacesuits
Lead Center: GRC
Participating Center(s): ARC, JSC, KSC

The primary medium for sending and receiving information from a crewmember is two-way voice communications. The function of the voice communications system may be extended to include data entry through the inclusion of a Automatic Speech Recognition (ASR) systems. Recent developments in ASR have lead to systems that are capable of connected word identification or speaker-independent word identification. These systems rely on very high fidelity audio link to the talker's speech.

While speech recognition technology has enjoyed significant advances in recent decades, alternate technologies for data entry exist. Such systems may enjoy advantages over speech recognition for the spacesuit application in areas such as overall Size, Weight and Power (SWaP) or system robustness.

The focus of this subtopic is on the development of systems and technologies in support of high fidelity speech and data entry for space suits. In addition to providing the necessary audio fidelity for ASR, the high fidelity audio systems also result in better voice communications for human-to-human communications. The topic therefore includes the related areas of inbound audio systems and hearing protection systems.

High Fidelity, In-Helmet Audio Systems
The space suit environment presents a unique challenge for capturing and transmitting speech communications to and from an crewmember. The in-suit acoustic environment is characterized by highly reflective surfaces, causing high levels of reverberation, as well as spacesuit-unique noise fields. Known sources of noise within the suit are both stationary and transient in nature. Noise within the suit can be acoustically borne or it can originate from structure-borne vibration. Noise originates from suit machinery, footfalls, suit arm and hip bearing, body movement noise and turbulent flow noise from devices such as oxygen spray bars and breath noise. Static pressure levels within the spacesuit can range from a small fraction of an atmosphere during Extravehicular Activity (EVA) operations to strong hyperbaric conditions that exist during terrestrial field-testing. These changes in static pressure level have significant effects on acoustic transduction. Additionally, in some spacesuits, the crewmember is afforded a wide range of motion within the torso of the suit. The wide range of motion means that the acoustic path between an crewmember's mouth or ear and the microphone or helmet mounted speaker varies significantly with movement, resulting in decreased sound pressure levels at the microphone and/or increased interference from competing background noise sources. In addition, vehicular operations can generate high levels of noise that are not fully attenuated by the spacesuit, helmet or headsets. Due to these factors, the quality of speech delivered to and from the inside of a spacesuit helmet can be low and can have a negative effect on inbound and outbound speech intelligibility and the performance of Automatic Speech Recognition (ASR) systems.

The traditional approach to overcome the challenges of the spacesuit acoustic environment is to use a skullcap-based system of microphones and speakers. Cap-based solutions mitigate many of the acoustic problems associated with in-helmet communications systems through the very short and direct acoustic transmission paths between the crewmember and the speakers and microphones. The skullcap's headsets and noise canceling microphones can also afford some degree of acoustic isolation for the crewmember from noise generated inside the spacesuit. Cap-based systems are less successful, however, in attenuating high noise levels generated outside the spacesuit (e.g., during launch, descent, burn activities, or emergency aborts), even when coupled with the launch/entry helmet. The use of noise canceling microphones can improve speech intelligibility, but only if the microphones are in close proximity to the crewmember's mouth. Many logistical issues exist for head-mounted caps. Crewmembers are not able to adjust the skullcap, headset or microphone booms during EVA operations (which can last from four to eight hours) or during launch/entry operations. Interference between the protuberances of the cap and other devices such as drinking/feeding tubes is a recognized issue during EVA. Comfort, hygiene, proper positioning and dislocation are major concerns for head-mounted caps. Wire fatigue and blind mating of the connectors are also problems with the cap-based systems. In order to accommodate anthropometric variations in crew heads, multiple cap sizes are required. Issues have recently been identified with existing communications systems regarding adjustment of microphone boom lengths, proper function over the wide ranges of static pressure experienced during suited operations, flow noise over the microphone elements, and integration with advanced helmet designs.

NASA is seeking systems, subsystems and/or technologies in support of improvements in speech intelligibility, speech quality, listening quality and listening effort for in-helmet aural and vocal communications. In addition, improvements in hearing protection are sought to protect the crew during all mission phases, in case hazardous acoustic levels and conditions occur.

The specific focus of this SBIR subtopic is on improving the interface between crewmember and the acoustic pickup (i.e., microphones) and generation (i.e., speaker) systems. Systems and devices are sought to improve or resolve acoustic, physical and technical problems (listed above) that have been associated with skullcap-mounted speakers and microphones, or allow for the elimination of skullcap-mounted speakers and microphones. In particular, voice communications systems are sought that have provided crewmembers with adequate speech intelligibility over background noise within, and external to, the spacesuit. Overall system performance must provide Mean Opinion Score (MOS) for Listening Quality (Lq) and Listening Effort (Le) of 3.9 or greater, or Articulation Index (AI) of .7 or better or 90% Speech Intelligibility (SI) in the crewmember's native language for both inbound and outbound speech communication. Specific technologies of interest include, but are not limited to:

- Acoustic modeling of the in-suit acoustic environment, including the ability to model structure-borne vibration in helmet and suit structures as well as transduction to and from the acoustic medium.
- Low-mass, low-volume, low-distortion, space-qualified speakers with low variation in sensitivity with static pressure. Changes in speaker sensitivity should be less than 2 dB over the speech band with changes in static pressure between 3 and 18 psia.
- Low-mass, low-volume, low-distortion high-sensitivity (> 5 mV/Pa), space-qualified noise canceling microphones with low variation in sensitivity with static pressure. Changes in microphone sensitivity should be less than 2 dB over the speech band with changes in static pressure between 3 and 18 psia.
- Attenuation of external noise by passive hearing protection that is comfortable for crewmembers during extended use.
- Development of theories, experiments and analysis in support of decomposition of end-to-end SI and/or MOS requirements to the spacesuit portion of EVA-to-Mission Operations Center (MOC), EVA-to-EVA or EVA-to-habitat voice loops. Comparison of SI system fidelity metrics to MOS system fidelity metrics.

In-helmet devices will need to be compatible with high humidity, low humidity and pure oxygen environments. Devices should be able to fit a wide anthropometric range of head and physical features found within the astronaut corps.

Additionally, demonstrations of novel system concepts for in-helmet audio communication are of strong interest. A partial list of such concepts includes:

- Near-field beamforming systems;
- Optical microphone systems;
- Highly directive sound production systems such as parametric sound systems;
- Active noise cancellation systems for hearing protection;
- Bone conduction microphones.

Systems and devices must include appropriate computer processing systems. The expectation is that a working and fully functional system or device will be delivered at the end of Phase 2.

Advanced Data/Text Entry for Spacesuits

The space suit environment presents a unique and challenging environment for control of suit-mounted processing equipment. Terrestrial user-interface devices for controlling portable processing equipment such as laptop computers typically rely on keyboard or touchpad input. Such devices are problematic in the space environment since a suited crewmember must interact with the processing equipment while wearing a pressurized glove. Speech recognition technologies have been proposed and investigated to provide user input, but alternative methods are also desired.

Currently, a suit's processing system has been primarily for providing life-support data-acquisition, monitoring, telemetry, and crewmember alerts. The traditional approach to interact with the EVA processing system is with suit-mounted toggle switches optimally sized for a gloved hand and located in the suit's chest area. NASA envisions future generations of suits to contain advanced communication, navigation, and information processing capabilities that will require better ways of interacting with the suited crewmember. It is likely that the processing unit(s) will be installed within the suit's backpack-mounted portable life support unit or in close proximity.

Crewmember usability and efficient operation are prime features of the next-generation input device. The device must operate robustly in the space and lunar environment and be tolerant of dust, vacuum, and radiation exposure. During Extra-Vehicular Activity (EVA), a suited crewmember needs to achieve as high a level of mobility as possible, so a suit-mounted computer-input device must not impede the movements of the suited crewmember or unduly burden the suit system with weight, volume, or electrical power constraints.

NASA is seeking systems, subsystems and/or technologies in support of improvements in suit-mounted computer system user-interface devices. Particular interest is in areas allowing the suited crewmember to control a computer processing system and provide text input accurately, at high speed, without little or no user fatigue for purposes such as note taking or control of the computer display screen. Possible approaches include chording keyboards, suit or glove mounted fabric keyboards or touch-pads or other technologies. Other technologies will also be considered. Concepts may consider both solutions installed internally (within the pure-oxygen pressurized envelop of the suit), externally (mounted on the exterior of the suit), or a combination of the two.

Techniques for routing wires or connections between the user interface device and the computer processing unit are also of interest. Techniques for routing the wires past bearings or avoidance of such will be considered.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Systems and devices must include appropriate computer processing systems. The expectation is that a working and fully functional system or device will be delivered at the end of Phase 2.

O3.03 Vehicle Integration and Ground Processing
Lead Center: KSC
Participating Center(s): MSFC, SSC

This solicitation seeks to create new and innovative technology solutions for assembly, test, integration and processing of the launch vehicle, spacecraft and payloads; end-to-end launch services; and research and development, design, construction and operation of spaceport services. The following areas are of particular interest:

Propellant Servicing Technologies Enabling Lower Life Cycle Costs
Technologies for advanced cryogenic fluid storage and transfer, servicing of chilled/densified fluids and advances in state-of-the-art ground insulation are needed to reduce launch operation costs by minimizing consumable losses. Solutions in support of helium conservation and recovery; recapture, reduction, and elimination of cryogenic propellants vented to atmosphere (zero boil-off); insulation for improved storage and distribution minimizing thermal losses; fire resistant liquid oxygen pumping systems; and instrumentation advances to enable high efficiency operations. Providing solutions with higher efficiency, lower maintenance and longer life while improving safety and improving liquid quality delivery.

Corrosion Control
Technologies for the prevention, detection and mitigation of corrosion/erosion in spaceport facilities and ground support equipment including refractory concrete. Solutions for: damage responsive coatings with corrosion inhibitors; poor-performing refractory concrete; protective coatings for non-painted surfaces; and new environmentally friendly protective coating options to replace products lost due to EPA regulation changes. Providing coating/protection solutions that meet current and emerging environmental restrictions and can endure the corrosive and highly acidic launch environment.

Spaceport Processing Systems Evaluation/Inspection Tools
Technologies in support of defect detection in composite materials; methods for determining structural integrity of bonded assemblies; and non-intrusive inspection of COPV, heat shield tiles and painted surfaces. Solutions for

detecting and pinpointing corrosion; predicting remaining coatings effectiveness/life expectancy; identifying composite defects and evaluating integrity; non-destructive measurement and evaluation of composite overwrapped pressure vessels; and damage inspection and acceptance testing of Orion heat shield. Providing solutions that reduce inspection times and provide higher confidence in system reliability and safety concerns and lower life cycle costs.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

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. NASA has divided its PNT interests into six focus areas: (1) Global Positioning System (GPS) (2) Distress Alerting Satellite System (DASS) (3) Flight Dynamics (4) Tracking and Data Relay Satellite System (TDRSS) (5) TDRSS Augmentation Service for Satellites (TASS) (6) Geodesy This year, NASA seeks technology in focus areas (1), (3), (4), and (5), and related areas that provides PNT support and services for NASA's current tracking and communications networks and systems—including tracking during launch and landing operations, and research and technology relevant to the planning and development of PNT support and services for NASA's Project Constellation, including lunar surface operations, and other Exploration and Science Programs that NASA may undertake over the next two decades. 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 Science MD 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

Range Safety requires accurate and reliable tracking data for launch vehicles. Onboard GPS receivers must maintain lock, reacquire very quickly and operate securely in a highly-dynamic environment. GPS Course Acquisition Code (CA) does not require classified decryption codes and has an accuracy of better than 30 m and 1 m/s. Although this accuracy is good enough for most Range Safety needs, better accuracy is needed for antenna pointing, docking maneuvers and attitude determination. CA code also offers little protection against deliberately transmitted false signals or "spoofing".

This solicitation seeks proposals in the following areas:

- Innovative technologies to increase the accuracy of the L1 C/A navigation solution by combining the pseudoranges and phases of the L1 C/A signals. Factors that degrade the GPS signal can be obtained by differencing the available carrier phase and pseudorange measurements and then removing this difference from the navigation solution.
- Technologies that combine spatial processing of signals from multiple antennas with temporal processing techniques to mitigate interference signals received by the GPS receiver. The coordinated response of adaptive pattern control (beam and null steering) and digital excision of certain interfering signal components minimizes strong jamming signals. Adaptive nulling minimizes interfering signals by the optimal control of the GPS antenna pattern (null steering).

These technologies should be independent of any particular GPS receiver design.

Research should be conducted to demonstrate technical fesability during Phase 1 and show a path toward a Phase 2 hardware and software demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

O4.02 Precision Spacecraft Navigation and Tracking
Lead Center: GSFC
Participating Center(s): ARC, GRC, JPL

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 or better velocity accuracies.

Research should be conducted to demonstrate technical feasibility during Phase 1, and show a path toward a Phase 2 hardware and/or software demonstration of a demonstration unit or software package that will be delivered to NASA for testing at the completion of the Phase 2 contract. The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) of the solicitation participates in this subtopic. Offerors are encouraged to take this in consideration as a possible flight opportunity when proposing work to this subtopic.

Purpose: NASA Needs vs. Current State of the Art
This solicitation is primarily focused on NASA's needs in three focused areas: onboard near-Earth navigation systems; onboard deep-space navigation systems; technologies supporting improved TDRSS-based navigation. Proposals that leverage state-of-the-art capabilities already developed by NASA such as GEONS (http://techtransfer.gsfc.nasa.gov/ft-tech-GEONS.html), Navigator (http://techtransfer.gsfc.nasa.gov/ft-tech-GPS-NAVIGATOR.html), GIPSY, Electra, and Blackjack are especially encouraged. 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 Specifications and Requirements:

Core Capabilities:

Onboard Near-Earth Navigation System
NASA seeks proposals that would develop a commercially viable transceiver with embedded orbit determination software that would provide enhanced accuracy and integrity for autonomous onboard GPS- and TDRSS-based navigation and time-transfer in near-Earth space via augmentation messages broadcast by 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 that is 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 System
NASA seeks proposals that would develop an onboard autonomous navigation and time-transfer system that can reduce DSN tracking requirements. Such systems 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 that would provide 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.

Optional Capabilities:

NASA may consider other proposals relevant to NASA's needs for precise spacecraft navigation and tracking that demonstrably advance the state-of-the-art.

Development Timeline Associated with NASA Needs:

Phase 1 deliverables should include documentation of technical feasibility, which should at minimum show a path toward hardware and/or software demonstration of a demonstration unit or software package in Phase 2.

Phase 2 deliverables should include a demonstration unit or software.

The proposer to this subtopic is advised that the products proposed may be included in a future small satellite flight opportunity. Please see the SMD Topic S4 on Small Satellites for details regarding those opportunities. If the proposer would like to have their proposal considered for flight in the small satellite program, the proposal should state such and recommend a pathway for that possibility.

O4.03 Lunar Surface Navigation
Lead Center: GRC
Participating Center(s): JSC

In order to provide location awareness, precision position fixing, best heading and traverse path planning for planetary EVA, manned rovers and lunar surface mobility units NASA has established requirements for organic navigation capabilities for surface-mobile elements of lunar missions. This topic will develop systems, technologies and analysis in support of the required capabilities of lunar surface mobility elements. Contemplated navigation systems could employ celestial references, passive or active optical information such as optical flow or range to local terrain features, inertial sensor information or other location-specific sensed data or combinations thereof. However, radiometric measurements are considered to be concomitant to the lunar communications network and the lunar network will likely be used to communicate state information between lunar mission elements. As such, the main emphasis of this topic is on systems that exploit radiometric measurements such as range, Doppler or Angle of Arrival. Radiometric measurements can be considered between lunar mission elements such as surface mobility units, elements of a lunar surface architecture (such as surface landers or habitation units or other surface mobility units) or elements of the lunar communications and navigation infrastructure such as surface communications towers or lunar communication/navigation orbiters. Earth-based nodes are not excluded from consideration, nor are two-way radiometric measurements, nor are non-NASA-standard (e.g. UWB) modulation schemes. Traverse-path planning systems and navigation-specific displays are also of interest.

Emphasis of the development is on navigation accuracy, Size Weight and Power (SWaP), systems that operate effectively with minimal communications/navigation infrastructure (such as towers or orbiters) or with complete autonomy, with minimal crew involvement or completely automatically. Unified concepts and systems that provide a range of hardware capabilities (possibly trading accuracy with SWaP) are of interest. Mature system concepts and technologies including system demonstration with TRL 6 components and internalized (by NASA) standards are required at the end of a Phase 2.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration and delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

O4.04 Timing
Lead Center: JSC
Participating Center(s): GRC, GSFC, JPL

One of the most critical components of robust relative navigation is accurate and reliable timing across the entire sensor suite. Clock errors, drift, and drift rates must be estimated and corrected. During extended duration operations small clock errors propagated from measurement to measurement can contribute to continued growth in positional errors. Improved timing estimation and reliability within a general navigation clocking system will improve navigational accuracy.

Purpose: This solicitation aims to develop two unique timing systems. The first timing system (TS) is for a relative navigation sensor suite to be utilized during lunar surface navigation that will utilize multiple sensors at different times. The sensor suite may include a star tracker, inertial measurement unit, vision-based feature recognition sensor, and RFID tag ranging devices. The TS will take an accurate time input from the primary base station at irregular intervals and a less accurate clock at periodic intervals from a software defined communications radio. The TS should, in an FPGA only, produce a clock signal suitable for time stamping and a clock pulse for four navigation sensors. This generated clock should be accurate to within 1ms of the base station input clock over a period of five minutes between primary clock inputs. Additionally, clock error, drift, and drift rates of the two input clocks and four output timing streams (time stamp and clock pulse) should be made available for analysis.

The second timing system is for proposals that improve timing standards. NASA seeks proposals that would improve accuracy for both ground-based tracking networks and onboard navigation systems by providing time and frequency standards that exceed the long-term performance of the GPS Block IIR Rb clocks (for ground-based applications) and current flight USO performance and also for tracking networks at ground-based locations. Timing accuracy is of the utmost importance for this TS; however, size, weight, and power consumption are still considerations. The goal of this TS is to improve the timing and frequency standards and, if possible, exceed the long-term performance of the GPS Block IIR Rb clocks in the ground-based application.

Core capabilities: Provide an accurate and self correcting time source suitable for use in a navigation system suite consisting of multiple sensors. The TS clock and time stamp output should be independently adjustable to the needs of the sensors.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward Phase 2 hardware and software demonstration, delivering a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Phase 1 Deliverables:

- A trade study on industry standard timing systems with a focus on overall accuracy and drift performance;
- Report on the tools and systems currently available;
- Recommendations on furthering the state-of-the-art in timing performance.

Phase 2 Deliverables:

- Demonstration of implemented timing system given the necessary inputs;
- Written report and presentation detailing the system performance including electrical and electronic characteristics;
- Delivery of the timing system and the environment used during development;
- Delivery of timing system math models for real-time simulation.

9.2 STTR Research Topics

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 Information Technologies for System Health Management and the Study of Space Radiation Environments and Associated Health Risks 189

T1.01 Information Technologies for Intelligent Planetary Robotics 189

TOPIC: T2 Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts 189

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TOPIC: T1 Information Technologies for System Health Management and the Study of Space Radiation Environments and Associated Health Risks

This topic seeks advances in the design, development, and operation of complex aerospace systems to enable safe operation in the event of system failures, innovative technologies for robotic exploration of planetary surfaces, and emerging technologies that will enable the determination and management of the health of space exploration systems improving operations and capability.

T1.01 Information Technologies for Intelligent Planetary Robotics
Lead Center: ARC

Since February 2004, NASA has been actively engaged in a long-term program to explore the solar system and beyond, beginning with robotic missions to the Moon in 2008 and leading eventually to human exploration of Mars. Several NASA studies have concluded that extensive and pervasive use of intelligent robots can significantly enhance planetary exploration, particularly for surface missions that are progressively longer, more complex, and must operate with fewer ground control resources.

The objective of this subtopic is to develop information technologies that improve the capability of mobile robots to explore planetary surface. Emphasis is placed on improving automatic operations that do not require robots to operate in close, physical proximity to humans, nor human-paced interaction or continuous control.

Proposals are sought which address the following technology needs:

- Ground control user interfaces and data management systems for robotic exploration. Conventional robot command systems do not adequately address planetary surface exploration needs, particularly in terms of time-delayed and command-cycle based human-robot interaction. Proposals should focus on software tools for planning command sequences; for event summarization and notification; for interactively monitoring/replaying task execution; and/or for managing non-terrestrial geospatial information.
- Physics-based simulation to develop and test planetary rover algorithms and systems. Existing mobile robot simulators (e.g., Player-Stage) lack the fidelity required to test high (and varying) levels of rover autonomy in non-terrestrial environments. Proposals are sought that provide robot simulation frameworks with models for planetary illumination, surface composition, specialized sensor and scientific instruments, communication, and rover resources.
- Autonomous surface navigation over long-distances and in permanently shadowed regions. Novel perception techniques that utilize passive computer vision (real-time dense stereo, optical flow, etc.), active illumination, repurposed flight vehicle sensors (low light imager, star trackers, etc.), and wide-area simultaneous localization and mapping are of particular interest.
- Control of tensigrity-based structures. Structures and mechanisms built on tensegrity structures are lightweight, compact energy efficient, and robust to unexpected contacts. To date, however, tensegrity structures have received little use in exploration due to the complexity and difficulty of programmed movement. Proposals should emphasize controllers to efficiently manage position and contact forces.

TOPIC: T2 Atmospheric Flight Research of Advanced Technologies and Vehicle Concepts

T2 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 DFRC 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 maturating 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 - particularly transonic 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 and systems are sought that will result in high performance in space power and propulsion systems that are long-lived in the relevant mission environment and that substantially enhance/enable future missions. The technology developments being sought would significantly increase the system performance through highly-efficient generation and utilization of power and in-space propulsion.

Innovations are sought that will significantly improve the efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, design flexibility/reconfigurability, autonomy, and reduce the cost of space power systems. In power generation, advances are needed in photovoltaic cell technology (including materials, structures, and the incorporation of nanomaterials); solar array module/panel integration (including advanced coatings, monolithic interconnects, and high-voltage operational capability); and solar array designs (including ultra-lightweight deployment techniques for planar and concentrator arrays, restowable/redeployable designs, high power arrays, and planetary surface concepts). In energy storage systems, advances are needed in primary and rechargeable batteries, and regenerative fuel cells. Advances are also needed in power management and distribution systems, power system control, and integrated health management.

Innovations are sought that will improve the capability of spacecraft propulsion systems. In electric propulsion technology, radioisotope electric propulsion advances 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. Innovations are needed for xenon, krypton, and metal propellant storage and distribution systems. In small chemical propulsion technology, advances are sought for non-catalytic ignition methods for advanced monopropellants and high-temperature, reactive combustion chamber materials. Advances are also sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems.

TOPIC: T4 Innovative Sensors, Detectors and Instruments for Science Applications

This topic solicits innovative sensors, detectors and instruments that support the research in Earth and its environment, the solar system, and the universe through observations from space. To assure that our Nation maintains leadership in this endeavor, we are committed to excellence in scientific investigation, in the development and operation of space systems, and in the advancement of essential technologies.

T4.01 Lidar, Radar and Coherent Fiber Budnle Arrays
Lead Center: GSFC

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.

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 UAV 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 (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 beam systems to provide horizontal coverage;
- Wind measurements (using direct-detection techniques);
- Remote measurements of carbon-based trace gases (CO_2, CH_4, and CO) for total column measurements from aircraft and spacecraft operating to nadir using the Earth's surface as a target, as well as for profiling measurements from the ground using atmospheric backscatter. These systems need tunable, narrow line-width lasers and sensitive detectors that operate in the 1.5 micron, 1.6 micron and 3.2-3.6 micron bands.

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 efficiency solid state power amplifiers (>5W at W-band, >20W at Ka-band and >50W at Ku-band);
- High duty cycle (~10%) power supplies and modulators for high-power Klystrons at Ka and band (~2 kW peak) for high-altitude (65,000 ft) operation.
- Cross track scanning Ka or W-band Doppler radar technologies with high sensitivity for clouds.
- Low sidelobe (better than -30 dB), high power scanning phased array antennas (X, Ku, Ka or W-band) for high-altitude operation (65,000 ft).
- High speed (output center frequency > 500 MHz), wide bandwidth (>200 MHz) adaptive versatile waveform generator for FM chirp (with amplitude modulation for ultra low sidelobe pulse compression) generation.
- Wind field retrieval processing using dual-beam, dual-look-angle conical scanning radar measurements.

Coherent Fiber Bundle Arrays

Future NASA flight missions are considering passive wavefront and amplitude control (spatial filtering) in astronomical applications such as the search for exo-planets. At least one recent NASA Discovery mission proposal called out the need for a coherent 2-dimensional array of fiber bundles for this application. We are interested in arrays of single-mode coherent fibers, configured as a fiber bundle, that operate in the visible wavelength region and act as an array of both amplitude and wavefront spatial filters for both astronomical and Earth sciences applications. Specific characteristics desired include:

- Coherent fiber bundles should be formed out of single mode fibers to maintain temporal and spatial coherence across the wavelength passband and such that they operate over acceptance angles of up to +/-1.25 degrees.
- 2D arrays comprising from 100 to 2,000 fibers with fiber-to-fiber spacing of from 50 microns up to 500 microns with placement accuracies of < 2.0 microns.
- There should be an array of lenslets on both the input and output side of fiber bundle with each input and output lenslet mapped to a single fiber, with anti-reflection coatings on the fiber ends and on the lenslets.
- Wavelength passbands should encompass the visible range of light but extending down to 0.25 microns and up to 1.0 micron if possible. The fibers should have no cross talk between them and maintain the input polarization state.

TOPIC: T5 Modeling and Simulation

Benchmark Numerical Toolkits for High Performance Computing: This topic addresses the need for well defined benchmarks to test and verify numerical toolkits for linear algebra applied to large problems running on serial and parallel computers. The goal of this work is to deliver a comprehensive numerical test suite that can be used in current and future high performance computing benchmarking activities. The toolkits can be either from public domain, for example PETSCi or LAPACK or from commercial vendors like Boeing Computer Services (BCS) or CASI.

Today's models reach sizes of millions of degrees of freedom. Parallel processing is used to achieve acceptable turn-around time. Although most of the public domain packages for numerical methods are well tested for small standard problems, little experience and published benchmarks exist for parallel processing of large models. Computations with explicit solvers, for example in the area of crash dynamics or fluid dynamics, do not require matrix based equation solvers and inherently exhibit good scalability on large numbers of processors. Analyses requiring implicit solvers, for example in the computation of thermally driven structural response, utilize large matrix equation solvers. In most cases, the matrices are sparse. However, in thermal radiation exchange problems, the matrices may be dense and unsymmetric. The proposed work must address the latter cases.

T5.01 Benchmark Numerical Toolkits for High Performance Computing
Lead Center: JPL

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The work must include:

- Benchmarks of models with analytical solutions;
- Benchmarks for indefinite matrices and pathological cases;
- Benchmarks of implicit solution algorithms with production models in the area of thermal and structural analysis;
- Document the strengths, weaknesses, and limitations of the toolkits used together with recommendations;
- Comparison of solutions on serial and parallel hardware;
- Study of wall clock performance with respect to the number of processors;
- Precision and round-off studies on serial and parallel machines.

The number of processors should be varied based on common architectures (64, 256, 512, 1024 etc.). The study should also include performance comparisons between distributed and shared memory machines as well as machines with a mixed memory architecture. Phase 1 can include the selection of problem sets and research with respect to the current state of the art (particularly identifying areas of insufficient coverage). Phase 2 will include implementation and demonstration of the problem set on selected architectures.

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 advancing the technologies in communication systems' filters and antennas; new dynamic radiation sensors; better and longer range no-power radio frequency (RF) sensors-tag for identification, position and sensor data; and highly effective algorithms for autonomous robotic handling to increase the flexibility and efficacy of robots deployed to the surface of the Moon and Mars missions. The new technologies being solicited include means to improve operational capabilities; improve crew safety; increase human productivity; reduce the size, weight and power; reduce the Extravehicular Activity (EVA) time required to setup and deploy outposts, habitats, science packages, and others; and abilities to enhance the success of future human exploration missions. The anticipated proposed technologies shall have a dramatic impact on achieving these goals of the Space Exploration Vision. Current on-orbit automated rendezvous and docking (AR&D) capability in low-Earth orbit (LEO) is constrained by sensor and effector mass, power, and accuracy limits. NASA/JSC has developed a GPS receiver specifically to address the sensor constraints. Proposals are sought to develop an AR&D demonstration platform that utilizes two pico-satellites in LEO. Relative GPS will function as the primary sensor in a scenario that will include formation flying along with AR&D. The proposal should address pico-satellite (1) development and construction (volume: 10"x5"x5", mass: 5kg), power system implementation, (2) data downlinking, including ground stations, and (3) maneuvering effector implementation.

T6.01 Formation Flying and Automated Rendezvous and Docking
Lead Center: JSC

Current on-orbit automated rendezvous and docking (AR&D) capability in low-Earth orbit (LEO) is constrained by sensor and effector mass, power, and accuracy limits. NASA/JSC has developed a GPS receiver specifically to address the sensor constraints. Proposals are sought to develop an AR&D demonstration platform that utilizes two pico-satellites in LEO. Relative GPS will function as the primary sensor in a scenario that will include formation flying along with AR&D. The proposal should address pico-satellite (1) development and construction (volume: 10"x5"x5", mass: 5kg), power system implementation, (2) data downlinking, including ground stations, and (3) maneuvering effector implementation.

Pico-Satellite Automated Rendezvous and Docking Development and Test Platform
This solicitation seeks to improve the current automated rendezvous and docking (AR&D) technologies by validating the NASA designed GPS receiver in an on-orbit AR&D operational scenario and creating a platform for enhanced AR&D verification platform in the formation flying pico-satellites. First, two pico-satellites must be constructed to accommodate the NASA's GPS receiver and other state-of-the-art miniaturized sensors and efforts for a 30 day LEO mission. The pico-satellites must meet strict requirements for mass (less than 5kg), volume (5"x5"x10"), power generation (10W continuous), and space ruggedness (30 day LEO mission).

Phase 1 Requirements: Demonstrate the pico-satellite formation flying platform by 1) exit from a shuttle cargo bay as a single unit; 2) pico-satellite separation once the units have cleared the shuttle cargo bay; 3) maintain a LEO for 30 days; 4) transmit data from the GPS receiver to ground stations.

Phase 2 Requirements: Demonstrate the AR&D technologies by performing 1) exit from launch vehicle 2) maintain a predetermined flight formation for a given period of time; 3) perform a controlled AR&D maneuver; 4) transmit data from the GPS receiver and other sensors to ground stations.

TOPIC: T7 Launch Site Technologies

One of the major challenges routinely faced at the Kennedy Space Center's launch and landing sites is to prevent hardware damage from the blasts associated launching spacecraft. This includes the prediction of the aerodynamics and vibro-acoustics of rocket plumes in the launch environment, the reduction of high velocity ejection of materials by the rocket plume, and protection of the surrounding hardware from these effects. This will be a greater challenge at extraterrestrial spaceports. When a spacecraft lands on the Moon or Mars, surrounding hardware may be damaged and contaminated by the high velocity spray of eroded soil particles, and the landing spacecraft may be affected by an upward spray along the reflection planes between multiple engines.

T7.01 Predictive Numerical Simulation of Rocket Exhaust Interactions with Soil
Lead Center: KSC

On lunar or martian spaceports, the blast protection infrastructure must be constructed (in part) using in situ materials, such as a berm made with soil or sintered soil to form a landing pad. There are a number of mission scenarios that will be different than the Apollo experience and that cause the erosion problem to be more significant. Thus, this needs to be assessed in hardware and architecture design.

The lunar soil erosion theory developed during the 1940's and 50's did not include some of the relevant physics and as such it does not allow us to quantitatively predict the blast effects (with sufficient confidence) for missions that include multiple spacecraft landing in close vicinity to one another on the Moon or Mars. Without these predictions, it is currently not possible to develop adequate blast mitigation and protection technologies. To obtain better predictions, the Kennedy Space Center desires the development of a software tool that numerically predicts the plume interactions with the soil for rockets landing or launching on the Moon and Mars, including the erosion rates and trajectories of ejected particulate matter.

The difficulties in developing a flow code to predict these effects include the unique lunar environment with the plume expanding into a vacuum, the difficulty in solving flow physics from first principles around discrete particle assemblages, the large spatial scale of the flow features compared to the vast number of lunar soil particles within that region, and the need to parameterize the erosion of soil to produce realistic predictions although realistic benchmarking experiments of lunar erosion are difficult to perform terrestrially. Innovations are sought, resulting in the improvement of software packages to improve the fidelity of predictions for lunar and martian blast dynamics. Examples include but are not limited to the inclusion of particle dynamics models for the eroding soil, greater understanding of the particle aerodynamics including lift and drag in the relevant flow regimes, improvement of turbulence models for the particle laden flow, improved erosion (emission) models to predict the erosion rate with greater confidence as a function of both gas and soil parameters, greater understanding of the structure of the boundary layer on the planet's surface considering the Knudsen and Mach numbers that may occur, and the ability to predict the diffusion of gas into the soil and how that loosens the soil to increase erosion and/or excavation processes.

TOPIC: T8 Research for Improving Heat Conversion Efficiency

NASA faces challenges to improve aircraft design, efficiently get man to space, and the challenge of accomplishing the mission once in space. The agency is seeking enhancement to or development of technologies for generating and/or storing power in light weight and thin devices.

T8.01 Revolutionary (>30% Conversion Efficiency) Thermo-Electric Devices
Lead Center: LaRC

Currently the conversion efficiency of thermo-electric devices which convert heat directly into electricity is not high enough to gain a substantial benefit for reliable use in aircraft, spacecraft, or missions. NASA is interested in new devices for extracting power from heat in, for example, turbine engines, the hot side of spacecraft, and even from the body heat of astronauts. Capturing this "wasted heat" and converting it to electricity could power radios on Mars, lighten the load of astronauts, or power lights spacecraft or aircraft. Commercial applications are vast. Concepts will be evaluated based on their potential conversion efficiency, power output per unit area, ease of manufacturing, and flexibility of applications. Light weight and thin are desirable characteristics for aircraft, spacecraft, and human-worn applications. Proposals will be evaluated based on the maturity level to which the technology will be developed.

TOPIC: T9 Technologies for Human and Robotic Space Exploration Propulsion Design and Manufacturing

Achieving the Space Exploration Goals that NASA has defined 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 Moon, Mars, and solar system. Implementing certain aspects of the NASA Vision for Space Exploration will require versatile, reliable space propulsion engines that can operate over a wide range of thrust levels, high specific impulse, and have multiple restart capability. 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, and lunar 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 superalloys 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 environment for systems, solid or liquid propellants, undergoing multi-phase combustion.
- Improvements in prediction of stability and stability margins for liquid, gaseous, and solid propulsion systems.
- Zero net positive suction pressure pump design and analysis techniques.
- Design and analysis tools that accurately model small valves and turbopumps.
- Data bases and instrumentation advances required for validation of previously mentioned predictive capabilities.

TOPIC: T10 Rocket Propulsion Testing Systems

NASA's Stennis Space Center (SSC) is interested with expanding its suite of test facility modeling tools as well as non-intrusive plume technologies that provide information on propulsion system health, the environments produced by the plumes and the effects of plumes and constituents on facilities and the environment.

T10.01 Large Propulsion System Testing Requirements
Lead Center: SSC

Facility Modeling Tools and Methods
Developing and verifying test facilities is complex and expensive. The wide range of pressures, flow rates, and temperatures necessary for engine testing results in complex relationships and dynamics. It is not realistic to physically test each component and the component-to-component interaction in all states before designing a system. Currently, systems must be tuned after fabrication, requiring extensive testing and verification. Tools using computational methods to accurately model and predict system performance are required that integrate simple interfaces with detailed design and/or analysis software. SSC is interested in improving capabilities and methods to accurately predict and model the transient fluid structure interaction between cryogenic fluids and immersed components to predict the dynamic loads, frequency response of facilities.

Component Design, Prediction and Modeling
Improved capabilities to predict and model the behavior of components (valves, check valves, chokes, etc.) during the facility design process are needed. This capability is required for modeling components in high pressure (to 12,000 psi), with flow rates up to several thousand lb/sec, in cryogenic environments and must address two-phase flows.

Challenges include: accurate, efficient, thermodynamic state models; cavitation models for propellant tanks, valve flows, and run lines; reduction in solution time; improved stability; acoustic interactions; fluid-structure interactions in internal flows.

Engine Health Monitoring
Innovative, standalone sensors for non-intrusively measuring physical properties of rocket engine plumes. Measurements of interest include, but are not limited to, metallic species, temperature, density, velocities, combustion stability and oxidizer to fuel ratio measurement.

Major challenge: Metallic detection in the plume at a level of 10-100 ppb during altitude simulation (1 psia and below) engine testing using spectroscopic absorption techniques.

Plume Environments Measurements
Advanced instrumentation and sensors to monitor the near field and far field effects and products of exhaust plumes. Examples are the levels of acoustic energy and thermal radiation and their interaction/coupling with test articles and facilities and measurements of the final exhaust species that will effect the environment.

Major challenge: Large scale engine plume dispersion modeling and validation.

NASA SBIR-STTR Technology Taxonomy

Avionics and Astrionics
- Airport Infrastructure and Safety
- Attitude Determination and Control
- Guidance, Navigation, and Control
- On-Board Computing and Data Management
- Pilot Support Systems
- Spaceport Infrastructure and Safety
- Telemetry, Tracking and Control

Bio-Technology
- Air Revitalization and Conditioning
- Biomass Production and Storage
- Biomedical and Life Support
- Biomolecular Sensors
- Sterilization/Pathogen and Microbial Control
- Waste Processing and Reclamation

Communications
- Architectures and Networks
- Autonomous Control and Monitoring
- Laser
- RF

Cryogenics
- Fluid Storage and Handling
- Instrumentation
- Production

Education
- General Public Outreach
- K-12 Outreach
- Mission Training

Electronics
- Highly-Reconfigurable
- Photonics
- Radiation-Hard/Resistant Electronics
- Ultra-High Density/Low Power

Extravehicular Activity
- Manned-Maneuvering Units
- Portable Life Support
- Suits
- Tools

Information
- Autonomous Reasoning/Artificial Intelligence
- Computer System Architectures
- Data Acquisition and End-to-End-Management
- Data Input/Output Devices
- Database Development and Interfacing
- Expert Systems
- Human-Computer Interfaces
- Portable Data Acquisition or Analysis Tools
- Software Development Environments
- Software Tools for Distributed Analysis and Simulation

Manufacturing
- Earth-Supplied Resource Utilization
- In-situ Resource Utilization
- Microgravity

Materials
- Ceramics
- Composites
- Computational Materials
- Metallics
- Multifunctional/Smart Materials
- Optical & Photonic Materials
- Organics/Bio-Materials
- Radiation Shielding Materials
- Semi-Conductors/Solid State Device Materials
- Superconductors and Magnetic
- Tribology

Microgravity
- Biophysical Utilization
- Combustion
- Liquid-Liquid Interfaces

Power and Energy
- Biochemical Conversion
- Energy Storage
- MHD and Related Conversion
- Nuclear Conversion
- Photovoltaic Conversion
- Power Management and Distribution
- Renewable Energy
- Thermodynamic Conversion
- Thermoelectric Conversion
- Wireless Distribution

Propulsion
- Aerobrake
- Aircraft Engines
- Beamed Energy
- Chemical
- Electromagnetic Thrusters
- Electrostatic Thrusters
- Feed System Components
- Fundamental Propulsion Physics
- High Energy Propellants (Recombinant Energy & Metallic Hydrogen)
- Launch Assist (Electromagnetic, Hot Gas and Pneumatic)
- MHD
- Micro Thrusters
- Monopropellants
- Nuclear (Adv Fission, Fusion, Anti-Matter, Exotic Nuclear)
- Propellant Storage
- Solar
- Tethers

Robotics
- Human-Robotic Interfaces
- Integrated Robotic Concepts and Systems
- Intelligence
- Manipulation
- Mobility
- Perception/Sensing
- Teleoperation

Sensors and Sources
- Biochemical
- Gravitational
- High-Energy
- Large Antennas and Telescopes
- Microwave/Submillimeter
- Optical
- Particle and Fields
- Sensor Webs/Distributed Sensors
- Substrate Transfer Technology

Structures
- Airframe
- Airlocks/Environmental Interfaces
- Controls-Structures Interaction (CSI)
- Erectable
- Inflatable
- Kinematic-Deployable
- Launch and Flight Vehicle
- Modular Interconnects
- Structural Modeling and Tools
- Tankage

Thermal
- Ablatives
- Control Instrumentation
- Cooling
- Reuseable
- Thermal Insulating Materials

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