National Aeronautics and Space Administration

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

Program Solicitations

Opening Date: July 7, 2006
Closing Date: September 7, 2006

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

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2006 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 2006 Solicitation period for Phase 1 proposals begins July 7, 2006, and ends September 7, 2006.

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 fulfills one or more NASA needs 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.

A proposal directed towards system studies, market research, routine engineering development of existing products or proven concepts and modifications of existing products without substantive innovation is considered non-responsive to the solicitations.

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 2006. Historically, the ratio of Phase 1 proposals to awards is approximately 8:1 for SBIR and 5:1 for STTR, and approximately 40% 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 Office of the NASA Associate Administrator provides overall policy direction for 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 Goddard Space Flight Center. NASA Glenn Research Center provides the overall procurement management for the programs.

The SBIR Program Solicitation is aligned with the needs of NASA Mission Directorates as described in Section 9.1.

The STTR Program Solicitation is aligned with needs associated with the core competencies of the NASA Centers as described in Section 9.2. The NASA Jet Propulsion Laboratory (JPL) does not participate in the management of the STTR Program.

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.

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 2.15, 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 2.19). 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.

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 2006 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. Contact via:

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:

Paul Mexcur, Program Manager
NASA SBIR/STTR Program Management Office
Code 408, Goddard Space Flight Center
Greenbelt, MD 20771-0001
Winfield.P.Mexcur@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 (amount requested, including cost sharing if any, less fee if any) 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 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.

2.9 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 2.13), 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.

2.10 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.

2.11 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.

2.12 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.

2.13 SBIR/STTR Technical Data

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

2.14 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.

2.15 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.

2.16 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).

2.17 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.

2.18 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.

2.19 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.

2.20 Women-Owned Small Business

A women-owned SBC is one 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. 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.**

Web site 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 (Optional – 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. *If the technical abstract is judged to be non responsive to the subtopic, the proposal will be rejected without further evaluation.*

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).

Travel. Travel is an acceptable cost when it is part of accomplishing the work proposed in Phase 1. Proposed travel must be described as to its purpose and benefits in proving technical feasibility, and is subject to negotiation and approval by the Contracting Officer and COTR at the time of award.

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 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 2006 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)). In rare and unique circumstances, the 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.

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.

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 (amount requested including cost sharing if any, less fee, if any).	The proposed subcontracted business arrangements with individuals or organizations other than the RI must not exceed 30 percent of the work (amount requested including cost sharing if any, less fee, if any).

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 (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 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 Briefing Chart (Optional). A one-page briefing chart is requested to assist in the ranking and advocacy of proposals prior to selection. Submission of the briefing chart is optional. It is not counted against the 25-page limit, and *must not* contain any proprietary data. An example chart is provided in Section 8.

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 (Optional – 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. *If the technical abstract is judged to be non responsive to the subtopic, the proposal will be rejected without further evaluation.*

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).

Travel. Travel is an acceptable cost when it is part of accomplishing the work proposed in Phase 2. Proposed travel must be described as to its purpose and benefits in conducting the research and development, and is subject to negotiation and approval by the Contracting Officer and COTR.

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

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.

(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)). 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.

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.

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 (contract cost less profit) must be performed by the proposing SBC.	A minimum of 40 percent of the work 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 Briefing Chart (Optional). A one-page briefing chart is requested to assist in the ranking and advocacy of proposals prior to selection. Submission of the briefing chart is optional, is not counted against the 50-page limit, and *must not* contain any proprietary data. An example chart is provided in Section 8.

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 Nation. 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. 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.

STTR: The clear delineation of the 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 or 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 transition 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. Each Center will make recommendations for award among those proposals that it evaluates. Center recommendations 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. Recommendations provided by the Centers do not guarantee selection for award. 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). After being selected for Phase 1 contract negotiations, but before the contract starts, the offeror shall 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.

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 Nation. 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 1 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 transition 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.

Each Center will make recommendations for award among those proposals that it evaluates. The Center recommendations 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). Recommendations provided by the Centers do not guarantee selection for award. 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. The offeror will be contacted by the appropriate Field Center for debriefing within 60 days of the selection announcement. If you have not received your debriefing by this time, contact the appropriate SBIR/STTR Field Center Program Manager.

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 40 percent of the successfully completed Phase 1 projects from the SBIR 2006 Solicitation will be selected for Phase 2. Phase 2 agreements are 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 40 percent of the successfully completed Phase 1 projects from the STTR 2006 Solicitation will be selected for Phase 2. Phase 2 agreements are fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.

5.1.2 Contracting. Fixed-price contracts will be issued for both Phase 1 and Phase 2 awards. Simplified contract documentation is employed; however, SBCs selected for award can reduce processing time by examining the procurement documents, submitting signed representations and certifications, and responding to the Contracting Officer in a timely manner. NASA will make a Phase 1 model contract and other documents available to the public on the NASA SBIR/STTR Website (http://sbir.nasa.gov) at the time of the selection announcement. **From the time of proposal selection until the award of a contract, only the Contracting Officer is authorized to commit the Government, and all communications must be through the Contracting Officer.**

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

Interim progress 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 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

Payments are commonly 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 by NASA. The first two payments will be made 30 days after receipt of valid invoices. The final payment will be made 30 days after acceptance of the final report, the New Technology Report, and other deliverables as required by the contract. Electronic funds transfer will be employed and offerors will be required to submit account data if selected for contract negotiations.

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 Optional Briefing Chart should not contain proprietary information**.**

5.8 Limited Rights Information and Data

Rights to data used in, or first produced under, any Phase 1 or Phase 2 contract are specified in the clause at FAR 52.227-20, Rights in Data--SBIR/STTR Program. The clause provides for rights consistent with the following:

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 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. Awardees must report inventions to the awarding agency within 2 months of the inventor's report to the awardee. The reporting of inventions should be accomplished in accordance with the negotiated contract.

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.

STTR: If cost sharing is proposed, then these added funds shall be included in the 40/30 work percentage distribution and reflected in the Summary Budget (Form C).

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 2.14. 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 that follows 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 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).

5.14.4 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." In particular, the requirements of Sections 5.27 and 5.28 should be noted as compliance will be required. NPR 7150.2 is available online at http://nodis3.gsfc.nasa.gov/lib_docs.cfm?range=7___.

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.

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, and C 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 are encouraged to upload an optional 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. 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:

<u>Sample E-mail for Successful Upload of Technical Proposal</u>

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 "Sign 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 7, 2006, 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. 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 2006 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 (Optional) 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 18, 2006, 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

Proposals may be withdrawn via the electronic handbook system hosted on the NASA SBIR/STTR Website (http://sbir.nasa.gov) with an endorsement by the designated SBC Official.

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:

Paul Mexcur, Program Manager
NASA SBIR/STTR Program Management Office
Code 408, Goddard Space Flight Center
Greenbelt, MD 20771-0001
Winfield.P.Mexcur@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

Information relating to the formulation of proposals is available via the following web sites:

NASA 2006 Strategic Plan: http://www.nasa.gov/about/budget/index.html
NASA Mission Directorates: 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

Form A – SBIR Cover Sheet

Subtopic Number

1. PROPOSAL NUMBER: **06 -** _ _ . _ _ _ _ _ _
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:
   NUMBER OF EMPLOYEES:
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	Yes	No
As defined in Section 2 of the Solicitation, the offeror qualifies as a:		
b. SBC Number of employees: _____	Yes	No
c. Socially and economically disadvantaged SBC	Yes	No
d. Women-owned SBC	Yes	No
e. HUBZone-owned SBC	Yes	No
As defined in Section 3.2.4 Part 11 of the Solicitation indicate if		
f. Work under this project has been submitted for Federal funding only to the NASA SBIR Program	Yes	No
g. 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:		
h. All 11 parts of the technical proposal are included in part order	Yes	No
i. Subcontracts/consultants proposed?	Yes	No
i) If yes, limits on subcontracts/consultants met	Yes	No
j. 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		
k. The offeror will comply with export control regulations	Yes	No

7. ACN NAME: 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:
   SIGNATURE: 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:	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, 6h (see the referenced sections for definitions).

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

   6i. 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.

   6j. 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.

   6k. 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 and E-mail: Name 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 **06 -** _ _ . _ _ _ _ _ _.

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. Technical Abstract (Limit 2,000 characters, approximately 200 words)/Technology Taxonomy (Select only the technologies relevant to this specific proposal)

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

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

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. **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.

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

7. **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.

8. **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.

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 progress 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
______	______	______
______	______	______
______	______	______

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: 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 (progress 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. Certifications in Form A are completed.
6. Proposed funding does not exceed $100,000. (Sections 1.4.1, 5.1.1).
7. Proposed project duration should not exceed 6 months. (Sections 1.4.1, 5.1.1).
8. Entire proposal including Forms A, B, and C submitted via the Internet.
9. Form A electronically endorsed by the SBC Official.
10. **Proposals must be received no later than 5:00 p.m. EDT on Thursday, September 7, 2006** (Section 6.3).

Form A – STTR Cover Sheet

1. PROPOSAL NUMBER: **06 -** _ _ . _ __ _ _ _ _
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. <u>CERTIFICATIONS</u>: 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.	Socially and economically disadvantaged SBC	Yes	No
c.	Woman-owned SBC	Yes	No
d.	HUBZone-owned SBC	Yes	No
As described in Section 2.11 of the Solicitation, the partnering institution qualifies as a:			
e.	FFRDC	Yes	No
f.	Nonprofit research institute	Yes	No
g.	Nonprofit college or university	Yes	No
As described in Section 3 of the Solicitation, the offeror meets the following requirements completely:			
h.	Cooperative Agreement signed by the SBC and RI enclosed	Yes	No
i.	All eleven parts of the technical proposal included in part order	Yes	No
j.	Subcontracts/consultants proposed? (Other than the RI)	Yes	No
	i) If yes, limits on subcontracts/consultants met	Yes	No
k.	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
l.	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:			
m.	Work under this project has been submitted for funding only to the NASA STTR Program	Yes	No
n.	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			
o.	The offeror will comply with export control regulations	Yes	No

7. ACN NAME: 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:
    SIGNATURE: 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:	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, 6i, 6l (see Section 2 for definitions).

   6h. 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).

   6j. 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.

   6k. 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.

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

   6o. 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 and E-mail: Name 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 **06 -** _ _ . _ _ _ _ _ _

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. Technical Abstract (Limit 2,000 characters, approximately 200 words)/Technology Taxonomy (Select only the technologies relevant to this specific proposal)

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)

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. **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.

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

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.

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 progress 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
________________________	________	________________________
________________________	________	________________________
________________________	________	________________________

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: 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 (progress 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, <u>subject to any rights of the Government therein</u>, as follows—

(1) Where Project Intellectual Property of RI is a potentially patentable invention, SBC will have an exclusive option for a license to such invention, for an initial option period of _______ months after such invention has been reported to SBC. SBC may, at its election and subject to the patent expense reimbursement provisions of this section, extend such option for an additional _______ months by giving written notice of such election to RI prior to the expiration of the initial option period. During the period of such option following notice by SBC of election to extend, RI will pursue and maintain any patent protection for the invention requested in

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

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

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

4. Follow-on Research or Development.

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

5. Confidentiality/Publication.

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

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

6. Liability.

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

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

7. Termination.

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

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

AGREED TO AND ACCEPTED--

Small Business Concern

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

Research Institution

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

STTR Check List

For assistance in completing your Phase 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. Certifications in Form A are completed.
6. Proposed funding does not exceed $100,000. (Sections 1.4.1, 5.1.1).
7. Proposed project duration should not exceed 12 months. (Sections 1.4.1, 5.1.1).
8. Cooperative Agreement has been electronically endorsed by both the SBC Official and RI. (Sections 3.2.5, 6.2).
9. Entire proposal including Forms A, B, C, and Cooperative Agreement 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 7, 2006** (Section 6.3).
12. Signed Allocation of Rights Agreement available for Contracting Officer at time of selection.

Example Format for Briefing Chart

NASA SBIR/STTR Technologies **Title of Proposal** **PI: PI's Name / Firm – City, ST** **Proposal No.: 06-1 _ _ . _ _ - _ _ _ _**	SBIR STTR
Identification and Significance of Innovation	<Place Picture Here>
Technical Objectives and Work Plan	NASA and Non-NASA Applications Contacts
NON-PROPRIETARY DATA	

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

The Aeronautics Research Mission Directorate will re-establish NASA's dedication to the mastery of core competencies in subsonic, supersonic, and hypersonic flight. This Directorate will develop system-level, multi-disciplinary capabilities to meet the needs of both civilian and military communities.

NASA is the nation's leading government organization for aeronautical research. This world-class capability is built on a tradition of expertise in core disciplines. NASA is restructuring the Agency's aeronautics programs to ensure long-term investments and fundamental research in both traditional aeronautical disciplines and relevant emerging fields that can be integrated into system-level, multi-disciplinary capabilities.

NASA will invest heavily in the core competencies of aeronautics in all flight regimes to produce knowledge, data, and design tools that are applicable across a broad range of air vehicles. This will include the continued stewardship on NASA's many aeronautics test facilities, including wind tunnels and propulsion test cells that are considered to be national assets.

http://www.aerospace.nasa.gov/

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 (NGATS). 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., fluid dynamics, computational methods, material science), which in turn is used to build integrated multidisciplinary system-level models, tools, and technologies. 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. The primary areas of program interest are 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 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; system-level integrated resilient control technologies; as well as effective vehicle-based flight/mission management under adverse, upset, and hazards conditions. 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.

A1.01 Vehicle-Centric 4D Trajectory and Mission Management
Lead Center: ARC

NASA is concerned with creating new and innovative methods for airborne detection, identification and resolution of tactical hazards to aviation. These hazards may include weather and other atmospheric phenomena, terrain, traffic, aircraft system failures, and aircraft/operator interactions. Research proposals are sought in the area of 4D vehicle-centric trajectory and mission management, with emphasis on mission planning, external hazard response, and workload reduction.

The three major research areas covered by this subtopic are:

Mission Planning
Dynamic changes in an aircraft's tactical situation require rapid generation of a flight plan that best accomplishes a global set of mission goals. Mission management (MM) uses cost functions and any-time planning algorithms to produce feasible flight plans. The specific capabilities desired in this area are the generation and specification of 4D trajectories, and defining requirements and constraints (look-ahead time, ground system interface, aircraft system integration, etc.) related to the planning of such trajectories.

Response to Detected External Hazards
Sensing systems detect obstacles, weather and other constraints in the flight path; MM commands short-term trajectory change, with compensating downstream legs to minimize schedule impact. Capabilities expected from this research are automated decision making and path planning in the presence of external hazards, along with requirements for the creation of automation systems to accomplish such tasks.

Workload Reduction
On-the-fly generation of complex mission-driven flight plans for search patterns, data collection experiments, and tracking problems. Important activities in this area include design criteria and principles for the creation of pilot-flight deck automation interfaces and algorithmic approaches related to trajectory management.

Examples of outcomes NASA expects from these research areas are provided below (this list is not exclusive of other high-potential ideas):

- Automated trajectory generation capability given a short-to-medium term time horizon;
- A flexible input and interface capability for the flight deck in terms of widely varying constraints, goals, costs and supporting systems;
- Procedural and algorithmic methods of achieving mission management goals under different and varying constraints;
- Working interfaces that allow a pilot to view a 4D trajectory and accept or reject it, modify and retransmit a 4D trajectory uploaded from ground-based automation systems, or generate and trial plan a 4D trajectory for air traffic control approval;
- Automated decision making and path planning capability that allows an aircraft to decide what particular actions are most appropriate to respond to specific situations, along with requirements for and analysis of the appropriate circumstances under which this capability should be exercised.

A1.02 Integrated Resilient Aircraft Control
Lead Center: ARC
Participating Center(s): DFRC, GRC, LaRC

The overarching goals for the Aviation Safety topic are to develop technologies, tools, and methods to (1) improve the inherent safety attributes of new and legacy vehicles, and (2) overcome safety technology barriers that would otherwise constrain full realization of the Next Generation Air Transportation System.

The specific technologies, tools and methods emphasized in this subtopic are vehicle dynamics and hazards effects modeling and simulation methods for coupled hazard effects assessment; detection, identification and prediction methods for flight safety diagnostics and prognostics; control and guidance methods for hazard mitigation, control recovery, and vehicle autonomy under adverse and emergency conditions; robust design and risk analysis and mitigation methods; advanced control structures and materials for resilient control; instrumentation for intelligent sensing, monitoring, and control; validation methods for complex models and adaptive systems; and software safety assurance and formal verification methods for safety-critical systems, leading to multi-disciplinary analysis and optimization capabilities that enable the development and validation of system-level integrated resilient control technologies to provide graceful recovery from potentially catastrophic in-flight failures/damage, external disturbances, vehicle upsets, and system and control input errors; as well as effective vehicle-based flight/mission management under adverse, upset, and hazards conditions. Proposals are sought in the following areas:

Resilient Flight Control

- Fault tolerance and hazard effects protection
- Onboard hazard effects assessment, mitigation and control recovery

Resilient Propulsion Control

- Damage tolerance and design for extended envelope operation
- Onboard hazard effects assessment, mitigation and control recovery

Resilient Airframe Control

- Damage tolerance and structural damage avoidance
- Onboard damage detection and identification, mitigation and control recovery

Resilient Vehicle Mission Management

- Control and performance management
- Vehicle-based mission management and autonomous collision avoidance
- Interface and communication management

Safety-Critical System V&V

- Software safety assurance methods for complex avionics systems
- Integrated V&V methods, tools and test techniques for adaptive control systems
- Predictive capability assessment methods and tools

A1.03 Aircraft Aging and Durability
Lead Center: GRC
Participating Center(s): ARC, DFRC, LaRC

Aircraft aging is a significant national issue that is being addressed by government agencies, manufacturers, operators, and academia. NASA's contribution to solving the problem is research on aging and damage processes in "young" aircraft, rather than life extension of legacy vehicles. Its emphasis is on new and emerging material systems/fabrication techniques and the potential hazards associated with their aging-related degradation. The intent is to identify aging-related hazards before they become critical, and develop technology to anticipate aging and maintenance needs in the design of future aircraft.

NASA performs multi-level research in aging science leading ultimately to multi-disciplinary analysis and optimization capabilities that will enable system-level integrated detection, prediction and mitigation of aging-related hazards in future civilian and military aircraft. To further the fundamental understanding of the underlying physics and to develop an ability to model the physical processes, foundational research is conducted in the following areas: sensing and diagnostic technologies; physics-based modeling; continuum-based models and computational methods; material science (metals, ceramics, composites); and characterization/validation test techniques. Building upon foundational research yields discipline-based products: nondestructive evaluation (NDE) systems; structural integrity tools; lifing methods; and concepts to mitigate aging-effects. By integration of discipline-based tools, multi-disciplinary methods and technologies are developed; e.g., detection capability is enhanced by coupling NDE with structural integrity analysis, prediction capability is enhanced by applying NDE (and vehicle health monitoring data) to improve model input and provide improved predictions of remaining life and strength, and mitigation capability is enhanced by applying predictive models to help develop advanced mitigation concepts.

Specifically, NASA requests proposals that assimilate the above multi-layer approach, which provide innovative solutions to one of the following problems:

- The use of integral metallic structure in airframe application provides unique crack growth and fracture characteristics that are not consistent with traditional metallic structure characteristics. Computational methods for elasto-plastic crack propagation, including non-self-similar growth and bifurcation of 2D and 3D cracks, are needed for predicting crack growth in complex metallic geometries. Computational methods must be incorporated into a user interface software tool.
- Computational methods for the prediction of strength of composite and metal/composite hybrid skin-stringer fuselage present the following technical challenges: numerical regularization techniques to improve convergence of delamination propagation simulation; and X-FEM for failure prediction that address interaction between in-plane and interlaminar failure modes. Solutions to these two challenges are sought.
- Novel techniques for large-area nondestructive evaluation (detection of damage and material degradation) of metallic and composite fuselage and wing structure are needed.
- Adhesive bonds are critical to integrity of built-up structure. Disbonds (i.e., gaps) can often be detected, but the strength of the adhesion between surfaces in contact is not obvious. Methods to detect bond degradation, predict disbond growth, and characterize weak bonds are needed.
- Advanced composite concepts for jet engine containment structures have unknown long-term service/environment effects. Better models and tools are needed for understanding these effects and for predicting engine blade-off event physics (i.e., the high strain-rate impact) to reduce risk and cost.
- New nickel-based superalloys which enable higher turbine disk operating temperatures have been developed. However, tools to understand and mitigate the long term durability and aging characteristics (e.g., microstructural instability and corrosion) of these alloys are needed.

- Degradation and damage that develops over time in engine hot section components can lead to catastrophic failure. Methods and sensors for characterization of degradation processes of these components (including ceramics) in harsh environments during system development are needed.
- Faults and hazards in aging vehicle wiring persist as a problem in legacy vehicles, and will pose risks in new vehicles. Novel methods (i.e., have not already been researched by FAA and DoD) are sought to detect and characterize degradation, and to predict useful life of wiring systems.

Technology innovations may take the form of tools, models, algorithms, prototypes, and devices.

A1.04 Aircraft Icing Avoidance and Tolerance
Lead Center: GRC
Participating Center(s): ARC

NASA is concerned with preventing encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. To maximize the level of safety, aircraft must be capable of handling all possible icing conditions by either avoiding or tolerating the conditions. Proposals are invited that lead to innovative new approaches or significant improvements in existing technologies for in-flight icing conditions avoidance (icing weather information systems) or tolerance (airframe and engine ice protection systems and design tools). With these emphases in mind, products and technologies that can be made affordable and retrofitable within the current aviation system, as well as for use in the future are sought:

- Ground and airborne radome technologies for microwave wavelength radar and radiometers that remain clear of liquid water and ice in all weather situations.
- In situ icing environment measurement systems that can provide practical, very low-cost validation data for emerging icing weather information systems and atmospheric modeling. Measured information must include location, altitude, cloud liquid water content, temperature, and cloud particle sizing and phase information. Solutions envisioned would use radiosonde-based systems.
- Ice protection and detection technology submittal must provide significant improvements over current systems or address new design needs. Areas of improvement can be considered to be: efficient thermal protection systems, including composite wing or structures applications; ice sensors that provide detection and accretion rate for all possible icing conditions; wide area ice detection; detection that serves both ground and in-flight applications; ice crystal detection probe (for non-research aircraft applications); engine icing probe (that can measure Liquid Water Content and Total Water Content inside engine passages); and de-icing systems that operate at near anti-icing performance. Any submittal must be cost competitive to current technologies.

A1.05 Crew Systems Technologies for Improved Aviation Safety
Lead Center: LaRC
Participating Center(s): ARC

NASA seeks highly innovative, crew-centered, technologies to improve the aerospace system. Such advanced technologies may meet this goal by ensuring appropriate situation awareness; facilitating and extending human perception, information interpretation, and response planning and selection; counteracting human information processing limitations, biases, and error-tendencies; identifying operator characteristics (a priori and in real time) that pertain to fitness for duty, design for individual differences and abilities, and intelligent information presentation and complementary automation. Such advanced technologies must be evaluated sensitively and in operationally-valid contexts. Therefore, NASA also seeks tools and methods for assessing the validity of human-in-the-loop system performance evaluations, and metrics and methods that sensitively assess the impact of innovations. Specific areas of interest include the following:

- Intelligent systems monitoring and alerting technologies for improved failure mode identification, recovery, and threat mitigation;

- Tools for aerospace vehicle interface and automation designs that prevent, detect, and mitigate the effects of human-error;
- Tools and methods to support communication, and collaborative/distributed decision-making;
- Data fusion technologies for real-time integration and integrity checking of single source information streams of varying spatial and temporal resolution;
- Flight deck information management technologies and modeling capabilities;
- Presentation and alerting for displays and aiding devices based on integrated streams of data with various levels of integrity;
- Presentation and aiding concepts for the display and use of data with spatial or temporal uncertainty, or of a predictive nature;
- Methods, sensors, and integration algorithms for determining operator and crew states of awareness (e.g., engagement, fatigue, immersion, etc.) and situation awareness content;
- Tools for assessing operator characteristics that determine fitness for duty, training level, error tendencies, crew/automation interaction style, or information presentation design;
- Technologies that complement individual capabilities for improved performance and access as an aerospace vehicle operator;
- Human-centered technologies to improve the access and performance of less-experienced operators and pilots from special population groups;
- Methods for analyzing the safety impact of human-centered technologies, human/automation roles, and procedures (human error modeling, human reliability assessment, fault tolerant systems);
- Scenarios, metrics, analysis methods, and tools for aerospace vehicle human-in-the-loop assessments with improved sensitivity and external validity;
- Theory and formal methods for interleaving multiple (e.g., normal and emergency) procedures;
- Theory and formal methods for automatic generation of procedures and recovery sequences.

Proposals should describe tools, models, operational procedures, instructional systems, prototypes, and devices for use in the flight deck, elsewhere by pilots, or by those who design systems for crew use. Proposals should be responsive to NASA program objectives and aim to be developed as marketable products.

A1.06 Aviation External Hazard Sensor Technologies
Lead Center: LaRC
Participating Center(s): ARC

NASA is concerned with new and innovative methods for airborne detection and identification of tactical hazards to aviation. These hazards may include weather and other atmospheric phenomena, terrain, traffic, and runway contamination. Examples of hazards include: convective weather, wind shear, wind gusts, turbulence, volcanic ash, hail, low visibility, wake vortices, lightning, terrain, air traffic, runway incursions, man-made obstacles, and wet/icy runways. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices. Although the emphasis is on airborne hazard detection, prediction, and avoidance; mitigation techniques using real-time sensor data, sharing of information to support hazard avoidance by other aircraft, collaborative decision-making, updates to terrain/obstacle databases, and provision of observations for input to weather models and forecast/nowcast products are also of interest. Examples include:

- New and improved airborne forward-looking sensor systems;
- Data fusion technologies for integrating disparate sources of flight-related information with on-board and off-board sensor data to detect and generate alerts of aviation hazards;
- Innovative technologies and methods to detect, predict, and quantify hazards in order to provide accurate information and guidance to enable pilot avoidance hazards, or to instigate strategies for mitigation;
- Decision-support tools and methods to improve collaborative and distributive decision-making.

A1.07 Integrated Vehicle Health Management
Lead Center: LaRC
Participating Center(s): ARC, DFRC, GRC

The purpose of this solicitation is to seek highly innovative and commercially viable technologies that will improve aircraft safety for current and future civilian and military aircraft, and to overcome aircraft safety technological barriers that would otherwise constrain the full realization of the Next Generation Air Transportation System. Specifically, this subtopic seeks technologies in support of the Integrated Vehicle Health Management Project (IVHM) that will contribute to the reduction of aircraft system and component failures and malfunctions that cause and contribute to aircraft accidents and incidents.

The goal of IVHM is to develop technologies to determine system/component degradation and damage early enough to prevent or gracefully recover from in-flight failures in both the near-future and next-generation air transportation systems. These technologies will enable nearly continuous on-board situational awareness of the vehicle health state for use by the flight crew, ground crew, and maintenance depot. To achieve this, we will advance the state-of-the-art in on-board health state assessment to enable the continuous diagnosis and prognosis of the integrated vehicle's health status. To help meet this goal, NASA seeks innovative technology development activities in the following areas:

- Airframe Health Management - including self-awareness and prognosis, anomaly detection and identification, and in-flight damage, degradation and failure mitigation;
- Propulsion Health Management - including self-awareness and prognosis of gas path, combustion, and overall engine state (containment systems and rotating and static components), and fault-tolerant system architectures;
- Aircraft Systems Health Management - including state-awareness and prognosis of landing gear, hydraulic and pneumatic systems, electrical and power systems, fuel and lubrication systems, avionics/communications, navigation, and surveillance/flight critical and flight management systems, and robust, distributed, fault-tolerant, self-recoverable architectures for flight critical aircraft applications;
- Environmental Hazard Management - including the prevention, detection, and mitigation of hazards such as ice accretion, lightning strikes, EMI/EMC, and ionizing radiation, as well as the direct and indirect effects of these hazards;
- IVHM Architectures and Databases - including system design, analysis and optimization, information management, data flow and communication, control and reconfiguration, architecture development and validation, and database development and management;
- Validation and Predictive Capability Assessment - including analysis, simulation, ground testing, flight-testing, environmental testing, and software assurance.

NASA's IVHM research will ultimately yield integrated, multi-disciplinary analysis and optimization capabilities that enable system-level designs providing graceful recovery from in-flight failures, computationally efficient tools for in-flight prognosis of aircraft health including integrated predictive and sensor capabilities, and preventative and adaptive systems for in-flight operability and informed logistics and maintenance. Innovative technology solutions are being sought for the following IVHM technical challenges:

- Large-scale distributed anomaly, fault, malfunction, degradation, and failure detection with data/decision/information fusion (multiple sensors, actuators, and processing nodes);
- Prevention, detection, isolation, and mitigation of multiple independent/correlated anticipated and unanticipated failures (modeling of correlated failures and system/vehicle effects, diagnosis and prognosis, real-time processing and decision-making for very large state spaces, and health state reasoning);
- Adaptive diagnostic and prognostic algorithms (adapts as systems and components age, are repaired, or replaced);
- Analytical methods to set local decision criteria so that global performance criteria are met (multi-dimensional optimization);

- Performance optimization in distributed systems (high probability of detection, low probability of false alarm);
- Vehicle-wide state and function monitoring of systems and structures (including digital avionics, auto-flight and control, propulsion, hydraulic, mechanical, pneumatic, electrical, and power generation and distribution systems);
- Large-scale distributed adaptive fault-tolerant processing architecture that is robust in adverse operating environments (EMI/EMC, ionizing radiation, low/high temperatures);
- Distributed hierarchical threat-tolerant self-healing embedded sensors and systems (embedded self-recovery mechanisms, adaptive, programmable and reconfigurable devices);
- Technology integration, verification, and validation (diagnostic and prognostic flight, airframe, and propulsion systems, environmental hazard management, advanced sensors and system architectures, V&V with predictive capability).

Technologies may take the form of tools, models, algorithm, prototypes, and devices.

TOPIC: A2 Fundamental Aeronautics

NASA is the Nation's leading government organization for civil aeronautical research. Within NASA's overall strategic plan Aeronautics has the goal to "Advance knowledge in the fundamental disciplines of aeronautics, and develop technologies for safer aircraft and higher capacity airspace systems." To address this goal NASA's Aeronautics Research Mission Directorate (ARMD) is organized into three separate Programs: Fundamental Aeronautics, Aviation Safety, and Airspace Systems.

The Fundamental Aeronautics Program is dedicated to the mastery and advancement of core aeronautics technologies across all flight regimes. NASA intends to invest broadly and deeply in these core competencies to produce knowledge, technology, and tools that are applicable across a broad range of air vehicles. The program encompasses cutting-edge, fundamental research in traditional aeronautical disciplines, as well as emerging fields with promising application to aeronautics. The overall program is long-term in scope as well as focused and integrated across disciplines. It is implemented through NASA's four research centers: the Ames Research Center, in Mountain View, California; the Dryden Flight Research Center in Edwards, California; the Glenn Research Center in Cleveland, Ohio; and the Langley Research Center in Hampton, Virginia.

To achieve these objectives NASA has defined a four-level approach to technology development: (1) conduct foundational research to further our fundamental understanding of the underlying physics and our ability model that physics, (2) leverage the foundational research to develop technologies and analytical tools focused on discipline-based solutions, (3) integrate methods and technologies to develop multi-disciplinary solutions, and (4) solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration.

The Fundamental Aeronautics will provide for results yielding the following:

- Technology innovation and integrated, multidisciplinary analysis tools;
- Rapid evaluation of new concepts and technology;
- Accelerated application of new technology to a wide array of vehicles;
- Reduced environmental impact and increased public benefit of future aircraft: lower emissions, less noise, higher efficiency, and safer operation.

Structurally, program is composed of four focused thrust areas: hypersonic flight, supersonic flight, subsonic fixed-wing aircraft and subsonic rotary-wing aircraft. Each thrust area, in turn, addresses specific discipline, multi-discipline, sub-system and system level technology issues relevant to that flight regime. However, 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 Fundamental Aeronautics subtopics are organized by discipline, not by flight regime, with a special subtopic for rotary-wing issues. The full list of Fundamental Aeronautics subtopics are: (1) Materials and Structures, (2) Combustion, (3) Acoustics, (4) Aeroelasticity, (5) Aerodynamics, (6) Aerothermodynamics, (7) Control and Dynamics, (8) Experimental Capabilities and Flight Research, (9) Systems Analysis, Design and Optimization, and (10) Rotorcraft.

Each of the subsequent subtopic sections will describe the scope, key issues and technical content of the subtopic. It will also include the specific areas of interest spanning the four flight regimes. Individual proposals are not restricted to any one specific technical area or any single part of the full flight regime. They may address any or all areas included in a subtopic and may cover any or all parts of the entire flight regime.

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 research thrusts to enable the design and development of advanced future aircraft. In general, technologies of interest that cover the four research thrusts (Subsonic Fixed Wing, Subsonic Rotary Wing, Supersonic, Hypersonic) include: fundamental materials development and characterization, multifunctional materials and structures development, structural health monitoring and damage assessment science, validated structural analysis tools, and computational materials development tools. More specific information on materials and structures technologies of interest in this program is given below.

Proposals are sought that address specific design and development challenges associated with airframe and propulsion systems and directly support improvements to future subsonic fixed wing aircraft. The potential impact of the proposed technologies should be linked to improvements in aircraft performance indicators such as vehicle weight, noise, lift, drag, lifetime, and emissions. Specific technology areas where contributions are sought include, but are not limited to the following:

- Advanced materials design concepts and processing development (e.g., multifunctional materials concepts, innovative approaches to damage tolerant lightweight structural materials, lightweight materials concepts to mitigate lightning strike damage, hybrid materials approaches to multifunctionality and/or improved durability and damage tolerance, and high-temperature materials for propulsion system applications);
- Design methods for material and structural concepts (in particular, multifunctional concepts) including variable fidelity methods, uncertainty based design and optimization methods, multi-scale computational methods, and multi-physics modeling and simulation tools;
- Adaptive materials and structures concepts (e.g., environmentally responsive materials and structures, intrinsically load/strain sensing materials and structures, active and/or highly flexible structures, shape memory and self-healing materials, innovative non-parasitic in situ methods to detect damage, impact and structural dynamics);
- Concepts and techniques for advanced multifunctional and/or adaptive material and structures characterization and evaluation (including combinations of thermal and mechanical loading environments);
- Identification, development and verification of degradation and failure mechanisms/criteria, residual strength (and other critical residual properties) and life prediction methods, and damage science design and analysis methods;
- Advanced materials fabrication and processing methods and joining and assembly methods, for ceramics, metals and polymers and/or hybrids of these materials;
- Tribological surface sciences, and mechanical components including oil-free bearings and seals technologies.

Supersonics aircraft require durable and reliable materials and structures to provide continuous operation at speeds in excess of Mach 2. Specific technology areas where contributions are sought include:

- Oxidative fail-safe CMC, CMC structures for liners and airfoils;
- Advanced engine containment prediction tools;
- High temperature shape memory alloys;
- Accelerated life prediction tools;
- Rapid design methods for aircraft structures;
- Novel hot acoustic absorber technologies are also of interest to address the sound problems with supersonic flights.

The ultra-high temperatures experienced by a hypersonic vehicle, coupled with storage challenges of advanced fuels requires advanced materials and structures technologies to enable safe reliable operation of the vehicles. Specific technology areas where contributions are sought include:

- Probabilistic design and lifing methods for high and cryogenic temperature materials;
- Design database development, structural joining techniques and characterization methods for advanced materials;
- Impact models for high and cryogenic temperature materials;
- Structurally integrated multifunctional thermal protection systems;
- Identification, development and verification of environmental and mechanical degradation and failure mechanisms, failure criteria, other design critical properties;
- Physics-based life prediction methods for advanced high temperature composites coupled with damage tolerant design and analysis methods;
- Computational materials development tools for durable high temperature materials;
- Development of composite material systems and coatings for significantly improved hypersonic environmental durability for increased mission lifetime;
- Development of durable structural sensor technology for extreme environments;
- Advanced thermal control structural and material systems through techniques to improve vehicle safety and decrease weight resulting from combined thermal and structural loads;
- Oxidation modeling;
- Modeling of high temperature composite structures manufacturing.

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

Combustion research will be 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 multiphase, 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 interest where research is solicited but is not restricted to includes:

- Validation data sets at appropriate conditions that can be used for physics-based model development;
- Detailed and reduced chemical kinetics mechanisms for practical fuels under rich and lean conditions for combustion calculations;
- Large Eddy Simulation submodels for reacting, multiphase flow simulations under realistic operating conditions;
- Turbulence-chemistry interaction models and validation data;
- Development of laser-based diagnostics and novel experimental techniques for measurements in reacting flows;
- Two-phase flow simulation models including liquid breakup and vaporization under subcritical and supercritical conditions;
- Combustion instability modeling and validation;
- Novel combustion simulation methodologies;
- Novel low emissions combustion concepts that enhance the state of the art in subsonic combustors;
- Active combustion control including high frequency actuators and sensors;
- Reformer technology and catalyst development for the processing of aviation fuels;
- Novel low emissions concepts suitable for low emissions operation at supersonic cruise conditions;
- 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.

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 (fan, jet, combustor, or turbine noise) and airframe (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: ARC
Participating Center(s): DFRC, GRC, LaRC

The NASA Fundamental Aeronautics program has the goal to develop system-level capabilities that will enable the civilian and military designers to develop revolutionary systems, in particular by integrating methods and technologies to develop 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.
- Development of unique control concepts 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.

Flight regimes of interest in the Fundamental Aeronautics program include subsonic, supersonic, and hypersonic. The goal of the program is to develop validated physics-based multidisciplinary design, analysis, and optimization tools, integrated with technology development. Topics of interest include (but are not limited to) the following:

- Structure-induced noise, flutter and dynamic response prediction, stiffness and strength tailoring, propulsion-specific structures, quasi-static aeroelasticity. Fluid-structure interaction, validation methods, data processing and interpretation methods, probabilistic modeling, rapid modeling analysis development, nonlinear 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. Stiffness and strength tailoring and actively controlled propulsion system core components (e.g. fan and turbine blades, vanes). High fidelity unsteady aeroelastic capability which utilize current and future computer capabilities effectively. Advanced turbomachinery active damping concept. Rapid, high-fidelity probabilistic aeroelastic modeling capability.
- Physics-based models for turbomachinery aeroelasticity related to highly separated flows, shedding, rotating stall, non-synchronous vibrations (NSV). Robust, fast-running, accelerated convergence, reduced-order CFD approaches to turbomachinery aeroelasticity for propulsion applications. Blade vibration measurement systems including closely spaced modes, blade-to-blade variations (mistuning) and system identification. Blade damping systems for metallic and composite blades, including passive and active damping methods.
- Aeroservoelasticity, including alternative control architectures, development and testing of control law concepts. Integrated tool set for fully coupled modeling and simulation of aeroservothermoelasticity / flight dynamic (ASTE/FD) and propulsion effects. Development of CFD-based methods (reduced-order models) aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, and flutter issues. Fast and accurate aeroelastic analysis methods to predict fan/compressor flutter vibrations in the presence of the inlet and neighboring blade rows. Vortical effects and nonlinear unsteady aerodynamics influence on the aeroelastic/ASE response of supersonic configurations.
- Lightweight structures under aerodynamic loads, with emphasis on aeroelastic phenomena in hypersonic domain. 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 with an emphasis on the development of novel, practical, lightweight, low-energy actuators;
- Wake decay models capturing the relevant physics into the near, mid, and far fields;
- 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: ARC
Participating Center(s): DFRC, GRC, LaRC

The accurate prediction of aerothermal environments is of crucial importance for meeting current goals of subsonic, supersonic and hypersonic thrust areas as well as supporting future missions of NASA by reducing uncertainties in design and development. Development of highly accurate tools to predict aerothermal environments and associated effects on vehicles is needed to enable advanced spacecraft for future missions.

Radiative heating has not been a critical issue for the Space Shuttle Orbiter due to its relatively low reentry velocities on the order of 7.5 km/s, or for other entry probes such as Genesis and Stardust due to their small sizes. However, the Crew Exploration Vehicle’s large size and high reentry velocities of approximately 10.5 km/s during lunar return missions make it imperative to study the phenomenon of shock layer radiation. Aerocapture missions to Titan, Neptune, and Venus also require the study of radiative heat transfer as well as of the internal structure and dynamics of the constituent gases.

Transition and turbulence effects are particularly complex in hypersonic flows because of the presence of shocks, real gas effects, non-smooth body surfaces with difficult-to-quantify roughness distributions, effects of nose bluntness, ablation, surface catalyticity, separated flows, and an unknown free-stream disturbance environment.
At heating rates encountered during hypersonic re-entry, the surface is ablating and the interaction of ablation products blowing into the boundary layer induces new interactions (chemical reactions, radiation absorption) that have strong impacts on surface heating rates and integrated heat loads.

Aerothermal analyses and management are furthermore relevant to the design of advanced propulsion systems. The isolators and nozzles in both rocket-based and turbine-based combined cycle engines are critical components of future reusable hypersonic vehicles.

Major research and technological advances are required in order to develop Ultra-High Bypass Ratio engines and high power density cores. A better fundamental understanding coupled with the ability to accurately simulate the aerothermodynamics of highly loaded turbomachinery is needed, along with innovative ideas such as flow control for increasing fan and compressor work factors without sacrificing efficiency and operability. Improvements in turbine cooling effectiveness, secondary flow, and component matching are also important for high-pressure ratio engines.

Research areas of interest include, but are not limited to, the following:

- Computational methodologies for the analysis of radiation and its transport in the shock layer surrounding planetary entry vehicles;
- Advanced physics-based thermal and chemical non-equilibrium chemistry models;
- High-order accurate numerical methods and multi-scale models for Large Eddy Simulation of hypersonic transition and turbulence;
- Efficient implicit algorithms for the solution of stiff systems like those generated by high-order discretization methods;
- Studies of the interaction of gases in the shock layer with the ablating material making up the thermal protection system of the vehicle;
- Software tools for coupling radiation, non-equilibrium chemistry, Reynolds-averaged Navier-Stokes, and large eddy simulation codes to enable the design, development, and validation of mission configurations for entry into planetary atmospheres;
- Experiments and diagnostics to understand the characteristics of hypersonic flow fields, either in flight or in ground-based facilities;
- Computational and experimental technologies for the accurate prediction of combined cycle phenomena such as shock trains in isolators, inlet unstart, and thermal choke;
- Computational modeling to improve the accuracy of flow simulations for highly loaded turbomachinery;
- Innovative flow control methods, such as aspiration and bleed to reduce the losses associated with highly loaded turbomachinery;
- Assessment of the capabilities and deficiencies of currently available thermodynamics models and codes for the development of new physics based models;
- Development of active flow control devices such as Dielectric Barrier Discharge plasma actuators for application to turbomachinery flow control.

A2.07 Aircraft 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 of dynamic modeling and flight/propulsion control. 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, 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. 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, 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:

For 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;

developing and applying innovative control methods and validating them through laboratory test and vehicle simulations as appropriate.

For supersonic flight, the technologies of interest include: methods for developing integrated dynamic models and simulation including flexibility effects and suitable for control design; novel control design methods for integrated aero-servo-elastic-propulsive 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 forebodies; integrated inlet/engine control to ensure safe (no inlet unstart) and efficient operation.

For hypersonic flight, the 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 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 mis-specification.

A2.08 Experimental Capabilities and Flight Research
Lead Center: DFRC
Participating Center(s): LaRC

Advances to the state of the art in both Experimental Capabilities and Flight Research are needed to support almost every aspect of the Fundamental Aeronautics programs under development in NASA. These tools will be used to generate experimental data for the creation and validation of advanced prediction models, as well as evaluate advanced concepts, both in the laboratory and in suitable facilities (e.g. wind tunnels, flight tests, etc.). New measurement techniques capable of measuring transient phenomena are needed to support acoustic noise model validation and turbulence measurements. Developing sensors capable of measuring environments in harsh environments (e.g. inside engines) are needed to support intelligent engine design. Proposals are sought for new flight testing technologies and capabilities in order facilitate evaluation of concepts at true flight conditions. More specific examples of research in this area are listed below.

Experimental Capabilities
Innovative technologies are sought that will advance current experimental capabilities and develop new measurement techniques to support other areas of Fundamental Aeronautics. These techniques will not only support traditional aeronautic measurements in wind tunnels, but also development of advanced concepts in areas such as structures and materials and propulsion design. Current experimental techniques are highly effective at measuring parameters under highly controlled conditions found in traditional wind tunnels and test chambers. What is necessary to support advanced designs is the ability to make continuous field, time-resolved measurements under conditions which are difficult to control. It is also highly desirable to reduce the setup and calibration effort associated with experimental measurement techniques. Some examples of research interests in this area may include but are not limited to:

- New capabilities for the assessing the properties of advanced lightweight materials under relevant flight loads combining mechanical, thermal, and pressure loads;
- Development and applications of novel high temperature MEMS sensors based on silicon carbide technology;
- Advanced testing techniques to address such phenomena as icing and scaling effects in wind tunnels;
- Development of high temporal resolution optical diagnostics (such as Particle Imaging Velocimetry) capable of operating at frequencies up to 50 kHz;
- Development of advanced videogrammetric systems capable of characterizing the 3D shape of aerodynamic surfaces with high data acquisition rates and increased precision.

Flight Research
The Flight Research area solicits innovative flight research experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment. This includes both test techniques and subsystems that will make flight research easier to achieve, as well as innovative vehicle system concepts at low maturity levels. The emphasis of this subtopic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and may require a demonstration or validation in an actual flight environment to fully characterize or validate it. Some examples of research interests in this area may include but are not limited to:

- Inflatable aero-structures;
- Innovative control surface-effectors;
- Innovative engine designs for UAVs;
- Noise reduction for Conventional Take-off and Landing/Short Take-off and Landing (CTOL/STOL) aircraft and engines;
- Aerodynamic systems optimization for planetary aircraft;
- Flexible system stability derivative identification;
- Innovative approaches to thermal protection that minimize aerodynamic performance degradation;
- Innovative approaches to structures, stability, control, and aerodynamics integration schemes;
- Innovative approaches to incorporation of UAV operations into commercial airspace.

This subtopic is intended to advance and demonstrate revolutionary concepts and is not intended to support evolutionary steps required in normal product development. Proposals should emphasize the need of flight research on a concept or technology as a necessary means of verifying or proving its worth; emphasis should also be given to multidisciplinary integration of advanced flight systems. The benefit of this effort will ultimately be more efficient aerospace vehicles, increased flight safety (particularly during flight research), and an increased understanding of the complex interactions between the vehicle or technology concept and the flight environment.

A2.09 Aircraft Systems Analysis, Design and Optimization
Lead Center: ARC

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.

Analyses 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 (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.

A2.10 Rotorcraft
Lead Center: ARC
Participating Center(s): DFRC, 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. Examples of technologies of interest are as follows.

Propulsion/Aeromechanics Integration: Encompassing dynamic and aerodynamic integration of rotorcraft. Including advanced configurations such as rotors operating at different speeds in hover and cruise (variable speed transmission/engine), high speed rotorcraft, and heavy lift rotorcraft. Possibly including on-blade active rotor control, or flow control for hub, blades, or engine inlet.

Super-Integrated Vehicle Management System: Integrated, broadband rotorcraft control system incorporating flight control system, engine control, airframe/drive train/rotor load control, active rotor control of vibration and noise, vehicle health management, and guidance for low noise operation. Including control design methodology development.

Integrated Rotorcraft Design: Advanced light weight structural and propulsion concepts with integrated functionality to achieve reduced interior noise, vibration, and maintenance/inspection requirements Includes gear vibration transmission through the gear/shaft/bearing/structural system and structural bonding techniques that increase fatigue life while allowing for post-bucking load capability for thin sheet sandwich construction.

Integrated Rotorcraft Design: Interactional aeroacoustics, encompassing dynamic, aerodynamic, aeroacoustic interactions of one or more main rotors, tail rotors, airframe, wings, empennage, engine, drive system. Possibly including active flow control for hub or fuselage drag reduction, or active rotor control.

Integrated Experimental Systems: Unified experimental techniques, integrating methods to enable efficient, multi-parameter, simultaneous measurements for characterizing rotorcraft behavior. Including unsteady pressure, blade deformation and position, flow field measurements, measurements that track wake vortex strength and position.

Examples of rotorcraft unique aspects of the aeronautics disciplines are as follows.

Materials and Structures: Advanced light-weight structural concepts exploiting material hybridization, selective reinforcement and material and geometric tailoring to achieve increased performance and durability while reducing weight, cabin noise and manufacturing cost, with emphasis on structural concepts for high oscillatory load environment of rotorcraft structures. Characterization of composite material properties under impact loading and models of impact damage. Characterization and simulation of fatigue damage in composite materials, crack/delamination growth models for spectrum loading, and high cycle fatigue thresholds, in particular for unique design and operational aspects of structures for rotor blades.

Propulsion: Research is solicited to improve rotorcraft propulsion and the ability to design and predict its performance in the following general areas:

Propulsion system (drives, engines, controls) technologies to enable variable speed rotor systems. Specific focus areas may include: enabling concepts and techniques for wide operability propulsion systems and variable speed drive systems/transmissions. Engine compressor stall control, engine flow control concepts for wide operability, cooling and secondary flow concepts for wide operability and integrated controls and modeling to support wide operability are sought. In addition, concepts for controlling and enabling variable speed drives, lightweight technologies and concepts and performance prediction capabilities for variable speed systems are sought.

Gearbox optimized propulsion systems in which both the engine and drive systems work together for improved performance. Specific concepts may include: dedicated gearbox lube systems coupled with oil-free engines; technologies to predict drive system windage losses and gear surface fatigue modeling; technologies to achieve lightweight propulsion such as composite propulsion structures and components; high power density electromechanical systems and efficient high power density propulsion concepts such as highly loaded components; engine flow control concepts; high temperature components; nano-composite components and other relevant propulsion system technologies. Propulsion system concepts must be focused on power range and operating environment required for rotorcraft.

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.

Aeroelasticity and Dynamics: Advanced rotorcraft hub and blade concepts for improved stability and loads capability. High-fidelity, first-principles approaches to rotorcraft stability calculation, including finite state and reduced order aerodynamic modeling approaches. Vibration reduction methods and techniques, including utilization of on-blade active control, individual blade control, or nonrotating frame active and passive means.

Aerodynamics: Airloading of rotor blades, including unsteady, compressible, viscous flows and blade-vortex interaction; stall and dynamic stall; rotor wake formation, propagation, dissipation, and interactions; rotor wake geometry. Aerodynamics of rotorcraft airframes, including rotor hubs, airframe drag, rotor-airframe-wing interactions of tiltrotors and compound configurations. Performance, including force and power of isolated rotors and of rotorcraft systems with influence of interactions between components. Behavior of rotors and rotorcraft in maneuvers and high speed flight, and advanced configurations heavy lift and slowed-rotor rotorcraft. Advanced computational fluid dynamics methods, including turbulence behavior unique to rotary wings.

Flight Dynamics and Controls: Rotorcraft flight dynamics and handling qualities. Including hover and low-speed guidance and situational awareness augmentation; autorotation control and guidance; variable-speed rotor control; low-cost low-speed air data system; improved simulation of low-visibility conditions (brownout, whiteout); control concepts for redundant effectors; affordable tactile cueing for retrofit into civil rotorcraft; study of redundancy/reliability required to achieve low-cost single-pilot IFR certification; continuously-variable transmission (current technology is focused on discrete-speed, transmission, but continuously-variable is highly desirable; flight control mitigation of structure/power train/rotor frequency overlap with primary control frequencies; proprotor control to provide helicopter-like response in heave for tiltrotor helicopter-mode operations.

Experimental Capabilities: Instrumentation and techniques for assessing scale rotor blade boundary layer state (laminar, transition, turbulent) and/or profile in simulated hover and forward flight conditions, measurement systems for large-field rotor wake assessment, instrumentation and techniques to measure dynamic boundary layer transition on the fixed system (fuselage) during scale model wind tunnel testing, multi-parameter temporally-resolved flow diagnostic techniques for wind tunnel testing of model-scale rotors and engine acoustic testing, fast time response pressure sensitive paints, alternatives to conventional slip rings (e.g. optical slip rings, reliable telemetry methods), high temperature and pressure sensors for engine applications, high temperature proximity sensors for turbine blade clearance measurements, sensors and/or methods for high accuracy rotorcraft velocity measurement in very low speed forward flight (< 30 knots), instrumentation and methods to measure the rotor tip path plane angle of attack, lateral and longitude flapping, and shaft angle in flight. Low-speed (0-30 knots) velocity measurement for flight test vehicles that tracks, measures, and displays vehicle ground speed while the aircraft travels in any direction, including backwards and sidewards flight. Non-contacting cockpit measurement of collective and cyclic control input.

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). The NGATS vision calls for a system-wide transformation leading to a new set of capabilities that will enable the system to respond to future needs of the nation for air transportation. 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. The NGATS concept for 2025 envisions the safe, efficient, reliable, and secure movement of large numbers of people and goods throughout the air transportation system. It is a system founded on an underlying set of operating principles. Central to these principles is the requirement for a system-wide transformation involving change in organization, as well as culture and policy to assure that the system meets the requirements of the user. The NGATS will provide cost-effective services that are responsive to changing user needs. The system will be designed for environmental compatibility and global interoperability. The major technical challenges are to:

- Accommodate projected growth in air traffic while maintaining safety;
- Provide all airspace system users more flexibility and efficiency in their utilization of airports, airspace, and aircraft classes;
- Reduce system delays; and,
- Enable new modes of operation that support the transition to NGATS operations in a continually evolving technical environment.

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.

The AS program integrates two projects: NGATS-Airspace and NGATS-Airportal.

A3.01 Next Generation Air Transportation System – Airspace
Lead Center: ARC
Participating Center(s): DFRC, LaRC

The primary goal of the NASA Next Generation Air Transportation System (NGATS) 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 NGATS-Airspace effort. The general areas of primary interest are Dynamic Airspace Configuration, Traffic Flow Management, and Separation Assurance. Specific research topics for NGATS-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 Next Generation Air Transportation – Airportal
Lead Center: LaRC
Participating Center(s): ARC

The airportal research of NASA's Airspace Systems (AS) Program focuses on key capabilities that will increase throughput of an airport runway complex and achieve the highest possible efficiencies in the use of airportal resources such as runways, taxiways, terminal airspace, gates, and aircraft servicing equipment. The primary capabilities addressed are: (1) Super-density operations, (2) Equivalent visual operations, and (3) Aircraft trajectory-based operations.

Super-density operations will entail reduced aircraft wake vortex separation standards and less restrictive runway/taxiway operations.

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.

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.

NASA's AS Program has identified the following Next Generation Air Transportation System (NGATS) Airportal research activities: Optimization of surface traffic; Dynamic airport configuration management; Advanced technologies to detect and avoid wake vortex hazards; New procedures for performing safe, closely spaced and converging approaches at closer distances than are currently allowed; and Modeling, simulation, and experimental validation research focused on single and multiple regional airports. Inherent within the AS Program approach is the integration of wake vortex 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 NGATS-Airportal effort. The general areas of primary interest are Surface Management Optimization and Wake Vortex Hazard Solutions. Specific research topics for NGATS-Airportal include:

- Airborne spacing algorithms and wake avoidance procedures for airports with closely spaced runways;
- All-weather wake vortex sensors (includes sensor/data processing innovations and basic physics of wake vortex sensing);
- 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 air traffic control tower personnel for optimized surface operations, including push back scheduling and management of airport surface assets;
- Dynamic airport configuration management;
- "Evaluator" integrated solutions for airportal management functions over multiple planning intervals;
- High resolution CFD and real-time modeling of wake vortex strength and location;
- High resolution measurement and/or prediction of terminal area atmospheric profiles (includes sensor and data processing innovations, weather forecasting, and the potential use of aircraft as sensors);
- Human/automation interaction and performance standards;
- Integration of decision-support tools across different airspace domains;
- Methodologies and/or algorithms to estimate environmental impacts of increased traffic on the surface and in the terminal airspace;
- Modeling and simulation of single airport operations for validating taxi planning concepts;
- Optimized 4D trajectory generation and conformance monitoring for surface and terminal airspace operations, including departure and arrival planning for individual flights;
- 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 towers;
- Wake vortex alleviation/mitigation technologies.

TOPIC: A4 Aeronautics Test Technologies

NASA has implemented the Aeronautics Test Program (ATP) within its Aeronautics Mission Directorate. The purpose of the ATP is to ensure the long term availability and health of the large aeronautics ground test facilities 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, Glenn Research Center and Langley Research Center. Classes of facilities within the ATP include low speed wind tunnels, transonic wind tunnels, supersonic wind tunnel, hypersonic wind tunnels, hypersonic propulsion integration test facilities, and air-breathing engine test facilities. A key component of ensuring a ground 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-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 to help in achieving the ATP goals of sustaining and improving our ground 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 ground test facilities.

A4.01 Test 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. By using state-of-the-art test measurement technologies and novel means of acquiring test data, 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. 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. Therefore, NASA is seeking highly innovative and commercially viable test measurement technologies that would increase efficiency or overcome research and development technology barriers for ground test facilities.

The first 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 data acquisition system improvements, skin friction experimental measurement techniques, and improved flow transition detection methodologies.

The second emphasis for this subtopic is a specific area of test measurement technology: instrumentation. Instrumentation examples include new or novel, non-intrusive measurement technologies for pressure, temperature, and force measurements; and force measurement (balance) technology development. 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 high ice water content conditions in an icing wind tunnel.

Proposals that lead to products or processes that are useful 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 Test Techniques and Facility Development
Lead Center: GRC
Participating Center(s): ARC, LaRC

NASA is concerned with continually improving on the efficiency and effectiveness of operation of its ground test facilities. NASA strives to operate its facilities in such a way as meet the requirements of the NASA research and development efforts into new and novel means of removing barriers to safe and efficient flight and to the exploration of space. To do so requires the use of state-of-art test techniques and creative facility performance capability enhancements. NASA is seeking highly innovative and commercially viable test techniques and facility performance technologies that would increase efficiency and effectiveness or overcome research and development technology barriers for ground test facilities.

Solutions are being sought in the areas of improvements in facility performance capabilities, e.g., expanded operating envelope, and enhanced or rapid characterization of facility performance. Solutions are also sought that are facility specific. Examples of facility specific projects include:

- Improved dynamic (forced oscillation) test capability at transonic and supersonic speeds;
- Improved flow transition detection methodologies;
- Modeling and simulation of high ice water content conditions.

The above are listed as examples only and should not be interpreted as the only areas of test technique and facility development innovative research proposals being sought.

Proposals that lead to products or processes that are useful 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.

9.1.2 EXPLORATION SYSTEMS

The Exploration Systems Mission Directorate aims to develop a constellation of new capabilities, supporting technologies, and foundational research that enables sustained and affordable human and robotic exploration. In order to support this complex mission, the directorate has been organized into eight overarching divisions: the Office of Research, Development Programs Office, the Office of Mission Integration, Acquisition and Mission Support, the Contracts Division, Requirements Division, the Office of Communication, and the Administration Office. Within these offices are numerous subdivisions integral to the objectives of ESMD, including Constellation, Exploration Systems Research and Technology, Prometheus Nuclear Systems and Technology, Human Systems Research and Technology, and more.

http://www.exploration.nasa.gov

TOPIC: X1 Systems Analysis and Integration

Definition of large, complex systems requires an understanding of system performance, cost and risk during each of the system's lifecycle phases (i.e., design, development, testing, deployment and operations). Accurate representations of the system's: (1) functional and physical interfaces are required to facilitate the analysis, design, and integration of the system and its elements; (2) costs, operational plans, and risks are required to balance the programmatic aspects of the system; and (3) performance projections and margins are required to understand payload options. Achieving an understanding of these complex interactions requires the development, analysis and refinement of models and simulations (M&S) across the lifecycle of the system in order to support a variety of analysis activities. Models currently being developed for Exploration Systems and Space Operations are categorized as subjective, constructive, operator-in-the-loop, hardware- and software-in-the-loop, and in-service operations. These models and simulations are used to address requirements generation, design definition, verification of requirements, testing and sustaining engineering. SBIR Topic X1 is aimed at addressing pressing issues that are still lingering in the area of analysis and M&S. Data required to perform analysis and execute models/simulations must be consistent, valid and cohesive across the analyses. Approaches to dealing with analysis data management and manipulation through the lifecycle are sought. The integration of cost and risk models early in the lifecycle of a system's analyses must be achieved to ensure that programmatic factors drive our plans. Modeling and simulation is key to achieving NASA's vision by providing the data required for early key decision-making.

X1.01 Full Data Coherency Systems for Engineering Systems Modeling and Simulation
Lead Center: MSFC
Participating Center(s): ARC, GRC, JPL, LaRC

In addressing the accuracy of analysis results, which are used to make program/project decisions, we typically assess the data, the models/simulations, and the analysts. This subtopic area will address the first of these concerns. Verification and validation approaches typically address the validity of the data used to perform the analysis. However, they do not address the issue associated with data cohesiveness and consistency. An issue in the development of integrated modeling/simulation for complex engineering systems arises when information is fed to the models with inconsistent coherency, where "coherency" is defined as appropriate versions, semantics/syntax, abstraction/resolution, and sequence. When, for example, serial/parallel simulations are run with revised input data from one source, other sources may or may not need to be held constant; similarly, input data of varying heritage, semantics, resolution, etc., may result in unexpected and inaccurate simulations. Proposals are sought for systems that manage full data coherency (not just version or sequence control) in modeling and simulation environments.

X1.02 System Lifecycle Integration of Cost and Risk Models
Lead Center: MSFC
Participating Center(s): ARC, GRC, LaRC

Traditional, and at times typical, analysis of new systems involves an assessment of the system's performance independent of the cost and risk associated with the design. Specifically, the cost and risk are assessed after the design, requiring integration "after the fact". The SE&I process, however, requires a balancing of cost, risk and performance throughout a system's lifecycle. An additional challenge associated with this subtopic area is the use of cost and risk techniques early in the design process where there exists little data (i.e., performance, cost, and risk) from which to draw upon for developing the cost/risk algorithms, associated relationships, and verification/validation artifacts. An approach for integrating cost and risk models early in the assessment, ensuring that they drive the design and not vice-versa, is required to address the challenges in the agency. Proposals are sought to address: (1) the integration of cost and risk models into a seamless integrated solution; (2) the early application of cost and risk modeling into the analysis cycle of a system; and (3) the approach to verification and validation of the integrated cost/risk models.

TOPIC: X2 Avionics and Software

The Exploration Systems Avionics and Software Topic focuses on the technologies, systems, and software that will enable the Vision for Space Exploration to achieve its goals. Integrated system health management technologies to track the state of spacecraft and instruments; spacecraft autonomy capabilities to enable greater operational flexibility and support dynamic missions for exploration vehicles and habitats; robust software engineering technologies to take programming from an art to an engineering science; and the radiation hardened and low-temperature tolerant processing and avionics to enable the advance software to work in physically demanding environments.

X2.01 Integrated Systems Health Management
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, MSFC

In order to increase the safety and effectiveness of future spacecraft and launch vehicles, innovative health management technologies are required throughout the system lifecycle including design, development, test, validation, integration, operation, maintenance, and disposition. Traditional means of supporting vehicle health, such as invasive inspections, are extremely limited in their utility for exploration missions. Other solutions, such as ground-based monitoring of telemetry data, become less useful as communication delays or bottlenecks increase. Under these circumstances, autonomous and automated solutions to systems health management provide the best means of increasing crew safety and mission success probability for future space exploration missions.

Another significant concern is the high cost of ground and mission operations. Future ground operations will require quick and efficient turnaround and processing of spacecraft for launch. In addition, new mission operations concepts must be developed to provide appropriate levels of safety and mission success factors while reducing support staff.

Proposals should be responsive to the overall goals and objectives of NASA's Constellation and Lunar Precursor and Robotic Programs. Proposals may address specific vehicle health management capabilities required for exploration system elements (crewed spacecraft, launch systems, habitats, rovers, etc.). In addition, projects may focus on one or more relevant subsystems such as propulsion, structures, thermal protection systems, power, avionics, life support, and communications. Proposals that involve the use of existing NASA health management testbeds (power, propulsion, systems integration, life support, diagnostics, networking, etc.) for technology validation are strongly encouraged.

Specific technical areas of interest related to integrated systems health management include the following:

- Methods and tools to enable concurrent design of system function and health management systems. These methods and tools should provide a means to optimize health management system design at the functional level to decide on failure detection methods, sensor types and locations, and identify additional functionality to safeguard against failures before costly design decisions have been made.
- Health monitoring and management technologies for increased situational awareness of system health, safety, and margins. Of special interest are innovative methods for sensor validation, robust state estimation, and model-based methods for fault isolation. Proposals should focus on data analysis and interpretation rather than development of new sensors.
- Data-driven methods for detection of failure precursors and recognition of anomalous patterns in large data sets. A specific emphasis is on methods that utilize propulsion system data sets.
- Concepts for advanced built-in-tests for spacecraft avionics that reduce or eliminate the need for extensive functional verification. Methods for reducing or disambiguating false alarms on built-in-tests are also of interest.
- Methods for robust control of critical components, subsystems, and systems and robust execution of critical sequences during flight. Of special interest are robust recovery methods and innovative approaches to functional redundancy for the purpose of enhancing safety, availability, and maintainability.

- 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.
- Human-system integration methods that are capable of summarizing sensor readings, presenting system status, assessing spacecraft capability and mission readiness, and proposing corrective actions in a manner that does not exceed the capacity of human understanding, especially in high-risk situations requiring rapid human response. Innovative ways for the health management system to convey a wealth of information quickly and effectively are desired.

X2.02 Spacecraft Autonomy
Lead Center: ARC

Automation and autonomy techniques are key elements in realizing the vision for space exploration. Intelligent automation of systems on crewed vehicles is instrumental for decreasing workload, reducing dependence on Earth-based support staff, enhancing response time, and reducing operations cost. Increased system autonomy for un-manned and manned vehicles reduces operations costs, while increasing operations efficiency and spacecraft capability by reducing the time required for humans to staff flight control positions and interact with the vehicles. To enable the application of intelligent automation and autonomy techniques, configuration and validation issues need to be addressed.

Reusable automation software must be adaptable to new applications without undue difficulty, and easily adjusted as the application operations change. The overhead of applying automation techniques to new applications is one of the two key obstacles to acceptance of such techniques in operations. A variation of the same issue is that of adjustment as requirements and application contexts change, which is inevitable in spacecraft operations.

The software and the adaptation to a given application must also be trusted before it can be accepted. Testing and other techniques are keys to establishing such trust and ensuring the correct function of automation systems. However, in both testing and validation, the complexity of intelligent software has proven to be a major obstacle. This has led to trust and correctness issues being another key obstacle to adoption of intelligent automation systems in both unmanned, and most importantly, in crewed vehicles.

Proposals in this area should include autonomy and automation software architectures that facilitate adaptation and ensure correctness. Specifically, proposals in the following technical areas are of high interest:

- Architectures for decision-making and closed-loop control that can be adapted to new applications with minimal reliance on intelligent systems expertise;
- Methodology and techniques for adapting autonomy software to applications, as well as for reconfiguring the software in response to changes;
- Representation and reasoning techniques for specifying properties for application interfaces, operations flight rules and autonomy software behaviors, and for deriving overall properties for autonomy software applications.

X2.03 Software Engineering Technologies for Human-Rated Spacecraft
Lead Center: ARC
Participating Center(s): GSFC, JPL, JSC

The objective of this subtopic is to bring to fruition 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 (including NASA contractors) engineers, and not only specialists.

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. Ensuring that these capabilities are reliable, and can be developed and maintained affordably, will be challenging but critical to NASA's exploration objectives. Proposals should clearly indicate how the technology is expected to address the challenge of reliability and affordability. 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. Projects can address technology development and maturation that provide for the following and related capabilities:

- Automated software generation methods from engineering models that are highly reliable;
- Scalable verification technology for complex mission software, e.g., model-checking technology that addresses the 'state explosion' problem and static-analysis technology that addresses mission-critical properties at the system level;
- Automated testing that ensures coverage targeted both at the system level and software level, such as model-based testing where test-case generation and test monitoring are done automatically from system-level models;
- Technology for calibrating software-based simulators and test-beds against high-fidelity hardware-in-the loop test-beds in order to achieve dependable test coverage;
- Technology for verifying and validating autonomy capabilities including intelligent execution systems, model-based diagnosis, and ISHM;
- Software-based radiation fault tolerance for computation;
- Methods and tools for development and validation of autonomic software systems (systems that are self protecting and self healing).

X2.04 Low Temperature, Radiation Hardened Avionics
Lead Center: MSFC
Participating Center(s): GSFC, JPL

Moon equatorial regions experience wide temperature swings from -180°C to +130°C during the lunar day/night cycle, and the sustained temperature at the shadowed regions of lunar poles can be as low as -230°C. Mars diurnal temperature changes from about -120°C to +20°C. All exploration endeavors, including robotic, habitat, and ISRU systems that are expected to reliably operate on the Moon or Mars surface for years will need electronics that are able to survive and operate in a wide temperature range and thermal-cycling environment. In addition, the electronics must operate reliably after a total ionizing dose (TID) >/= 50 krads (Si) and provide single-event latchup immunity (SEL) >/= 100 MeV cm^2/mg. The lunar and Martian temperatures are well outside the specification range of military and commercial electronics. While many types of devices, especially Si CMOS transistors, can operate down to low temperatures, there are significant circuit design challenges that need to be addressed, especially in the case of mixed-signal and analog circuits.

In addition, thermal cycling present in lunar and especially Mars environments introduces reliability concerns associated with mechanical stress and fatigue of the IC package. For example, compounds optimized for Earth-like packaging of electronic systems have glass transition temperatures that are within the cycling range of these environments, and cycling of electronic systems packaged using these materials will likely result in package failures. Hence, the choice of packaging technology and material combination used is extremely critical for these missions.

Proposals are sought in the following specific areas:

- Wide temperature (-180°C to +130°C) and low-temperature (-230°C), radiation-tolerant and SEL immune, low power, mixed-signal circuits including analog-to-digital converters, digital-to-analog converters, low-noise pre-amplifiers, voltage and current references, multiplexers, power switches, microcontrollers, and integrated command/control/drive electronics for sensors, actuators, and communications transponders.
- High-density packaging able to survive large numbers of thermal cycles (hundreds) and tolerant of the extreme temperatures of the Moon and Mars, including appropriate selection of packaging materials combinations (substrates, die-attach, encapsulants, etc.) modular system level electronics packaging, including power, command and control, and processing functions, enabling integration of electronics with sensors and actuators elements.
- Radiation-tolerant, SEL immune, wide temperature (-180°C to +130°C), and ultra-low temperature (-230°C) RF electronics for short range and long-range communication systems.
- Computer Aided Design (CAD) tools for predicting the electrical performance, reliability, and life cycle for low-temperature electronic systems and components.
- Physics-based transistor device models valid at temperature ranging from -230°C to +130°C to enable design, verification and fabrication of custom low power mixed-signal and analog circuits.
- Low-temperature (-230°C) circuit design methodologies facilitating novel layout designs for integrated mixed-signal and analog circuits.

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.

TOPIC: X3 Environmental Control and Life Support (ECLS)

Environmental Control and Life Support (ECLS) encompasses the process technologies and equipment necessary to provide, monitor, and control a livable environment within a crewed spacecraft or surface habitat cabin. Functional areas of interest to this solicitation include atmospheric management; atmosphere revitalization and water recovery systems; waste management; habitation systems including crew accommodations; fire protection systems; and environmental monitoring. Technologies are needed for crewed space exploration missions supporting the Vision for Space Exploration with emphasis on missions to the lunar surface, including short duration lunar sortie missions and long duration lunar outpost. Vehicles of interest include the Lunar Surface Access Module (LSAM) and Lunar Outpost (LO). Special emphasis is placed on development of technologies that will fill existing gaps, have a significant impact on reduction of mass, power, volume and crew time, and increase safety and reliability.

X3.01 Spacecraft Cabin Atmospheric Management and Habitation Systems
Lead Center: JSC
Participating Center(s): ARC, GRC, JPL, KSC, MSFC

Atmospheric management and habitation systems supporting critical needs for lunar mission architectures are requested. Vehicles and habitats are expected to be significantly restricted with respect to habitable volume and may operate at reduced atmospheric pressure with elevated oxygen concentrations. Improved non-regenerative and regenerative processes technologies for atmospheric quality control must be developed. The ability to economically supply atmospheric gases and refill storage tanks in flight will be needed. Isolating habitable volumes from surface dust and disposing of accumulated particulate matter will be challenges. Habitation systems must be innovative, extremely space efficient, and re-configurable (dual or multi-use).

Atmospheric Management
Atmospheric management encompasses the range of process technologies and equipment to remove impurities and condition crewed spacecraft and habitat cabin atmospheres, supply and store atmospheric gases, and achieve mass

closure by recycling resources and using in situ resources. Process technologies typically involve separations and reactions. Separations-based processes include physical adsorption, absorption, and mechanical filtration processes. Reaction based processes include chemical adsorption, oxidation, and reduction. Techniques for enhancing NASA's present capabilities are sought. Areas of emphasis include:

- Atmospheric Purification and Conditioning: Process technologies for single and dual function atmospheric purification and conditioning based on novel embodiments of commercially available adsorbent, chemisorbent, and catalyst media are required. Novel engineered media substrates to enhance durability, energy efficiency, and mass transfer leading to increased reliability, functional capacity, and smaller size relative to NASA's existing experience are sought. Specific challenges exist for efficiently removing ammonia, formaldehyde, and carbon monoxide from cabin atmospheric gases using process technologies that can be regenerated in place. Process technologies for removing and sequestering carbon dioxide from cabin atmospheric gases via means other than adsorption or chemisorption and conditioning carbon dioxide for use in reduction processes to facilitate cabin mass balance closure are also of interest.
- Supply and Store Atmospheric Gases: Novel means for supplying and storing oxygen and nitrogen under sub-critical conditions that lead to enhancements in energy efficiency, reduced mass and volume, and mission flexibility are sought.
- Recycle Resources and Use In Situ Resources: Novel means for supplying atmospheric gases using gas purification process waste products or means to more directly couple carbon dioxide and moisture removal to extract usable oxygen are sought.

Dust Control and Abatement

Dust and particulate matter contamination are challenges that must be overcome for lunar and Mars surface exploration. Particulate contamination originating from the external surface environment or from internal sources are both of concern. Development of regenerable process technologies and equipment to minimize the impacts of surface dust on crew health and life support equipment are sought. Novel approaches to isolate habitable volumes from surface dust and to remove dust from the spacecraft atmosphere, space suits and equipment are sought. Candidate technology solutions should provide high efficiency, long-lived removal capacity and be amenable to regeneration in place. Areas of emphasis include:

- Particulate Matter Removal and Disposal: Process technologies for removing and disposing of surface dust and particulate matter are sought. Salient features for this application include capability for regeneration in place, long-lived removal capacity and high efficiency.
- Isolation Technologies: Process technologies and design concepts to isolate habitable volumes from surface dust are sought. Such process technologies and design concepts may employ a variety of techniques to prevent surface dust from being transported through an airlock into the habitable part of the spacecraft or habitat cabin.

Habitation Systems

Habitation systems include crew accommodations, provisions, housekeeping and crew interfaces with vehicle systems including life support. Products can include applied research, system analysis, mockup evaluation, functionality demonstrations/tests, and actual prototype hardware. Proposals may address the following considerations and themes: re-configurable crew volumes and work stations for multi-gravity environments (micro and reduced gravity), multi-use work stations, multi-gravity translation strategies, physically and psychologically ergonomic personal volumes, automated deployment, quiescent operations between missions, multi-purpose stowage systems, advanced hygiene systems, automated housekeeping, and commonality of hardware/systems. Specific areas in which advanced habitability system innovations are solicited include:

- Crew Hygiene Systems: Low maintenance/self-cleaning fecal, urine, menstrual, emesis, hand/body wash, and grooming systems. Specific areas include non-foaming separators and no-rinse/non-alcohol hygiene products. Toilet systems should consider air, liquid, vacuum, and low-gravity transport methods. Collected waste should be prepared for recovery or long-term stabilization. Integrated hygiene systems should provide acoustic and odor isolated private crew volumes compatible with multi-gravity interfaces.

- Crew Accommodation Systems: Reconfigurable, deployable, erectable, or inflatable integrated crew accommodations that support crew wardroom, dining, conference, sleeping, relaxation activities and or stowage. May include visual and acoustical isolation, illumination, quiet ventilation/thermal control, audio-visual communication/entertainment, and off-nominal uses (emergency medical or repair) while maintaining hygienic conditions. Stowage systems may include interior/exterior stowage systems for partial gravity environments that maximize usable volume and include contents identification and inventory control systems.
- Clothing Systems: Low mass reusable or long usage clothing options that meet flammability, out gassing, and crew comfort requirements. Cleaning and drying systems for re-use of clothing that have low-water usage, non-toxic cleaning agents compatible with physicochemical or biological water reclamation systems, or that do not require water.

X3.02 Water Processing and Waste Management
Lead Center: JSC
Participating Center(s): ARC, GRC, KSC, MSFC

Advanced life support systems will be essential to enable human planetary exploration as outlined in the Vision for Space Exploration. These future systems must provide additional mass balance closure to further reduce logistics requirements and to promote self-sufficiency. Requirements include safe operability in micro- and partial-gravity as well as ambient and reduced-pressure environments, high reliability, regeneration, minimal use of expendables, ease of maintenance, and low system volume, mass and power. Proposals should explicitly describe how the work is expected to improve power, volume, mass, logistics, crew time, safety and/or reliability, giving comparisons to existing state-of-the art technologies. Although this solicitation is directed at technologies for lunar missions, crosscutting technologies that are also applicable to human missions to Mars or that are compatible with both partial and microgravity environments may be of interest. Technologies that perform several functions or that eliminate the need for intermediate processing steps are also of interest. Additional documentation and information can be found at http://advlifesupport.jsc.nasa.gov, including the expected composition of solid wastes and wastewater which can be found within the "Baseline Values and Assumptions Document".

Water Reclamation
Efficient, direct treatment of wastewater and product water consisting of urine, wash water, humidity condensate, and/or product water derived from in situ planetary resources to produce potable and hygiene water supplies. Treatment methods for long duration lunar surface missions should seek higher levels of mass closure. Treatment methods for short-to-moderate duration lunar missions (several weeks to several months) may have lower recovery rates (<80%) or may be designed to treat fixed volumes of water. Areas of emphasis include:

- Stowable small-scale gravity-independent water treatment units for contingency or back up use for treatment of condensate, contaminated potable water or wastewater, which may incorporate flow-through units such as ion exchange, adsorption, multi-filtration and/or osmotic filtration;
- Disinfection and residual disinfectant technologies for potable water storage and point-of-use that are compatible with wastewater processing systems including biological treatment;
- Techniques to minimize or eliminate biofilms, microbial contamination and/or solids precipitation from potable water, wastewater and water treatment system components such as pipes, tanks, flow meters, check valves, regulators, etc.;
- Physicochemical methods for primary wastewater treatment to reduce total organic carbon from 1000 mg/L to less than 50 mg/L and/or total dissolved solids from 1000 mg/L to less than 100 mg/L; and
- Post-treatment methods to reduce total organic carbon from 100 mg/L to less than 0.25 mg/L in the presence of 50 mg/L bicarbonate ions, 25 mg/L ammonium ions and 25 ppm other inorganic ions.

Solid 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:

- Volume reduction of wet and dry solid wastes;
- Small and compact fecal collection and/or treatment systems;
- Water recovery from wet wastes (including human fecal wastes, food packaging, brines, etc.);
- Stabilization, sterilization, and/or microbial control technologies to minimize or eliminate biological hazards associated with waste;
- Mineralization of wastes (especially fecal) to ash and simple volatile compounds (e.g. carbon dioxide and water);
- Containment of solid waste onboard spacecraft that incorporates odor abatement technology;
- Partial-gravity containment devices or systems with low volume and mass that can maintain isolation of disposed waste on planetary surfaces; and
- Microgravity-compatible technologies for the containment and jettison of solid wastes in space.

Water Recovery from Byproducts of Water and Waste Processing - Brines and Slurries
Water recovery systems produce brines and slurries from water processing systems that use technologies such as reverse osmosis and distillation. Dissolved solids and organics can total about 3% to 20% by weight of the solution. Technologies for recovery of water from brines and slurries, which provide an increased level of mass closure of advanced life support systems, are of interest. The products of these systems may be dry solids and purified water low in total organic carbon.

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

Environmental Monitoring and Control
Monitoring technologies are employed to assure that the chemical and microbial content of the air and water environment of the astronaut crew habitat falls within acceptable limits, and that the 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 major constituents in the air and lunar dust. Extendibility to trace monitoring for longer missions is a plus. 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 to simultaneously monitor several major constituents and dust, and/or trace constituents.

- Substances from an external environment such as 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.
- For longer missions, water monitoring will be required. Needs will include sensitive, fast response, online analytical sensors to monitor suspended liquid droplets, dispersed gas bubbles, and water quality, particularly total organic carbon.
- Monitoring of other species of interest include dissolved gases and ions, and polar organic compounds such as methanol, ethanol, isopropanol, butanol, and acetone in water reclamation processes; and particulate matter, major constituents (such as oxygen, carbon dioxide, and water vapor) and trace gas contaminants (such as ammonia, formaldehyde, ethylene) in air revitalization processes. Both invasive and noninvasive techniques will be considered.

- Monitoring of microbial species, especially pathogens, primarily in water, will be important for longer missions. Enabling technologies may include proper sample preparation and handling, with minimal operator effort and minimal or no reagent usage.
- Crew members will employ software tools to help them interpret sensor data. Methods are sought which will assist the crew in using sensor data to detect and predict failures.

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.

Spacecraft Fire Protection Systems
The objective of fire protection strategies on exploration spacecraft is to quantitatively reduce the likelihood of a fire and reduce the impact to the mission should a fire occur. 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 describing innovations in all of these areas are applicable, they are particularly sought in the following areas:

- Advanced fire detection strategies are desired that respond uniquely to one or more fire or pre-fire characteristics such as thermal radiation, smoke, or gaseous product. These sensors should be appropriate for the unique fire behavior in low- and partial-gravity environments yet effectively discriminate between fire signatures and relevant spacecraft nuisance sources. Fire detection systems particularly attractive for long-duration exploration missions will have reduced mass, power, and volume requirements and exhibit high degrees of reliability, minimal maintenance, and self-calibration.
- 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. These systems would be effective in low- and partial-gravity environments and have minimal mass and volume requirements. Applicable technologies would be highly reliable with little or no maintenance, have multi-use capability and/or be replenishable during a mission, 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 detection or suppression system.

TOPIC: X4 Lunar In Situ Resource Utilization (ISRU)

Instead of bringing everything from Earth, a key to fulfilling the goal of sustained and affordable human and robotic exploration will be the ability to use resources that are available at the site of exploration to "live off the land", known as In Situ Resource Utilization (ISRU). Past studies have shown making propellants and other mission critical consumables (life support and power) in situ can significantly reduce mission mass and cost, and also enable new mission concepts (e.g. surface hoppers). The ability to excavate and manipulate regolith can also have significant mass and risk reduction benefits. The primary objectives for the following ISRU subtopics are to develop technologies and systems that meet Lunar Precursor and Robotic Program (LPRP) and human lunar exploration mission objectives in the following areas: (1) Lunar regolith excavation, handling, and material transportation; (2) Oxygen production from lunar regolith processing; and (3) Lunar volatile resource extraction, separation, and storage, especially in the permanently shadowed craters at the lunar poles. To support future LPRP and human missions, the technologies and systems developed must meet the following:

- LPRP payload mass and power requirements are unknown at this time, however notional payloads should be designed to < 100 kg, not to exceed 500 Watts of average power.

- Technology and systems for lunar human Sortie mission demonstrations should be notionally 1/5th scale of early Outpost mission needs and no smaller than 1/10th scale. Payloads should be nominally 100 to 200 kg and no greater than 500 kg in mass.
- The current estimate for lunar human Outpost needs are 2 MT of oxygen per year for life support and EVA usage, and 7 MT of oxygen per year for propulsion to support two ascent missions per year.

X4.01 Lunar Regolith Excavation and Material Handling
Lead Center: JSC
Participating Center(s): GRC, KSC, MSFC

Lunar regolith excavation, handling, and material transportation deal with all aspects of lunar regolith handling for site preparation, resource collection, and construction activities. Excavation and transport technologies and systems are required to support regolith excavation and transport to support oxygen production from regolith (notionally down to 0.5 m), and regolith excavation and transport to support site construction and reactor placement (notional depth down to 3 meters and berms up to 3 meters). To maximize the benefits of incorporating in situ resource utilization (ISRU) capabilities into missions, ISRU excavation and material handling systems must require the minimum amount of mass and power to accomplish the tasks and need to process 100's of times their own mass of extracted resource in their useful lifetimes. Hardware must also be able to operate in wide temperature ranges (-160°C to 123°C), abrasive environments, and partial-gravity. In addition, the maintenance, human supervision, crew operation, and crew training required for these systems must be minimal and affordable. Excavation metrics of interest include: excavation rate (kg/hr), excavation efficiency (power required/excavation rate), and excavation depth and berm height. Specific areas of interest include:

- Evaluation of granular physics in low gravity and development of models and its effect on material excavation and handling;
- Dust-insensitive and/or abrasion-resistant excavation hardware, actuators, seals and bearings; and
- Dust mitigation and construction techniques to minimize dust generation around landing pads, habitats, dust-sensitive instruments, and airlocks.
- Low energy excavation techniques for excavating compacted lunar regolith down to 50 cm.

X4.02 Oxygen Production from Lunar Regolith
Lead Center: JSC
Participating Center(s): GRC, KSC, MSFC

Oxygen production from lunar regolith processing consists of receiving regolith from excavation and material transportation and chemically, electrically, and/or thermally extracting oxygen from the metal and non-metal compounds in lunar regolith. Other resources of interest, such as silicon, iron, titanium, aluminum, etc. may also be processed in the future based on technologies developed for oxygen production.

To maximize the benefits of incorporating ISRU capabilities into missions, oxygen production from regolith systems must require the minimum amount of mass and power to meet production rates and need to process 100's of times their own mass of extracted resource in their useful lifetimes. Hardware must also be able to operate in abrasive environments and partial-gravity, and may need to be shut down for extended periods of time during lunar night if power is not available. In addition, the maintenance, human supervision, crew operation, and crew training required for these systems must be minimal and affordable. Process evaluation metrics of interest include: oxygen production rate (kg/hr), oxygen production efficiency (Watts per mass of product produced per hour), percentage oxygen extracted from regolith, closed loop operations (minimal if any feedstocks from Earth), and mass of Earth consumables used per mass of oxygen produced. Specific areas of interest include:

- Solar thermal concentrators and furnaces (> 1000°C and > 2000°C);
- Processes to extract oxygen from lunar regolith, excluding production techniques that utilize hydrogen, carbon monoxide, and/or methane reduction of regolith. Consideration needs to be given to examining the impact of shutting down to a minimal level during lunar night if processing power is not available;
- Processes to extract silicon from lunar regolith;
- Regolith feed inlet designs and sealing mechanisms that allow continuous feed or large number of cycles for batch processing that are tolerant to dust/abrasion and high temperatures (> 1000°C), and allow minimal loss of processing reagent and product gases;
- Spent regolith outlet inlet designs and sealing mechanisms that maximize thermal management and minimize processing reagent and product losses; and
- Long-life electrodes/electrolytes for electrolysis-based regolith processing concepts.

X4.03 Lunar Polar Resource Prospecting and Collection
Lead Center: JSC
Participating Center(s): GRC, KSC, MSFC

Lunar volatile extraction, separation, and collection consists of all aspects of locating and characterizing lunar volatile resources (especially polar hydrogen/water); excavating regolith in the permanently shadowed craters (-233°C and down to 2 meters); mechanical, thermal, chemical, and/or electrical processing of this regolith to release volatiles; identifying/quantifying all volatiles; and separating and collecting volatiles of interest. Metrics of interest include: excavation rate (kg/hr); excavation efficiency (power required/excavation rate); resource extraction efficiency (Watts per mass of volatiles produced per hour); collection efficiency (mass collected vs. total evolved); and collection purity (mass collected of desired product vs. total collected). Specific areas of interest include:

- Excavation techniques for soil-like to rock-like regolith (70MPa), depending on water content, and very cold (40K to 100K) regolith and local environment conditions;
- Gas separation and collection techniques for a product stream containing various concentrations of hydrogen, carbon dioxide, nitrogen, helium, water, ammonia, and methane;
- Demonstration of sealing technology for repetitive (> 50 times) use at a wide range of temperatures (40K – 500K nominal and up to 1500K maximum) in abrasive, electrostatic, high vacuum environment; and
- Regolith thermal processing concepts that maximize heat transfer and minimize processing times for regolith with low thermal conductivity.

TOPIC: X5 Extreme Environment Mechanisms

In early robotic missions, and later in outpost missions, permanently shadowed regions of the Lunar surface (e.g., the bottoms of craters in the polar regions). These areas appear to remain at temperatures of 50°K to 80°K (-223°C to -193°C). Current surface exploration hardware has demonstrated capability to operate in the range of 158K to 273K (-115°C to 0°C) on Mars. However, the technical challenges of developing and demonstrating hardware that can operate over 100°C colder than current capabilities are significant. The major technology drivers of the low temperature mechanism technology development are to significantly enhance operation of mechanized parts by (1) lowering the operating temperature for the life of the component and (2) improving mechanism performance (e.g., torque out put, actuation performance, lubrication state) at the lunar environment conditions of cold and vacuum. 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), lunar sortie and the lunar outpost missions. This topic area is responsible for mid-level technology research, development, and testing through experimental and/or analytical validation.

X5.01 Motors and Drive Systems for Cryogenic Environments
Lead Center: GSFC
Participating Center(s): GRC, JPL, JSC, LaRC

This subtopic focuses on the development of selected hardware and support technologies for motors, drive systems and related mechanisms 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 146K (-190°C to +127°C). Actual operational temperatures may be somewhat different. The component technologies developed in this effort will be utilized for rovers, operational equipment, 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, and full solar 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 gear boxes, suspension systems, material components (i.e., wiring, harnesses, insulating materials, and jackets/covers) that are flexible in cryogenic environments; advanced lubricants and lubrication technology; and an accelerated means of life testing for cold temperatures.

TOPIC: X6 Lightweight Structures and Materials

The SBIR topic area of Structures and Materials centers on developing lightweight structures technologies to support Lunar Lander, and Lunar Habitats, with relevant technology made available to the CEV and CLV programs. Lightweight structures 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 Lightweight Structures program utilizes and combines multi-center R&D teams into a focused activity for developing lightweight structure technology for the primary load bearing structure of the pressurized elements of the Vision for Space Exploration (VSE) program. In addition, development for non-pressurized primary structures will be considered where there is synergy with the development of the pressurized structures. The major technology drivers of the lightweight structure technology development are to significantly enhance structural systems for man-rated pressurized structures 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. This topic area is responsible for mid-level technology research, development, and testing through experimental and/or analytical validation. Subtopics in this area include Radiation Shielding Materials, Lightweight Primary Structures, and Advanced Materials.

X6.01 Radiation Shielding Materials and Structures
Lead Center: LaRC
Participating Center(s): ARC, MSFC

Revolutionary advances in radiation shielding materials and structures technologies are needed to protect humans from the hazards of space radiation during NASA missions. All radiation species are considered, including particulate radiation (electrons, protons, neutrons, alpha particles, light ions, heavy ions, etc.) and including electromagnetic radiation (ultraviolet, x-rays, gamma rays, etc.). All space radiation environments in which humans may travel in the foreseeable future are considered, including low-Earth orbit, geosynchronous orbit, Moon, Mars, etc. The primary areas of interest for this 2006 solicitation are: (1) radiation shielding materials systems for long duration lunar surface protection for humans; and (2) lightweight radiation shielding materials systems for short term in-space operations for humans. Specific areas in which SBIR-developed technologies can contribute to NASA's overall mission requirements for advanced radiation shielding materials and structures include, but are not limited to, the following:

- New and innovative lightweight radiation shielding materials and structures to shield humans in crew exploration vehicles, large space structures such as space stations, orbiters, landers, rovers, habitats (both rigid and inflatable concepts), spacesuits, etc. The materials emphasis is on non-parasitic radiation shielding materials, or multifunctional materials, where two of the functions are radiation shielding efficiency and structural integrity.
- Radiation laboratory and spaceflight data to validate the shielding effectiveness of radiation shielding materials and structures.
- Physical, mechanical, structural, and other relevant characterization data to validate and qualify multifunctional radiation shielding materials and structures.
- Comprehensive radiation shielding databases to enable designers to incorporate and optimize radiation shielding structural materials into space systems during all the design phases.
- New and innovative processing methods to produce quality-controlled advanced radiation shielding materials of all forms – resins, fibers, fabrics, foams, microcomposites and nanocomposites, fiber-reinforced composites, light alloys, and hybrid materials.
- New and innovative fabrication techniques to fabricate advanced radiation shielding materials into useful products and structural components.
- New and innovative manufacturing techniques to produce quality-controlled advanced radiation shielding products and structural components, including innovative scale-up methods for producing quality-controlled viable quantities of advanced radiation shielding materials and structures.
- New and innovative commercialization strategies to introduce advanced radiation shielding materials and structures into the marketplace to enable availability of the technologies for use by NASA and the space exploration community.

X6.02 Lightweight Pressurized Structures Including Inflatables
Lead Center: LaRC
Participating Center(s): GRC, JPL, MSFC

This subtopic solicits innovative structural concepts that support the development of lightweight structures technologies that could be applicable to CEV, CLV and Lunar surface landers and habitats. The targeted innovative lightweight structures are for primary pressurized structures such as cyrotanks and crewed vehicles (landers and habitats). Innovations in technology are needed to minimize launch mass and costs, and increase operational volume for minimal launch volumes while at the same time maintain required structural performance for loads and environments. Of particular interest are the following structural concepts:

- Cryotank structural systems that are low mass and minimize cryogen boil-off. These concepts can include new techniques in structural concepts, manufacturing, and incorporation of tank liners or innovative insulating materials that improve on SOA designs used today.
- Lightweight multifunctional structural systems that include radiation shielding, impact shielding, thermal management, damage tolerance and durability, and/or integral diagnostics/health monitoring capabilities are of interest if they can be developed to improve the efficiency (mass/performance) of the structural system over the parasitic systems used today.
- Inflatable structures are considered as viable technique to improve volume for crew in habitats and potentially other crewed vessels. However, areas of risk need to be mitigated to build confidence in the use of these structures. In particular, durability in the presence of micrometeoroid, orbital debris and crew load induced damage, radiation-shielding protection, equipment placement and tie down concepts, and efficient packaging concepts are of interest.

Development of concepts can include structural components, improved low cost manufacturing processes, methods of validation, and/or predictive analysis capabilities. Technological improvements that focus on risk reduction/mitigation, and development of reliable yet robust designs are also being sought under this announcement.

X6.03 Material Concepts for Lightweight Structure Technology Development
Lead Center: MSFC
Participating Center(s): GRC, LaRC

This subtopic solicits innovative research for advanced material concepts that support the development of lightweight structures technologies that should be applicable for space transportation vehicle systems, propulsion systems, and planetary access and operations. Advanced materials are targeted that could be implemented into structural and propulsion systems for CEV, CLV and lunar mission vehicles, landers, and habitats. Innovations in technology are needed to increase specific strength and stiffness, provide radiation shielding, enable thermal management, and reduce Micrometeoroid/Orbital Debris (MMOD) damage potential while maintaining safety, reliability and reducing costs.

Advanced material systems and their corresponding manufacturing and processing techniques are desired. Examples would include, but are not limited to, advanced polymer matrix, ceramic matrix, and metal matrix composites; high performance metals material systems (e.g. advanced aluminum alloys, titanium alloys, super alloys, refractory alloys); hybrid material systems, multifunctional material systems, self-monitoring and self-healing material systems; and mature applications of nano-structured materials. Processing examples would include, but not limited to, composite fiber tape placement, non-autoclave curing, ceramic processing, freeform fabrication, bonding of composites, metallic thermal spray, and friction stir welding/processing.

Development of concepts can include material system characterization, methods of validation, and/or predictive analysis methods that improve understanding of the technology to reduce risk and need for conservatism in design and demonstration of integrated system performance. Damage tolerance is a specific area of interest to include analytical tools, non destructive evaluation technology and experimental techniques. NDE methods and techniques are needed to include 3D imaging and modeling of defects, and NDE technologies for determining early degradation of composites.

TOPIC: X7 Operations of Exploration Equipment

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 new technologies to support low-Earth orbit (LEO), robotic precursor, and human exploration missions, providing systems that interact with humans, handle surface equipment and move people and their payloads across planetary surfaces. The objective is to produce new technology that will reduce crew extra-vehicular activity (EVA) and intra-vehicular activity (IVA) workloads and risk in LEO, and Lunar operations and reduce the total mass and volume of equipment and materials required to support missions. The proposals should focus on technology to improve the operations of exploration equipment, allowing for less expensive, more productive and less risky missions. This research will provide technology for the critical functions that fall into three phases of surface exploration. The first phase of surface exploration will be functions that are needed prior to crew arriving at a site. These precursors may be hours, days, weeks or years ahead of the crew landing on the surface. The second phase of surface exploration will be during a crew’s stay at the site. This work will include supporting the crew in IVA and in EVA tasks. The third phase of surface exploration will include long-term maintenance of the facility, as well as supporting science performed between crews.

X7.01 Supportability Technologies for Long-Duration Space Missions
Lead Center: JSC
Participating Center(s): LaRC

The objective of this subtopic is to develop technologies that can support the goal of significantly reducing the mass and volume of material required to support long-duration human spaceflight missions. Eventually, as the distance of mission destinations increases, resupply will become impossible. Therefore, unless support materials are prepositioned, it will be necessary for all required materials to be transported with the crew. The difficulty presented by this situation is compounded by the need for more material as mission duration increases. Capabilities to address these issues should be developed and demonstrated in conjunction with long duration lunar missions and, as they reach sufficient maturity, will be valuable enhancements to these missions.

This subtopic seeks proposals addressing maintenance and repair technologies that enable repair of failed hardware at all levels, technology that supports the production of replacement components during a mission, and technologies that reduce the quantity of material directly supporting the crew. Proposals are sought which address the following technology needs:

- Compact, portable systems to generate reverse engineering data to support manufacturing of replacement items during a mission. This will allow generation of a duplicate part based on an existing part if CAD models are not available.
- Real-time non-destructive evaluation during layer-additive processing for on-the-fly quality control. This will provide capabilities for in-process quality control and may serve as an input for closed-loop process control. Equipment should be portable, compact, and capable of integration with layer-additive manufacturing systems.
- Non-destructive material property determination. This will provide an in-process quality control capability to ensure that material deposited during layer-additive processing meets required material property criteria. Equipment should be portable, compact, and capable of integration with layer-additive manufacturing systems.
- Recycling/generation of feedstock materials for deposition processes. This will provide the capability to recycle failed parts and material removed from near-net-shape parts during machining operations to serve as feedstock material for subsequent layer-additive manufacturing. Initial focus should be placed on metallic materials. Additionally, emphasis should be placed on total system mass and volume.
- Compact, portable multi-axis machining systems. This will provide subtractive manufacturing capabilities to achieve final design dimensions and surface finishes following layer-additive processes that produce near-net-shape parts. Equipment to accomplish this should be of the minimum mass and volume possible while still providing required capabilities.
- Compact, portable, vacuum-compatible multi-axis manipulator. This will provide the capability for complex manipulation of the item itself, the processing equipment, or both during layer-additive manufacturing and machining. To be compatible with the widest variety of candidate processes, manipulation equipment should be vacuum compatible. Additionally, equipment to accomplish this should be of the minimum mass and volume possible while still providing required capabilities.
- Laundry system. This will provide the capability for extended reuse of crew clothing. Any laundry system must utilize a minimal amount of water or no water at all. Any water used should be easily recycled – either being reintroduced into the spacecraft water system or recycled internal to the laundry system. Additional emphasis should be placed on the mass and volume of the equipment and minimization of power requirements.

X7.02 Human-System Interaction
Lead Center: JSC
Participating Center(s): ARC, JPL, LaRC

The objective of this subtopic is to create an effective and efficient operational interface between a human and a robotic system that is supporting the human. This subtopic seeks to develop automation technology that reduces the risk of Extra-Vehicular Activity (EVA), improves the productivity of Intra-Vehicular Activity (IVA) and facilitates remote operations by both flight crew and ground control. Automation and robotics capabilities include the ability to use robots for operational tasks (assembly, maintenance, inspection, payload transport, etc.), real-time advisory systems that will support the space and lunar based crew, and mission operation concepts and systems that link ground supervisors across time delays to remote spacecraft and robots. Proposals are sought which address the following technology needs:

- Telepresence and variable autonomy teleoperation systems that support human and robot teams operating: (1) in a shared space, (2) close but separated, (3) somewhat remote, and far remote. Particular interest is given to systems that flexibly support human-robot operations in the presence of time-delays of up to 10 seconds.
- Software frameworks and interaction infrastructures that facilitate the creation and operation of joint human-agent teams. Conventional control architectures do not adequately address human-system interaction needs, particularly in terms of coordination, teaming, direct and indirect commanding, and information sharing between humans, robots, and distributed software agents. Of particular interest are extensions to existing NASA human-robot architectures and software frameworks including: automatic event and situation summarization, notification and dialogue based on user state (role, availability, location, interface), centralized task coordination/dispatch, user activity monitoring, and automated detection of domain events.
- Adaptive user interfaces including perception (visual gesturing), speech recognition, context awareness, computational cognitive models and/or collaborative 3D graphics, and EVA display devices (i.e., pressure-suit compatible devices and displays). Specific design objectives include enabling more natural interaction with autonomous systems, facilitating situational awareness, increasing overall productivity by reducing the amount of interaction effort the human has with the robot, and flexibly displaying multi-modal and mission-specific data.
- Embedded real-time advisory and action planning systems for fully autonomous integrated systems that support remote and onboard vehicle operations for the Crew Exploration Vehicle (CEV).
- Engineering systems that support flight demonstrations of dexterous robots working with EVA crew using CEV and ISS to prove capabilities for space and lunar operations. This will provide human, robotic and human-robot team options for dexterous EVA tasks, robotic EVA capabilities for excursions into high radiation fields beyond Low Earth Orbit (LEO), and the ability to respond to onboard situations with prompt EVA action.
- Accurate and affordable methods for prototyping and evaluating human-system interaction. This includes model-based simulation and trade studies for analyzing multiple interaction “dimensions” (spatial distribution, autonomy level, team makeup, task dependencies, etc.) and missions (pre-cursor robotic, short-stay sorties, and long-duration outpost).
- Vehicle control systems and navigation sensors that support on-board driving, teleoperation, and autonomous operations. Control systems should support multiple control modes, include activity monitoring and operator intent prediction, and tolerate up to 10 seconds of time-delay. Navigation sensors that utilize passive computer vision (real-time dense stereo, optical flow, etc.) and/or active illumination (for recognizing/tracking non-textured objects and operation in permanently shadowed regions) are of particular interest.

X7.03 Surface Handling and Mobility, Transportation, and Operations Equipment (Lunar or Mars)
Lead Center: JSC
Participating Center(s): ARC, GRC, JPL, LaRC

The objective of this subtopic is to provide new capabilities for delivery, handling, transfer, construction and repackaging of Extra Vehicular Activity (EVA) equipment and preparation of site infrastructure for lunar operations. This includes access/handling and transportation equipment/carriers for delivery and deployment of materials, components, and infrastructure; surface systems for site clearing, pad construction, and regolith manipulation; and commodities distribution systems (including umbilicals) for routing to equipment and infrastructure. These new capabilities are required to make planetary surface missions more reliable, safer, and affordable.

Several vehicle features will be critical to surface operations: expanded mobility, range and duration, life support recharge, crew following, automated path planning, automated driving, and obstacle avoidance. Vehicles with life support recharge capabilities will extend useful EVA time. The ability of a vehicle to follow a crewmember will enable science and exploration support equipment to be carried for the astronaut as well as extend the traverse distances. While the utility of autonomy is easily recognized when the crew is not on the surface, these functions could also be advantageous to long traverses and rescue or emergency operations when crewmembers are present.
Proposals are sought which address the following technology needs:

- Highly reliable and durable surface systems for site preparation, pad construction, site sampling and prospecting are needed for planetary exploration. Sample collection may require excavating, picking, and physical manipulation of materials, as well as tagging and transport to an analysis site. Emphasis will be placed on proposals that address both manned and unmanned vehicle control operating capabilities of the surface system.
- Flexible and adaptive systems to deploy and emplace site infrastructure, such as beacons for communication, survey, navigation, etc. Emphasis should be placed on developing lightweight, power-efficient manipulation devices (dexterous and non-dexterous) that can be deployed on small rovers and that are appropriate for multiple tasks. Much of this activity can be performed with teleoperated and semi-autonomous robots controlled from ground. Some of this activity, however, will also require human presence at the site. In both cases, the effectiveness of Human-Robot interaction (HRI) will have a major impact on the efficiency and productivity of mission operations.
- Access/handling and transportation equipment (including cargo carriers) for delivery and deployment of materials, components, and infrastructure. Vehicle systems that can self-deploy, that can function in rough and steep terrain, and that can controlled at various levels of autonomy are of particular interest.
- Commodities distribution systems (including umbilicals) for routing to equipment and infrastructure. Commodities distribution systems are necessary to interconnect distributed surface assets (e.g., access/handling and transportation equipment, launch and landing systems, communication relays, power plants) to support long-duration sorties and sequential mission architectures.
- Vehicle control architectures that support on-board driving, teleoperation, and autonomous operations. Particular emphasis is placed on architectures that can flexibly support and adapt to multiple control modes, that include activity monitoring and operator intent prediction, and that can tolerate up to 10 seconds of time-delay.
- Highly reliable, durable, and long-life systems (mechanical, electrical, software, power train, lubricants, etc). This includes design and implementation of integrated actuator, suspension and control avionics for surface vehicles and evaluation of test articles in field experiments (preferably in lunar analog environments).

TOPIC: X8 Energy Generation and Storage

This topic intends to develop power capabilities that are on the critical path to enabling human exploration beyond Earth orbit. Areas of primary interest are: power generation/actuation for launch vehicles utilizing non-toxic fluids; orbital and planetary surface energy storage; and non-solar power generation. The Exploration Systems Assessment Study (ESAS) architecture desires nontoxic fluids to reduce ground processing facility requirements and to increase safety for the crew. Hydrazine (toxic) is currently used to drive the Solid Rocket Booster (SRB) and Space Shuttle Main Engine (SSME) Auxiliary Power Units (APUs), which in turn provide power for actuation for engine gimbal. Development efforts using nontoxic power generation for launch vehicles is required. ESAS architecture elements, including the Crew Exploration Vehicle (CEV), Lunar Surface Access Module (LSAM), robotic missions, and surface systems, require long-life/ high-capacity/high-density energy storage on the order of up to 10 kW. Lithium ion batteries are required to be human-rated at load profiles that are currently higher than state-of-the-art, and, are required to operate over a greater range of temperatures for the lunar environment. The ESAS architecture requires advanced fuel cells to meet LSAM and surface system design margins. Fuel cell systems provide power largely independent of environment (solar incidence), which allows greater mission flexibility and will typically provide larger power levels for less total mass for short-duration missions. The exploration architecture identifies permanent human lunar habitation shortly following a set of crewed sortie missions. The permanent habitation phase requires lunar night stays, extended EVAs, expanded science and surface operations and the utilization of ISRU to demonstrate and validate capabilities needed for Mars exploration. The expected power requirements will exceed that practically furnished by conventional technologies. The ESAS study identified surface nuclear fission systems to satisfy the power requirements for lunar extended stays, particularly at non-polar regions and nuclear power extensibility to Mars exploration.

X8.01 Non-Toxic Launch Vehicle Power for Thrust Vector and Engine Actuation
Lead Center: GRC
Participating Center(s): MSFC

The next generation of NASA launch vehicles and spacecraft will minimize the use of hydraulic power systems due to their inherent inefficiencies. These hydraulic systems will be replaced with all electric power components. NASA is interested in optimizing these electric components to maximize system reliability and efficiency while minimizing overall size and mass. Of particular need are electric actuation systems, including electromechanical (EMA) and electrohydrostatic (EHA). These are important in order to realize the full potential of the more electric power systems. The actuator systems will consist of both the actuator and associated controls. These systems will be used for a number of applications including thrust vector control, engine actuation and vehicle surface actuation. The technology would directly benefit programs such as Constellation which have a variety of requirements for the Crew Launch Vehicle, Cargo Launch Vehicle, Lunar Surface Access Module, and others. These systems may range from a few horsepower to greater than 50 horsepower, and the associated electronics may see temperature extremes up to 175°C. To make electric actuation a more viable option, improvements in mass, size, efficiency and power density are sought for both the actuator and associated controls. Current state-of-the-art actuators suitable for engine thrust vector control on a launch vehicle have a power density of 1kW/kg for duplex drives (two motors driving one transmission, not including inverters and controllers). Innovations are sought to increase this power density to at least twice the SOA. In addition, state-of-the-art controllers can be 20 – 50% of the actuator size and weight alone, therefore novel approaches to minimizing controller mass and volume are sought. Innovative approaches to redundant electric actuator systems and redundancy systems management will also be considered which would help reach the single fault tolerant vehicle requirements. Technologies of specific interest include:

- Lightweight, high power density electric actuators and controls in the 5 – 10 hp range for use on vehicles such as Crew Launch Vehicle and Earth Departure Stage, with an actuator density goal of 2kW/kg and controller density of at least 1.5 kW/kg;
- Lightweight, high power density electric actuators and controls suitable for 30 – 60 hp applications on vehicles such as Cargo Launch, with an actuator density goal of 2kW/kg and controller density of at least 1.5 kW/kg;

- Actuation and control technologies capable of operating over wide temperature ranges – up to a chassis temperature of 175°C;
- Novel redundant EA systems and redundancy management approaches for single fault-tolerant vehicle applications.

X8.02 Space Based Nuclear Fission Power Technologies
Lead Center: GRC

NASA is interested in the development of highly advanced systems, subsystems and components for use with fission power systems for future Lunar and Mars robotic and manned missions. Anticipated power levels range from 10's of kilowatts to 100's of kilowatts. Proposals are sought for critical technologies for fission power systems to meet the following anticipated missions and applications.

The current Vision for Exploration identifies the first human lunar landing in 2018 with subsequent long duration lunar stays of approximately 6 months in 2022. Fission-based systems are anticipated to enable the long duration stay over the lunar night. Initial planetary base power levels are anticipated to be between 30 – 50 kWe.

Planetary surface human base applications may include: habitats, resource processing and propellant production/liquefaction/maintenance, surface mobility for both robotic and piloted rovers, excavating and mining equipment and science stations. Human Mars mission activities could require power in the 100 kWe range.

Potentially, robotic outpost as a precursor to human Mars exploration with 50 – 500 day stays could be the proving ground for smaller fission systems. A 20 – 30 kWe system could support science applications such as: deep drilling, resource production demos, rovers, weather stations, etc.

Specific technology topics of interest are:

- Advanced, high efficiency, high temperature power conversion > 20%, 25 kWe to 100 kWe unit size;
- Electrical power management, control and distribution. 1000 – 5000 V;
- High temperature, low mass thermal management/heat rejection < $6kg/m^2$;
- Deployment systems/mechanisms for large radiators, surface mobility systems for remote emplacement of power systems, innovative methodology for use of indigenous shielding materials;
- High temperature materials or coatings compatibility with local soil and atmospheric environments;
- Systems/technologies to mitigate planetary surface environments. Dust accumulation, wind, planetary atmospheres (CO_2, corrosive soils, etc.);
- Power system design considerations for long life (> 5 years), autonomous control and operation, including sensor technologies;
- Radiation tolerant systems and materials (including lunar, Mars and in-space environments) for robust, long life operation;
- Innovative methodologies and approaches to accelerated life testing.

In addition to reducing overall system mass, volume and cost, increased safety and reliability are of extreme importance. It is envisioned that these technologies would be used on robotic and human missions and it is to NASA's advantage to develop those technologies that transcend robotic to human mission requirements with a minimum of redesign. Technologies that easily and efficiently scale in power output and can be used in a host of applications (high commonality) are desired.

X8.03 Space Rated Batteries and Fuel Cells for Surface Systems
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

Human-rated energy storage devices are required to enable future robotic and human exploration missions. Advanced battery, fuel cell and regenerative fuel cell systems are sought for use in a wide range of Exploration mission applications including portable power for landers, rovers, and astronaut equipment, and stationary energy storage applications such as base power, and storage systems for crew exploration vehicles and spacecraft. Technology advances that will reduce the weight and volume, improve the efficiency, life, safety, system simplicity and reliability of electrochemical systems, specifically rechargeable batteries and fuel cell systems are desired. The specific advancements of interest are outlined below.

Advanced Secondary Battery Systems
Areas of emphasis for advanced battery systems include technology advancements that contribute to the following cell-level performance goals: specific energy > 180 Wh/kg, calendar life >15 years, and operating temperature range -60°C to 60°C and cycle life at 100% DOD > 2000 cycles. Systems that combine all of the above characteristics and demonstrate a high degree of safety are desired.

Specific technology areas sought are improved component materials that include non-toxic cathodes with specific capacities in excess of 250 mAh/g at the C rate and 25°C, and electrolytes that provide safe, non-flammable, non-hazardous operation. Cells that exhibit tolerance to mild abuse such as overcharge and over temperature are desirable. Chemistries and/or cell design capable of rapid recharge (< 15 minutes) are sought. Micro and nano-engineered materials are an area of emphasis to enhance capabilities.

Innovative concepts for the design and management of packaged battery modules with specific energy >140 Wh/kg and energy density > 300 Wh/l are of keen interest.

Proposals addressing micro-batteries, structural batteries, and/or integrated power generation and are sought.

Fuel Cell Systems
Fuel cell (FC) systems with power capabilities in the range of 100-1000 watts and 1-10 kW are of interest, as are regenerative fuel cell (RFC) energy storage systems in the 10 – 25 kW power range.

Specifically, technological advances are sought for FC/RFC based systems that contribute to system simplicity and improved reliability through (1) innovative, integrated system-level design concepts, and (2) passive ancillary components. An example of these advances at the system level is primary and/or regenerative fuel cell systems that minimize or eliminate reactant re-circulation external to the stacks themselves. Examples at the component level include replacement of pumps and other active, motorized mechanical ancillary components with passive devices that perform the functions of both reactant management and thermal control.

Advanced FC/RFC development at both the system and component levels should focus exclusively on proton-exchange-membrane PEM technology utilizing pure hydrogen, oxygen, and water as reactants.

TOPIC: X9 Propulsion and Propellant Storage

The Exploration Systems architecture presents some propulsion challenges that require new technologies to be developed. Some of these technologies are affordable high reliability booster engines; long term cryogenic propellant storage, management, and acquisition; deep throttle cryogenic propellant space engines; cryogenic propellant reaction control engines; and non-toxic storable propellant space engines. Furthermore, specific technologies are required in valves, regulators, combustion devices, turbopumps, ignition, instrumentation, modeling, controls, materials and structures, pressurization, mass gauging, and cryogenic fluid management. The anticipated technologies to be proposed are expected to be capable of being made flight qualified and certified for the flight systems and dates to meet mission requirements.

X9.01 Long Term Cryogenic Propellant Storage, Management, and Acquisition
Lead Center: GRC
Participating Center(s): ARC, JSC, MSFC

This subtopic includes technologies for long term cryogenic propellant storage, management and acquisition applications in-space as well as on the lunar surface. These technologies will impact cryogenic systems for space transportation orbit transfer vehicles, space power systems, spaceports, spacesuits, lunar habitation systems, robotics, and in situ propellant systems. Each of these applications has unique performance requirements that need to be met. The sizes of these systems range from the small (< 20 m^3 for supercritical air and payload cooling) to very large (> 3400 m^3 for LOX and LH_2 propellant storage). Advanced cryogenic technologies are being solicited for all these applications. 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.

Technology focus areas are divided as follows: fluid transfer/liquid acquisition devices, mass gauging/advanced instrumentation, passive systems, storage and distribution components, and refrigeration systems. Innovative concepts are requested for cryogenic insulation systems, fluid system components, and instrumentation. 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. This subtopic solicits unique and innovative concepts in the following technologies:

Fluid transfer/Liquid Acquisition Devices
Liquid acquisition devices capable of preventing gas ingestion into engine feed lines in low gravity, analytical models of LAD's to predict LAD performance in low gravity and to determine the effect of autogenous/non-autogenous pressurants on LAD wicking capability, techniques to minimize vaporization inside the LAD channel caused by incident heating through tank wall/lines and/or changes in tank pressure.

Mass Gauging/Advanced Instrumentation
Methods of determining liquid quantity gauging in propellant tanks in low gravity, high accuracy differential pressure transducers which can operate submerged in liquid cryogen and in-space fluid leak detectors.

Passive Systems
Advanced insulation technology including low loss cryogenic propellant tank penetrations and insulation materials capable of retaining structural integrity while accommodating large operating temperatures ranging from cryogenic to elevated temperature conditions, advanced tank support systems capable of supporting tanks during the launch environment, but decoupling on on-orbit to minimize thermal loads and passive thermal control designs for cryogenic fluid storage on the lunar surface.

Storage and Distribution Components
Advanced low-gravity submersible pumps and helium compressors designed specifically for in-space cryogenic operation, low heat leak cryogenic quick disconnects capable of sealing against the vacuum of space, long-life, low power valves for LO2 and LH_2 capable of sealing at cryogenic temperatures, being cycled many times without consuming pressurant gas and with minimal thermal loss and pressure drop.

Refrigeration Systems
Advanced LO_2 and LH_2 cryocooler concepts for in-space operation that are reliable, lightweight, low input power and capable of removing 5 to 10 watts of heat at 77 K and at 20 K, respectively, concepts to integrate Broad Area Cooling (removing heat over large areas and long distances) into in-space storage of LO_2 and/or LH_2 and heat exchanger designs for large-scale storage systems designed densification of LO_2 and LH_2.

X9.02 Innovative Booster Engine Manufacturing, Components, and Health Management
Lead Center: MSFC

The goal of this subtopic is the development of innovative components, manufacturing techniques, health management systems, and design and analysis tools for boost propulsion. Although solid or hybrid rocket propulsion is specifically emphasized, compelling proposals related to liquid engine boost propulsion are also invited. Technologies that would contribute to increased mass fraction and decreased sensitivity to manufacturing and handling effects are particularly welcome, as are those that would reduce the time, cost, and complexity associated with designing and manufacturing large booster rockets. Specific areas of interest include:

- Concepts for solid or hybrid propulsion systems and related components that would lead to increased payload mass fraction over current solid rocket motors;
- Concepts for solid or hybrid auxiliary propulsion systems that can be throttled to provide enhanced vehicle maneuverability;
- Health management technologies, including embedded sensors and modeling methodologies, that would improve the ability to monitor the reliability of solid or hybrid rockets during manufacturing, handling, and flight;
- Manufacturing techniques that allow for reductions in the cost and schedule required to fabricate and test solid or hybrid rockets;
- Propulsion system concepts, components, and fabrication processes designed to reduce the production costs of liquid propellant rocket engines for large expendable boosters;
- Improved design and analysis tools that enhance the engineering evaluation of advanced chemical propulsion system concepts;
- Test data that provides for validation of existing design and analysis tools; and
- New propellant ingredients or formulations that would increase the propellant specific impulse while maintaining a Department of Transportation Class 1.3 hazard classification. Proposals that would experimentally synthesize and characterize new ingredients, or formulate and demonstrate new propellants, are highly encouraged, whereas proposals that rely heavily on the screening of potential new ingredients by quantum chemistry or other computational and theoretical methods are discouraged.

Proposals that address more than one of these items are highly encouraged.

X9.03 Cryogenic and Non-Toxic Storable Propellant Space Engines
Lead Center: GRC
Participating Center(s): JSC

This subtopic intends to examine a range of key technology options associated with cryogenic and non-toxic storable propellant space engines. This engine technology is solicited for use in lieu of the toxic but currently operational nitrogen tetroxide and monomethylhydrazine engine technology, which has recently seen performance improvements from 310 to 325 seconds of specific impulse using advanced rhenium thrust chamber technology.

Performance improvements are a consideration, but are not the main objective of this solicitation. The Space Shuttle Orbiter Upgrade Program identified non-toxic reaction control system (RCS) propulsion as a key technology to reduce vehicle operations costs on the ground, and estimated that a significant reduction in RCS propulsion system cost is possible by the use of non-toxic propellants. In addition, the use of astronaut extravehicular activity for in-space refueling of space systems or the refueling of vehicles with humans aboard such as the International Space Station is extremely hazardous with toxic propellants. These safety concerns drive mission planners to the use of more costly propulsion modules that are fueled and sealed on the ground.

The general objectives of this solicitation derive from the NASA goals of safe, reliable, affordable and effective human and robotic missions in support of the overall U.S. Vision for Space Exploration. Successful proposals will be focused investments that systematically validate and/or invalidate key technologies and design concepts that might transform how the U.S. will pursue future space exploration goals.

The specific technology to be supported by this subtopic is multi-use in-space cryogenic and non-toxic storable propellant rockets. This technology includes the development and demonstration of key operational and performance characteristics of a range of new space engines, i.e., orbit transfer, descent, ascent, and pulsing attitude control engines. These engines can be compatible with the future use of in situ propellants such as oxygen and hydrogen or methane, but propellants consistent with low cost ground operations such as ethanol, JP-5 and nitrous oxide and monopropellants are also solicited.

Proposals are solicited for both thruster development and thruster component technologies such as, but not limited to, long-life, highly reliable ignition systems, durable, low-mass propellant injectors, and long-life combustion chamber designs. Proposals are also solicited for propulsion system component technologies such as valves, instrumentation, controls, multi-purpose structures and both electric and turbine driven pumps. Examples include, but are not limited to, highly-reliable, long-life, fast-acting cryogenic valves that tolerate high thermal loading due to heat soak-back in low-thrust, pulsing propulsion systems; cryogenic instrumentation such as pressure and temperature sensors that will operate for months/years instead of hours; and high-reliability, long-life turbopump bearings. Technologies are also solicited that enable deep-throttling turbopumps to operate at off-design flow coefficients while eliminating flow instabilities such as cavitating surge. Examples include, but are not limited to, inducer designs that can operate with a high degree of vapor content or cavitation in the propellant flow and pump diffusion systems with reduced sensitivity to flow separations. Strategies for engine and component protection from dust, radiation, and other environmental effects are also solicited. Finally, proposals are solicited for modeling efforts that enable reduced thruster development costs and schedules.

X9.04 Nuclear Thermal Propulsion
Lead Center: GRC
Participating Center(s): MSFC

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

Preliminary solid core NTP system concepts could be based on a high thrust/high Isp (~850 – 950s) NTP system that would use a fission reactor with U-235 fuel as its source of thermal energy. During the short primary propulsion maneuvers of a typical conceptual mission, large quantities of thermal power (100's of MWt) would be produced within the NTP system and removed using LH_2 propellant that is pumped through the engine's reactor core. The superheated hydrogen gas is then exhausted out the engine's nozzle to generate thrust. Representative ranges of engine performance include: (1) hydrogen exhaust temperatures ~2500 – 2900 K, (2) propellant flow rates ~7 – 13 kg/s, (3) chamber pressures ~500 – 1500 psi, and (4) nozzle expansion area ratio ~200:1 – 500:1.

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

- High temperature, low burn-up carbide- and ceramic-metallic (cermet)-based nuclear fuels with improved coatings and/or claddings to reduce fission product gas release into the engine's H_2 exhaust stream;
- Reliable, high temperature materials, fabrication techniques, and concepts for non-reactor portions of NTP systems;
- Light-weight, multi-use shielding materials and designs;
- High temperature, radiation tolerant instrumentation and avionics for engine health monitoring. Non-invasive designs for measuring neutron flux (outside of reactor), chamber temperature, operating pressure, and H_2 propellant flow rates over wide range of temperatures are desired;
- Long life, lightweight, reliable hydrogen turbopump designs and technologies;
- Lightweight, long life, high heat flux thrust chambers, regenerative-cooled nozzles and radiation-cooled skirt extensions that are compatible with hot hydrogen;
- Radiation tolerant materials compatible with above engine subsystem applications and operating environments.

TOPIC: X10 Thermal Protection

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. For example, if existing materials were to be used for the proposed Mars Sample Return mission, the TPS mass fraction would be on the order of 40%. The potential savings that could be achieved with some investment in TPS technology development is sizeable.

X10.01 Ablative Thermal Protection System for CEV
Lead Center: ARC
Participating Center(s): JSC, LaRC

The Crew Exploration Vehicle (CEV) will first be used for transporting crew and cargo to the Space Station and later for the human exploration of the Moon and Mars. The Thermal Protection System (TPS) for the CEV will have to protect the crew and cargo from entry heating at entry velocities of approximately 8 km/s for Space Station missions, 11 km/s for lunar return missions, up to 8 km/s for Martian aerocapture and entry, and between 12 – 15 km/s for Martian return missions. Ablative TPS is an enabling technology for all CEV superorbital reentry missions.

Ablation Modeling
The heat shield for CEV will employ a TPS material that pyrolyzes and ablates at high temperature for mass-efficient rejection of the aerothermal heat load. Pyrolysis is an internal decomposition of the solid that releases gaseous species, whereas ablation is a combination of processes that consume heat shield surface material (including chemical reactions, melting, and vaporization). For the design and sizing of TPS materials, it is imperative to have reliable simulation tools that can compute surface recession rate, in-depth pyrolysis, and internal temperature histories under general heating conditions. In addition, lunar and Martian reentry environment heating will consist of significant radiation from the shock layer. The models need to include the effect of not only convective but radiative heating as well.

Therefore, advances are sought in modeling of radiation, gas surface interactions, ablation mechanisms, pyrolysis, and other processes such as coking and charring. Specifically for charring, advances are sought in the development of a low density charring ablator model to give insight into how conductivity changes as function of temperature and pressure for the virgin material and for the material as it pyrolyzes.

Instrumentation
TPS sensors and experimental diagnostic tools are required to provide traceability of TPS sizing tools, design, and material performance. Traceability will lead to higher fidelity design tools, which in turn will lead to risk reduction and decreased heat shield mass on missions requiring atmospheric aerocapture or entry/reentry. Decreasing heat shield mass will enable certain missions that are not otherwise feasible and directly increase payload. Heat flux sensors and surface recession diagnostic tools are essential to advancing the state of TPS traceability for material modeling and aerothermal simulation.

Advances in the understanding of how heat flux sensor performance changes upon integration of the sensors into TPS materials in ablative environments through simulation or experimental investigation are sought. Specifically, the following list of sensor materials is of primary interest:

- Type K, C, R, and S thermocouples
- Sapphire windows
- Inconel superalloys
- Pure platinum
- Teflon

For surface recession, advances in optical methods (photometrics/tomography) are sought.

Non-destructive Testing Techniques and Novel Techniques for Material Characterization
The CEV heat shield will be the largest ever built. During manufacturing and integration, it will be necessary to understand the variability in material properties, to determine voids and inclusions, to assess bondline integrity, and to ensure that the established flight heat shield requirements are met.

For this purpose, advances in NDE and proposals of novel techniques for material characterization applicable for ablative TPS are sought.

Ablation Materials Development
Early NASA missions [Gemini (1964-1966), Apollo (1966-1973), and Mars Viking (1976)] employed new ablative TPS materials that were tailored to each specific entry environment. However, after Mars Viking, NASA-sponsored ablative TPS development essentially ceased as the research focus shifted to reusable TPS in support of the Space Shuttle. For example, the Pioneer Venus (1978) and Galileo (1995) missions employed carbon phenolic TPS material that had previously been developed by the United States Air Force for ballistic missile applications. Over the past 40 years, NASA has adopted a risk averse philosophy relative to TPS, i.e. use what was used before since it has been flight-qualified. For Mars Direct Return, the entry velocities will be in the range of 12–15 km/s. Heritage carbon phenolic can satisfy Mars Return requirements however the TPS mass fraction would be less than optimal. Thus, advances toward new reliable and efficient TPS materials are desired. Similarly, development of adhesives, joints, penetrations, and seals are of equal importance and advances are sought.

TOPIC: X11 Thermal Management

All spacecraft and extraterrestrial bases require thermal management systems. The long duration lunar bases that are foreseen in 15 years will present several challenges to the design and operation of active thermal control systems. Even though system design may be easier for the reduced gravity of the Moon than it is for the microgravity case of a spacecraft, the large variations in thermal environment and the risk of contamination by lunar dust will complicate system design. Innovative thermal systems and components are needed for this next phase of human space exploration.

X11.01 Thermal Control for Lunar Surface Systems
Lead Center: JSC
Participating Center(s): GRC, GSFC, JPL

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 at lunar twilight, resulting in a benign thermal environment. The long duration lunar bases that are foreseen in 15 years will see large variations in their thermal environment during the Moon's day/night cycle. Long stays 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, heat pumps, and thermal storage devices.

For radiators on the Moon, lightweight deployable radiators are required that will operate at temperatures between 150 and 300K. Shading devices and strategies would allow them to reject more heat in the hot lunar environment. In addition, variable emissivity coatings would prevent freezing during the long, cold, lunar night. Also, the dusty environment of an active lunar base will require dust mitigation and removal techniques to maintain radiator performance over the long term.

Heat pumps (especially high lift) may be required for heat rejection in the lunar environment.

The lunar base active thermal control system will include high efficiency, long life mechanical pumps. Lightweight, high-performance thermal switches plus thermal energy storage and rejection devices could be used to accommodate the extremes of the available heat rejection. 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.

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.

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 1/6th Earth-normal gravity of the Moon.

Lightweight, low volume, robust Extravehicular Activity (EVA) systems are needed that maximize human productivity and improve the capability to perform useful work tasks on the lunar surface. Low-venting or non-venting regenerable support subsystem(s) are needed for crewmember cooling, heat rejection, and removal of expired water vapor. Lightweight and freezable radiators will be needed for thermal control. Innovative direct crewmember thermal control garments are sought, i.e., variable conductivity flexible suit layups that can function as a heat sink for high metabolic loads and as an insulator during period of low physical activity.

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 and behavioral health problems. Furthermore, the development of new vehicles for the human exploration of space provides the ideal opportunity to build the human element into the man-machine system at the outset, greatly simplifying activities and reducing the overall costs to the program. Additionally, significant advancements in food technologies will be needed for long-duration missions for both Lunar and Mars missions. Subtopic X12.01 Food and Galley seeks innovative technologies for providing shelf-stable food with a shelf-life of 3 – 5 years, new food packaging technologies that eliminate or minimize waste, and new technologies for on-orbit meal preparation and dining. Subtopic X12.02 Space Human Factors seeks models for predicting human performance in flight environments and activities, tools for designing and evaluating human interfaces, just-in-time information tools to aid astronauts in routine and emergency operations, as well as acoustic monitoring and abatement technologies for in-flight use.

X12.01 Food Access Beyond Low Earth Orbit
Lead Center: JSC

Exploration missions beyond low Earth orbit greatly limit allowable consumables and require development of innovative low maintenance, reconfigurable, reusable, or self-sufficient food production. Since regularly timed resupply will not be possible for a Mars mission, all the prepackaged shelf-stable food, ingredients, and equipment to provide a complete diet for six crewmembers for more than three years will have to be provided at the beginning of the mission. Advancements are necessary to develop a combination of extended duration shelf-life stored foods augmented with fresh foods.

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. 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. Once on the lunar or planetary surface, it may be possible to use bulk packaging of meals or snack items. These food products will require specialized processing conditions and packaging materials.

Current food packaging technologies represent a potentially significant trash-management problem for exploration-class missions to the Moon or Mars. New food packaging technologies are needed that minimize waste by using high barrier packaging with less mass and volume and/or by using packaging. Another opportunity would be development of a packaging material that can readily be reused by the crew to make objects of value to the space flight mission. All packaging materials must have adequate oxygen and water barrier properties to maintain the foods' 3 – 5 year shelf life.

Food preparation systems will be required to heat and rehydrate the shelf stable food items and to prepare meals from the processed and resupplied items. Technologies to support on-orbit crew meal storage, preparation, dining activities, and trash dispensing are being sought.

Food quality and safety are essential components in the maintenance of crew health and well-being. Efforts should be focused on control of food spoilage and food quality throughout the entire shelf life of the food. Effects of radiation on the stored food system quality are also needed. Food quality and safety efforts should be focused on identification and control of microbial agents of food spoilage, including the development of countermeasures to ameliorate their effects through food processing and food packaging.

X12.02 Long-Duration Space Human Factors
Lead Center: JSC
Participating Center(s): ARC

The long-term goal of this subtopic is to enable planning, designing, training, and executing long-duration human space missions that are up to 5 years without re-supply and real-time communications to Earth. Specifically, the focus of this subtopic is on the development of innovative crew equipment, technologies for human performance assessment/modeling/enhancement, and design tools for engineers to incorporate human factors engineering requirements into hardware and software. Proposals that aim at developing and addressing the following specific technology needs are solicited.

Technologies are needed for monitoring and maintaining human performance non-intrusively. Specifically, the technologies we seek are (1) minimally invasive and un-obtrusive devices and techniques to monitor the behavior and performance (physical, cognitive, perceptual, etc.) of individuals and teams during long-duration space flights or analog missions, as well as (2) embedded measures to detect significant changes in crew readiness to perform physical or cognitive tasks.

Methods and models are needed for predicting human performance. The particular technologies we seek are (1) methods and models for predicting effects on physical performance by encumbrances of clothing, space suits, etc., (2) models for predicting effects of physical environment (e.g., lighting, noise, temperature, contaminants) on human performance, (3) models to simulate and optimize interactions between humans and equipment/vehicle, (4) capability to implement time-delay algorithm and functionality into simulations for higher fidelity and effectiveness, and (5) models for predicting performance due to the effects of cognitive changes.

Cost-effective and reliable tools are needed for aiding the design and evaluation of human-system interfaces for speed, accuracy, and acceptability. The particular tools we seek shall (1) provide automated analysis of computer-user interfaces for complex display systems to conduct objective review of displays and controls, (2) determine compliance with guidelines and standards, and/or (3) offer quantitative measures of the effectiveness of user interfaces for task-sensitive evaluations.

Tools are needed to facilitate user interface design for human computer interfaces, procedures, labels, and instructions. These tools shall assist the designer in incorporating contextual information such as the user's task, the user's knowledge, and the system's limitations.

Tools are needed to build just-in-time system and operational information software that aid human users to conduct routine and emergency operations and activities. Such tools shall be either (1) effective and efficient job aids (e.g., "intelligent" manuals, checklists, and warnings) to support designing flexible interfaces between users and large information systems, or (2) methods for developing "facilitators" (procedures, labels, etc.) adapted for developing space vehicle and payload applications.

Acoustic monitoring systems are needed to accurately and autonomously monitor acoustic sound pressure and noise exposure levels in long-duration space vehicles. These technologies shall provide (1) acoustic sensor systems consisting of fixed and/or crew-worn transducers, (2) sound pressure level information as a function of frequency and/or time, (3) typical sound level meter and acoustic dosimeter functionality, and (4) the capability for autonomous operations and data transfer. Operation and data acquisition parameters of such systems shall be controllable either by ground personnel or the crew.

Innovative acoustic flight materials are needed for noise abatement. These materials shall function as acoustic absorbers, barriers, vibration isolators, dampers, spacecraft wall treatments, transparent containment, or combinations of these. These materials must be shown to satisfy space flight material requirements, such as off-gassing and flammability, and shall be easy to apply to hardware. The acoustic properties of these materials' shall be demonstrated through absorption or transmission loss testing, or by other standard acoustic testing techniques.

TOPIC: X13 Space Radiation

The space radiation environment is very different from the terrestrial radiation environment. It includes high-energy protons from solar activity as well as energetic heavy ions from galactic cosmic sources and their secondaries generated in vehicle structures. The success of future human exploration missions, especially future missions beyond low Earth orbit will depend on technologies that will allow astronauts to safely live and work in the space radiation environment. Technologies that will allow NASA to measure the biological effects of the unique types of radiation in the space environment are necessary to elucidate the types of countermeasures that are required and their efficacy. Subtopic X13.01, Radiation Health, seeks innovative technologies for increasing the throughput and capabilities in heavy ion beam experiments for radiobiology at the Brookhaven National Laboratory, automated and high-throughput techniques for identifying small scale cellular radiation damage from protons or heavy ions, and radiation dosimeters for manned and unmanned spaceflight.

X13.01 Space Radiation Health Research Technology
Lead Center: JSC
Participating Center(s): ARC, LaRC

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 distinct from terrestrial forms of radiation, being comprised of high-energy protons and heavy ions and their secondaries produced in shielding and tissue. The Radiation Program Element uses the NASA Research Announcement as a primary means of soliciting research to reduce the uncertainties in risk projections, however, there are specific areas where the SBIR technologies can potentially contribute to NASA's overall goal:

Ground-based Heavy Ion Accelerator Research Support Equipment
NASA utilizes Facilities at Brookhaven National Laboratory (BNL) (for more information see www.bnl.gov/medical/NASA/NSRL_description.asp) to conduct fundamental radiobiology and physics experiments. However the Facilities at BNL were not developed with NASA's high number of investigators in mind, thus there are areas where technology developments can improve efficiency and throughput. Technologies of specific interest include, but are not limited to, the following:

- Advanced animal support equipment, sample holders, live imaging of samples on the beam line during heavy ion irradiation, or specimen transport systems that allow remote transport into and out of the target areas and precise positioning of specimens in the beam line with minimal human interaction in the target areas;
- Environmental control for cell studies while in the beam line, and automated fixation capabilities to perfuse small cell and tissue samples directly after exposure to the ion beam;
- Advanced detector systems to provide rapid assessments of elemental fluence spectra and neutron fluence spectra following heavy ion irradiation of biological or shielding samples.

High Throughput Genomic Analysis Techniques
Following low dose irradiation of cells by protons and heavy ions, damage is localized to only a very few cells. The ability to separate cells with or without genetic changes in an automated manner is of interest. Current technologies are inefficient in identifying small-scale genetic changes (less than several thousand base-pairs (Mbp)) under these conditions. Technologies of interest are:

- Complementary technologies to the fluorescence in situ hybridization (FISH) method used to score large scale (>1 Mbp) genetic changes to chromosomes following low dose irradiation in order to rapidly score small-scale genetic changes (<1 Mbp);
- Imaging techniques to rapidly identify with high accuracy undamaged cells from a cell population irradiated at low doses.

Reliable Radiation Dosimeters for Manned and Unmanned Spaceflight
Current environment dosimeters have exceeded their designed lifetimes and should be replaced. These include small active dosimeters to monitor individual astronauts' exposure, Tissue Equivalent Proportional Counters (TEPC), Charged Particle Directional Spectrometer (CPDS) capable of internal and external deployment, and externally deployed electron and neutron detectors. New software needs to be fault tolerant and updated to current operating systems, new hardware and software must be fully documented (schematics, etc.). Areas of interest are:

- Advanced spaceflight detector systems to provide reliable environment data for a specific spectrum of energies, including real time dosimetry providing dose and particle types, and energies and cumulative dosimeters, for characterizing space environments for use onboard spacecraft and planetary surfaces, as well as alarm systems for Solar Particle Events. Dosimeters should provide time resolved linear energy transfer (LET) data and have embedded LET-based quality factor algorithms for determining dose equivalent. The expected radiation environment includes protons from 10 Mev to 1 GeV, electrons from .5 Mev to 7 Mev, primary and secondary HZEs (He to Fe) from 10 Mev/amu to 1 Gev/amu and secondary neutrons from 1 Mev to 200 Mev. NASA acknowledges the difficulty in measuring secondary neutrons from interactions of protons and heavy ions with spacecraft structures and has particular interest in this area.

TOPIC: X14 Exploration Medical Capabilities

Human exploration capabilities must keep the crew healthy so they can adequately perform their mission and return safely to Earth. These two subtopics seek innovative technologies in Human Health Countermeasures and Autonomous Medical Care to prevent degradations in performance and health from the adverse physiological responses to the space flight environment and to provide medical support in both normal activities and medical emergencies. They assure that there will be no long-term adverse health consequences while supporting a healthy and productive sustained human presence. The Lunar In Situ Autonomous Health Monitoring (X14.02) subtopic seeks an innovative multiparameter monitoring system suitable for monitoring astronaut health during Extravehicular Activity on the lunar surface which can also find use in intravehicular medical montioring and care. The Health Preservation in the Space Environment (X14.01) subtopic seeks either an instrumented treadmill or resistance exercise system suitable for flight mission and ground research use, a method for monitoring the effectiveness of pharmaceuticals in space, instrumentation for non-invasive measurement of intracranial pressure during space flight, or a non-invasive method for assessing strength via micro- and macro-architecture.

X14.01 Health Preservation in the Space Environment
Lead Center: JSC
Participating Center(s): ARC, GRC

Living and functioning efficiently and safely in space and in the hypogravity of the Moon (1/6g) or Mars (3/8g), requires an understanding of the effects of micro- and hypogravity and other space-environment related factors on human physiology responses and adaptations to a unique set of imposed demands. As a result, a variety of countermeasures are needed to mitigate the deleterious changes that occur during space flight and upon subsequent exposure to reduced-gravitational environments. The ability to monitor the effectiveness of countermeasures and alterations in human physiology during space exploration missions, particularly when several countermeasures are used concurrently, is equally important.

This subtopic seeks innovative technologies in several very specific key areas. As launch costs relate directly to mass and volume, instruments and sensors must be small and lightweight with an emphasis on multi-functional capabilities. Low power consumption is a major factor, as are design enhancements to improve the operation, design reliability, and maintainability of these instruments in the environment of space and on planetary surfaces. As the efficient use of time is extremely important, innovative instrumentation setup, ease of usage, improved astronaut (patient) comfort, noninvasive sensors, and easy-to-read information displays are also very important considerations. Extended shelf-life and ambient storage conditions of consumables are also key necessities. Ability to operate in 0g, 1/6g, and 3/8g become more important as we march towards human Moon and Mars missions.

Exercise and Related Hardware
Miniaturized exercise hardware (treadmill or resistance exercise); physiological monitoring devices; and metabolic gas (carbon dioxide, oxygen) analysis systems for use with exercise and miniaturized interactive feedback and entertainment systems. A tool or toolkit should simulate and visualize the exercise device design and performance. A comprehensive, scaled 3D/virtual human model interface would be valuable to show biomechanical and kinetic effects of the exercise device. Relative physiological data from anthropometry to stress/fatigue to trauma/insult onset should be targeted.

Noninvasive Pharmacotherapy and Monitoring
Development of innovative technologies resulting in noninvasive methods for diagnosis, treatment, and therapeutic drug monitoring is needed to facilitate effective pharmacotherapy of humans in space. Many questions remain about the effectiveness of pharmaceuticals in micro- and hypogravity environments, which may interfere with their activity by sensitizing or desensitizing the crew member or interfering in other ways with the desired physiological effect. Micro-encapsulation of drugs and development of novel drug delivery systems under micro- and hypogravity conditions. Devices for continual monitoring of physiology during pharmacotherapy would also be advantageous to ensure that on-orbit expression of therapies relates to on-earth histories.

Instrumentation for Noninvasive Measurement of Intracranial Pressure During Space Flight
Abrupt transitions between differing gravitational environments have profound physiologic impacts on human space travelers. For instance, immediately following insertion of the spacecraft into Earth orbit, cephalad fluid shifting occurs. Over the next several days, all crewmembers onboard suffer from what has been termed Space Adaptation Syndrome (SAS) that varies in severity from person to person. The prevailing theory for the appearance of the constellation of symptoms (headache, malaise, vomiting, vertigo, etc.) which comprise this syndrome implicates a “sensory conflict” in information provided by the adapting vestibular system and by visual inputs. Another theory implicates the increased intracranial pressure (ICP) that likely accompanies the cephalad fluid shifts in the genesis of SAS. Additionally, decreased ICP following return to Earth’s gravity may explain symptoms experienced by many crewmembers. Thus, novel approaches to noninvasive measurement of ICP are needed to determine the etiology and pathogenesis of the untoward physiologic effects that plague human space travelers during abrupt transitions between different gravitational environments. A more complete understanding of these phenomena will lead to better prevention and treatment modalities that will in turn decrease risks to the health and performance of crew-members during transitional periods of both high to low and low to high gravity environments.

Non-invasive Technology to Assess Bone Micro- and Macroarchitecture
A complete assessment of bone strength will better monitor life-time skeletal integrity and will generate data critical for developing probability fracture risk models in younger crew members. Novel technology for non-invasive assessments of “bone quality” indices such as microarchitecture, macroarchitecture and trabecular bone mineral density (BMD).

X14.02 Lunar In Situ Autonomous Health Monitoring
Lead Center: JSC
Participating Center(s): ARC, GRC

Exploration missions to the lunar surface will be characterized by science goals and objectives which will require crewmembers to actively investigate the accessible exterior environment via Extravehicular Activity (EVA). During the EVA sorties, it will be critical for the crewmembers to be able to monitor their personal health status and to make decisions based on feedback from intrinsic biomedical monitoring systems. Furthermore, it will be necessary to simplify these systems for rapid donning and doffing, automatic checkout capability, annunciation and guidance during suit anomalies, and ensuring the health and safety of each crewmember. Therefore, the sensors that will be used for biomedical monitoring need to be low profile (perhaps incorporated into an undergarment), accurate, reliable, and with as few wires as possible. In addition, the use of electrodes with electrode gel and overtapes has not been highly successful, resulting in skin irritation, adhesion problems, stowage concerns and limited life/inventory issues. Furthermore, our experience has demonstrated that commonality between and among systems is highly beneficial. For this reason, the biomedical sensors used for monitoring EVA should be applicable for intravehicular use as well. Some of the parameters that would be desirable for EVA monitoring include:

- Metabolic Rate
- Heart Rate
- Thermal Control
- ECG (possible)
- Oxygen Consumption Rate
- CO_2 Level (in the oronasal area)
- CO_2 Generation Rate
- Core and/or Skin Temperature
- Radiation Monitoring (possible)
- Oxygen Saturation Level

In addition, development of device(s) capable of being used in an IVA system which is common with the EVA system is highly desirable. All of these, whether used for IVA or EVA, must be comfortable for the crewmember, allow the crewmember to continue performing tasks, and must not preclude normal activities when used for IVA monitoring (e.g. hygiene, eating, working at the computer, and exercising).

9.1.3 SCIENCE

The fundamental goal of the Vision for Space Exploration is "to advance U.S. scientific, security, and economic interests through a robust space exploration program." By pursuing the goal of the Vision for Space Exploration, NASA will keep the Nation at the cutting edge of science and technology, as outlined in the 2006 NASA strategic plan (available at http://www.nasa.gov).

Science both enables, and is enabled by, exploration. Keeping this in mind, the science objectives of the NASA Science Mission Directorate is to develop a balanced overall program of science and exploration consistent with the redirection of the human spaceflight program, including:

1. Study planet Earth from space to advance scientific understanding and meet societal needs: (i) Develop predictive capability for changes in the ozone layer, climate forcing, and air quality, weather and extreme weather events, water cycle change and fresh water availability and carbon cycle and ecosystem; (ii) Quantify global land cover change and terrestrial and marine productivity, key reservoirs and fluxes in the global water cycle; (iii) Understand the role of oceans, atmosphere, and ice in the climate system and predicting its future evolution, Earth surface changes and variability of the Earth's gravitational and magnetic fields; and (iv) Expand and accelerating the realization of societal benefits from Earth system science.

2. Understand the Sun and its effects on Earth and the Solar System: (i) Understand the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium; (ii) Understand how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields; and (iii) Predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers.

3. Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space: (i) Learn how the Sun's family of planets and minor bodies originated and evolved; (ii) Understand the processes that determine the history and future of habitability in the solar system, including the origin and evolution of Earth's biosphere and the character and extent of prebiotic chemistry on Mars and other worlds; (iii) Identify and investigate past or present habitable environments on Mars and other worlds, and determining if there is or ever has been life elsewhere in the solar system; and (iv) Explore the space environment to discover potential hazards to humans and to search for resources that would enable human presence.

4. Discover the origin, structure, evolution, and destiny of the universe, and search for Earth-like planets: (i) Understand the origin and destiny of the universe, phenomena near black holes, and the nature of gravity; (ii) Learn how the first stars and galaxies formed, and how they changed over time into the objects we recognize in the present universe; (iii) Learn how individual stars form and how those processes ultimately affect the formation of planetary systems; and (iv) Create a census of extra-solar planets and measuring their properties.

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

http://science.hq.nasa.gov

TOPIC: S1 Robotic Exploration of the Moon and Mars

NASA is aggressively pursuing the search for resources on the Moon necessary to sustain prolonged human habitation and the search for water and life on Mars using robotic explorers. NASA is investing in key capabilities to enable advanced robotic missions to the Moon and Mars. This suite of technologies will enable NASA to rapidly respond to discoveries this decade and pursue the search for water and life at Mars wherever it may lead. The technologies developed and tested in each mission will help enable even greater achievements in the missions that follow. See URL: http://marstech.jpl.nasa.gov/ for additional information on Mars Exploration technologies. Key goals are to (1) conduct robotic expeditions to further science and to test new exploration approaches, technologies, and systems that will enable future human exploration of the Moon and Mars; and (2) conduct sustained, long-term robotic exploration of Mars to understand its history and evolution, to search for evidence of life, and to expand the frontiers of human experience and knowledge.

S1.01 Surface Robotic Exploration
Lead Center: JPL
Participating Center(s): ARC

Sample acquisition and handling will be important elements of future landed missions. Sample manipulation technologies are needed to enable handling and transfer of unstructured samples from a sampling device to instruments and sample processing systems. Shallow core, rock, 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 samples will be of similar volumes. Actual samples to be analyzed in instruments will likely be small subsamples so the means for subsampling and manipulation of the original sample and subsamples needs to be developed. Minimal size and mass components and systems have the greatest benefit.

Mobility technology is needed to enable access to difficult-to-reach sites such as distant locations or 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 and marsupial systems are two 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, e.g., a primary vehicle could provide long traverse to the vicinity of a challenging site and then deploy a smaller vehicle with steep mobility access capability for access to the site. Innovative low-mass, low-power, and highly modular systems and subsystems are of particular interest.

The program is also interested in new sensors such as small, low-power lidar for more robust navigation.

Examples of planetary robotics system are shown at http://robotics.jpl.nasa.gov.

S1.02 Subsurface Robotic Exploration
Lead Center: JPL
Participating Center(s): ARC

Robust systems for accessing the subsurface of the Moon and Mars are critical to the next generation of robotic explorers. 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).

Research should be conducted to develop compact, low-power, lightweight subsurface sampling systems with access to depths of 1 – 3 m below the surface. A relevant mission scenario for this type of drill would include drilling multiple holes from a mobile platform, such as a rover. For reference, current Mars-relevant rovers range in mass from 200 – 800 kg.

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. Additional areas of interest include understanding the limitations of dry drilling into mixed media, including icy mixtures of rock and regolith.

Also of particular need are means of acquiring subsurface rock and regolith samples with minimum contamination. This contamination may include contaminants brought to the sample by the drill itself, material from one stratigraphic layer contaminating samples collected at another depth (sample cross-contamination), or Earth-source microbes brought to the Martian surface prior to drilling ('clean' sampling from a 'dirty' surface).

S1.03 Martian Entry, Descent and Landing Sensors
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.

TOPIC: S2 Robotic Exploration Throughout the Solar System

NASA's program for Solar System Exploration seeks to answer fundamental questions about the Solar System and life: How do planets form? Why are planets different from one another? Where did the makings of life come from? Did life arise elsewhere in the solar system? What is the future habitability of Earth and other planets? The search for answers to these questions requires that we augment the current remote sensing approach to solar system exploration with a robust program that includes in situ measurements at key places in the solar system, and the return of materials from them for later study on the Earth. We envision a rich suite of missions to achieve this including a comet nucleus sample return, a Europa lander, and a rover or balloon-borne experiment on Saturn's moon, Titan, to name a few. These robotic explorers will pursue compelling scientific questions, demonstrate breakthrough technologies, identify space resources, and extend an advanced telepresence that will send stunning imagery back to Earth. Numerous new technologies will be required to enable such ambitious missions. This topic includes investments in technology to enable the delivery and access of scientific instruments to planetary surfaces and atmospheres. This includes landing, flying, roving, and digging, as well as sample acquisition for delivery to instruments. This topic will also address Earth entry vehicles for sample return missions, planetary protection, and contamination control for in situ missions. The planetary bodies of interest are the Moon, Mars, Venus, Titan, and the icy satellites of the outer planets.

S2.01 Astrobiology and Atmospheric Instruments for Planetary Exploration
Lead Center: JPL
Participating Center(s): ARC

This subtopic supports the development of advanced instruments and instrument technologies to enable or enhance scientific investigations on future planetary missions. New measurement concepts, advances in existing instrument concepts, and advances in critical components are all of interest. Proposers are strongly encouraged to relate their proposed technology development to future planetary exploration goals. These goals include geochemical, geophysical and astrobiological objectives.

Astrobiology includes the study of the origin, evolution, and distribution of life in the universe. New technologies are required to enable the search for extant or extinct life elsewhere in the solar system, to obtain an organic history of planetary bodies, to discover and explore water sources elsewhere in the solar system, and to detect microorganisms and biologically important molecular structures within complex chemical mixtures. Biomarkers produced by microbial communities are profoundly affected by internal biogeochemical cycling. The small spatial scales at which these biogeochemical processes operate necessitate measurements made using microsensors. The search for life on other planetary bodies will also require systems capable of moving and deploying instruments across, and through, varied terrain to access biologically important environments.

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.

Examples of instruments that will meet the goals include, but are not limited to, the following:

- Instrumentation for definitive chemical, mineralogy, and isotopic analysis of surface materials: soils, dusts, rocks, liquids, and ices at all spatial scales, from planetary mapping to microscopic investigation. Examples include advanced techniques in reflectance spectroscopy, wet chemistry, laser-induced breakdown spectrometers, water and ice detectors, novel gas chromatograph and mass spectrometry, and age-dating systems;

- Instrumentation for the assessment of surface terrain and features. Examples include lidar systems and advanced imaging systems;
- Geophysical sensing systems to determine the near-surface and subsurface structure, textures, bulk components, and composition, such as seismic sensors, porosity measurement devices, permeameters, and surface penetrating radars;
- Instrumentation focused on the identification and characterization of biomarkers of extinct or extant life, such as prebiotic molecules, complex organic molecules, biomolecules, or biominerals;
- Instrumentation for the chemical and isotopic analysis of planetary atmospheres;
- Advanced detectors for solar absorption spectrometry. One example is a detector that is fast and linear, i.e., does not saturate under high photon fluxes;
- Environmental sensing systems, such as meteorological sensors, humidity sensors, wind and particle size distribution sensors, and sounders for atmospheric profiling;
- Particles and fields measurements, such as magnetometers, and electric field monitors; and
- Enabling instrument component and support technologies, such as laser sources, miniaturized pumps, sample inlet systems, valves, integrated bulk sample handling and processing systems, and fluidic technologies for sample preparation.

Instruments specific to astrobiology include:

- For Mars or Venus exploration, technologies that (using X-ray, neutron, ultrasonic, and other types of tomography) would enable a noninvasive, nondestructive analysis of biomarkers inside rocks and ice to depths 10 – 20 cm with spatial resolutions of 2 – 10 microns;
- Technologies that would enable the aseptic acquisition of samples under conditions of extreme environments;
- For Europa and Enceladus exploration, technologies to enable the penetration of ice and/or access to subsurface vents are required;
- High sensitivity (femtomole or better), high-resolution methods applicable to all biologically relevant classes of compounds for separation of complex mixtures into individual components;
- High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures;
- Biotechnology-determining mutation rates and genetic stability in a variety of organisms as well as accurately determining protein regulation changes in microgravity and radiation environments;
- Automated chemical analytical instrumentation for determining gross metabolic characteristics of individual organisms and ecologies as well as chemical composition of environments;
- High-resolution, high-sensitivity (femtomole or better) methods for the isolation and characterization of nucleic acids (DNA and RNA) from a variety of organic and inorganic matrices; and
- Microscopic techniques and technologies to study soil cores, microbial communities, pollen samples, etc., in a laboratory environment for the detailed spectroscopic analysis relevant to evolution as a function of climate changes.

S2.02 In Situ Planetary Atmospheric Measurement Technologies
Lead Center: JPL
Participating Center(s): ARC, GRC, GSFC, MSFC

Proposals are sought for technologies that enable the in situ exploration of the surface and deep atmosphere of Venus and the deep atmospheres of Jupiter or Saturn for future NASA missions. Venus features a dense, CO_2 atmosphere completely covered by clouds with sulfuric acid aerosols, a surface temperature of 486ºC, and a surface pressure of 90 atmospheres. Although already explored by various orbiters and short-lived atmospheric probes and landers, Venus retains many secrets pertaining to its formation and evolution. NASA is interested in expanding its ability to explore the deep atmosphere and surface of Venus through the use of long-lived (days or weeks) balloons and landers. Survivability in extreme high temperatures (~480°C) and high pressures (~100 atmospheres) is also required for deep atmospheric probes to giant planets. Technology advancements to permit operation and survivability in high-temperature/high-pressure planetary environments are sought in the following areas:

Pressure Vessels and Structural Shells
Historically, titanium and aluminum have been used as structural shells or pressure vessels for extreme environment planetary probes and landers. Improvements in the state-of-the-art of pressure vessel materials are sought to reduce the mass of such components by 20 to 50% over titanium shells. New structural shell materials shall exhibit high strength and stiffness at elevated temperatures and shall be resistant to creep and buckling under high external pressures.

Thermal Control Systems
Survivability of electronic components in high temperature environments relies on three basic areas of thermal control: isolation, thermal capacitance and/or refrigeration. Specific improvements in are sought in the development of:

- Lightweight and stable insulation materials with a conductivity less than 0.1 W/m-K at 486ºC and 90 atm pressure;
- Thermal energy storage systems with 300 – 1000 kJ/kg energy density through either phase changes or chemical heat absorption;
- High performance, low mass refrigeration cooling systems capable of pumping on the order of 100 Watts of heat from a 100ºC source to the Venus sink temperature of 486ºC. In this area, particular attention must be paid to the power source for such a system. A total systems approach must be considered as opposed to development of a particular component.

High Temperature Electronics

- Science and engineering sensors able to operate at 486ºC and 100 bar, including for example, high temperature imagers, hybrid imaging system that utilizes high temperature fiber optics, seismometers, and pressure sensors;
- High-temperature, low-power, and ultra low-power electronics and electronic packaging technology for sensor and actuator interfaces at 486ºC, including low-noise (10 nV/sqHz) preamplifiers, power amplifiers and transmitters (S-band), temperature stable oscillators, drivers (with 0-100 V digital output for driving piezoelectric, electrostatic, or electromagnetic actuators), and high value (on the order of one to hundreds of micro Farad) capacitors;
- Computer aided simulation tools for predicting the performance, reliability, and life cycle for high-temperature electronic systems and components.

High Temperature Motors and Actuators

- Actuators for sample handling and acquisition systems including high-temperature drills, motors, and actuators able to operate in the 486ºC, 90 atmosphere surface environment of Venus.

S2.03 Energy Conversion and Power Electronics for Deep Space Missions
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

Proposals are solicited to develop advanced energy conversion and power electronics to enable or enhance the capabilities of next decadal deep space missions, with potential missions to Europa, Venus, Titan, and primitive bodies. These missions require power systems with long life capability and high reliability and offering significant mass and volume savings and improved efficiency compared to the state of practice (SOP) devices. Other desired capabilities are high radiation tolerance, and ability to operate in extreme environments (high and low temperatures and over wide temperature ranges).

Extreme Photovoltaics Energy Conversion

NASA has an increasing interest in solar array technology for deep space missions. The science community is currently pushing for solar missions that go as far as Saturn. PV proposals are sought to develop advanced photovoltaic devices and systems that can operate in extreme environments and offer significant mass and volume savings over the SOP systems. Photovoltaic cell and array technologies should also have significant improvements in efficiency, specific power, cost, and ability to operate in high-radiation, extreme-temperature environments such as near sun (high-intensity, high-temperature - HIHT) environment or deep space (low-intensity, low-temperature - LILT) environments. Extreme Photovoltaic technologies of interest are:

- Solar cells that can function effectively under LILT conditions and high radiation environments for deep space missions beyond 4 AU;
- Solar cells that can operate high temperatures (up to 450°C) for near sun missions (< 0.2 AU);
- Solar arrays with high specific power (> 250 W/kg) and low stowage volume for solar electric propulsion missions.

RPS Energy Conversion

Radioisotope power systems (RPS) are presently used in some planetary surface missions and deep space science missions that go beyond 4 AU. Proposals are sought to develop advanced RPS technologies that would contribute to a system with long life capability (> 14 years), high conversion efficiency (> 20%), and high specific power (> 8 – 10 W/kg). The radioisotope power conversion systems of interest are, Stirling, Thermoelectrics (TE), and Thermophotovoltaics (TPV). All proposed energy conversion technologies must be able to operate in deep space environments with high radiation and wide-temperature operations (-200°C to >300°C). A high priority for NASA is the development of advanced static power conversion technologies (TPV or TE) that offer greater than 20% thermal-to-electric conversion efficiency for an RPS system, as well as power conversion approaches that can operate in the extreme environments of Venus and Europa.

Thermophotovoltaic technologies should focus on demonstrating converter component technologies that offer improved performance parameters:

- Photovoltaic devices capable of operating at high temperature (> 50°C) and high current density for extended durations (> 14 yr) while maintaining high performance;
- Optical filters that offer high spectral efficiency and high temperature survivability (> 150°C);
- Emitter materials that offer high efficiency as well as low evaporative losses suitable for extended (14 yr) operation;
- Solar concentrator based TPV systems with concepts for thermal energy storage and their integration with the emitter systems.

Thermoelectric technologies should focus on:

- High temperature and performance thermoelectric materials. NASA is interested in nanostructured thermoelectric materials with potential for ZT > 2 and ability to operate at temperatures and lifetimes compatible with RPS systems;
- Innovative packaging of thermoelectric elements in closed or compact arrays;
- Sublimation coatings or methods.

Stirling power conversion technologies should focus on:

- 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);
- Advanced regenerators with improved durability and high temperature capability while maintaining high performance;

- Lightweight, high-efficiency linear alternators with low EMI and capable of high-temperature operation;
- High temperature heater heads (> 850°C) and joining techniques.

Advanced Photovoltaics Energy Conversion
Photovoltaic cell and array technologies with significant improvements in efficiency, mass specific power, stowed volume, cost, radiation resistance, and wide operating conditions are solicited. Photovoltaic cell technologies for wide temperature operation and radiation environments are solicited. Potential array technologies of interest include:

- Rigid and deployable arrays;
- Concentrators (rigid or inflatable, primary or secondary);
- Ultra-lightweight arrays for lightweight, flexible;
- Thin-film photovoltaic cells;
- Electrostatically clean spacecraft solar arrays.

Energy Conversion Thermal Management
Thermal technology areas include heat rejection, composite materials, heat pipes, pumped loop systems, packaging and deployment, including integration with the power conversion technology. Highly integrated systems are sought that combine elements of the above subsystems to show system level benefits.

S2.04 Flexible Antennas and Electronics for L-Band Remote Sensing
Lead Center: JPL

Electronically steerable L-band, phased array antennas are needed for missions to the Moon, Mars, Titan, Europa and Venus for remote sensing applications and support of communications. Flexible, lightweight active arrays enable better packaging efficiency for the antenna and are critical for these missions. These antennas will be deployed on orbiting spacecraft and on rovers or aerial platforms such as lighter than atmospheres (LTA) vehicles or airplanes.

When used for active remote sensing, L-band also provides the capability to detect surface and subsurface topology including density contrasts within the ice or dust and subsurface water or warm ice. In addition, the use of L band frequencies enables proximity communications between the in situ vehicle and a spacecraft in orbit or on a flyby trajectory.

Currently, manufacturing reliable passive arrays with required tolerances is challenging and the only method for integration of the electronics is to attach and interconnect the electronic components on the surface. This method is expensive, unreliable, and impractical for large arrays. Technologies enabling large area flexible antennas, including flexible electronics, are needed. State-of-the-art, flexible, printable electronics have low switching frequencies. Innovative new materials or processes will be needed to enable devices that can handle the gigahertz frequencies needed for radar. In addition, large area manufacturing methods are needed to manufacture these passive and active antennas.

S2.05 Planetary Balloons and Aerobots
Lead Center: JPL
Participating Center(s): GSFC

Innovations in materials, structures, and systems concepts have enabled buoyant vehicles to play an expanding role in NASA's Solar System Exploration Program. Balloons and airships will carry scientific payloads on Mars, Venus, Titan, and the outer planets 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:

Hot Air (Montgolfiere) Balloons for Titan
NASA is considering the use of hot air (Montgolfiere) balloons for Titan using waste heat from the radioisotope power source (RPS). Proposals are sought for concepts and prototypes for this balloon that have the following nominal characteristics: 2000 Watts of available RPS waste heat, a 100 gm/m^2 balloon envelope material, 160 kg of payload mass (including the RPS but excluding the balloon), and a controllable altitude over the range of 0 to 10 km with the ability to maintain a +/- 20 m tolerance near the surface (93K, 1.46 bar). It is important that the balloon be storable in a typical entry vehicle for transport to Titan and be deployed and inflated upon arrival. Preference will be given to proposals that include cryogenic testing to validate the thermal performance models upon which the design is based.

Apex Valve for Montgolfiere Balloons
Solar-heated Montgolfiere balloons are an attractive platform for the exploration of Mars, particularly the polar regions which experience long periods of solar illumination during summer solstice. These balloons can be altitude controlled through selective venting of the heated gas through a valve located at the apex of the balloon. Proposals are sought for concepts and prototypes for this valve to be used on a solar-heated balloon on Mars. Typical specifications include large flow area (10 m^2), low mass (few kilograms), packaged into a small volume for transport to Mars (< 0.1 m^3) and consume minimal electrical energy (< 5 W).

Aerial Deployment Modeling Tool
Planetary aerobots at Mars, Titan, and Venus will likely be aerially deployed and inflated during parachute descent after arrival at the destination. Proposals are sought that would provide computer modeling tools that can simulate this complex process. Of particular importance is the ability to model the balloon shape and material stresses as a function of time, taking into account the aerodynamic forces generated by the parachute and by the uninflated or partially inflated balloon, as well as transient loads during balloon deployment from its storage container. The balloons can be either polymer film or polymer film plus reinforcing fabric laminates.

Metal Bellows for High Temperature Venus Balloons
Cylindrically-shaped metal bellows are a potential solution to the problem of making balloons that can tolerate the 460°C temperatures near the surface of Venus. Commercial off-the-shelf metal bellows are limited in diameter to approximately 0.4 m. NASA seeks proposals for metal bellows technology that can produce prototypes in the range of 1 – 2 m in diameter and 5 – 10 m long; tolerant of sulfuric acid; good fatigue properties at 460°C; and areal densities of up to 1 kg/m^2.

TOPIC: S3 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 nano-technology, and wavefront sensing and control are needed to build telescope for Earth science that have the potential to cost between $50 to $150M.

S3.01 Precision Spacecraft Formations for Advanced Telescope Systems
Lead Center: JPL
Participating Center(s): GSFC

This subtopic seeks hardware and software technologies necessary to establish, maintain, and operate hyper-precision spacecraft formations to a level that enables cost effective large aperture and separated spacecraft optical telescopes and interferometers. Also sought are technologies (analysis, algorithms, testbeds) to enable detailed analysis, synthesis, modeling, and visualization of such constellations.

In a formation for large effective telescope apertures, multiple, collaborative spacecraft in a precision formation collectively form a variable-baseline interferometer. 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. It is important that, in order to enable precision spacecraft formation keeping from coarse requirements (relative position control of any two spacecraft to less than 1 cm, and relative bearing of 1 arcmin over target range of separations from a few meters to tens of kilometers) to fine requirements (micron relative position control and relative bearing control of 0.1 arcsec), the interferometer payload would still need to provide at least 1 – 3 orders of magnitude improvement on top of the S/C control requirements. The spacecraft also require onboard capability for optimal path planning and time optimal maneuver design and execution.

Development of combined nanometer-level precision formation flying control of numerous spacecraft and their optics is required to enable large baseline (1 to 10's of km), sparse aperture UV/optical (and perhaps X-ray) tele-scopes and interferometers needed for ultra-high angular resolution imagery.

Proposals addressing staged-control experiments that combine coarse formation control with fine-level wavefront sensing based control are particularly encouraged. Innovations that address the above precision requirements are solicited for formation systems in the following areas:

- Integrated optical/formation/control simulation tools;
- 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; and
- Six degrees of freedom precision formation test beds.

S3.02 Proximity Glare Suppression for Characterization of Faint Astrophysical Objects
Lead Center: JPL

This subtopic addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources and innovative advanced wavefront sensing and control for cost-effective space telescopes. Examples include: planetary systems beyond our own, the detailed inner structure of galaxies with very bright nuclei, binary star formation, and stellar evolution.

Contrast ratios of one million to ten billion over an angular spatial scale of 0.05-1.5 arcsec are typical of these objects. Achieving a very low background requires control of both scattered and diffracted light. The failure to control either amplitude or phase fluctuations in the optical train severely reduces the effectiveness of starlight cancellation schemes.

This innovative research focuses on advances in coronagraphic instruments, starlight cancellation instruments, and potential occulting technologies that operate at visible and infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission. Much of the scientific instrumentation used in future NASA observatories for the astrophysical sciences will require control of unwanted radiation (thermal and scattered) across a modest field of view. The performance and observing efficiency of astrophysics instruments, however, must be greatly enhanced. The instrument components are expected to offer much higher optical throughput, larger fields of view, and better detector performance. The wavelengths of primary interest extend from the visible to the thermal infrared. Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development, and innovative instrument design, as well as in the fabrication of subsystem devices to include, but are 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;
- Metrology for detailed evaluation of compact, deep density apodizing masks, Lyot stops, and other types of graded and binary mask elements. Development of a system to measure spatial optical density, phase inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of masks and stops is needed;
- Interferometric starlight cancellation instruments and techniques to include aperture synthesis and single input beam combination strategies;
- Fiber optic spatial filter development for visible coronagraph wavelengths;
- 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 104 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;
- 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. The most promising DM technology may be sensitive to temperature, so developing a MUX that has very low thermal hot spots, and very uniform temperature performance will improve the control of the mirror surface;
- High precision wavefront error sensing and control techniques to improve and advance coronagraphic imaging performance; and
- Highly reflecting broadband coatings.

S3.03 Precision Deployable Structures and Metrology for Advanced Telescope Systems
Lead Center: JPL

Planned future NASA Missions in astrophysics, (such as the Single Aperture Far-IR (SAFIR) telescope, 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 telescopes 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 may be achieved through passive means (e.g., via a high stiffness system) or through active control. 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 control distributed on or within the structure (downstream corrective and adaptive optics are not included in this topic area); actuator systems for alignment of reflector panels (order of cm stroke actuators, lightweight, submicron dynamic range, nanometer stability); 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 tens of points on the primary mirror. Also measurement of the metering truss. Innovative systems which minimize complexity, mass, power and cost are sought.

The goal for this effort is to mature technologies that can be used to fabricate 20 m class, lightweight, ambient or cryogenic flight-qualified telescope primary mirror systems. Proposals to fabricate demonstration components and subsystems with direct scalability to flight systems (concept described in the proposal) 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 on the scale of 3 m for characterization.

S3.04 Optical Devices for Starlight Detection and Wavefront Analysis
Lead Center: MSFC
Participating Center(s): GSFC, JPL

This subtopic addresses the unique problems associated with collecting and pre-detection processing of star light for advanced optical telescopes and telescope arrays. This topic includes innovative optical subsystems, devices and components that directly collect and process optical signals and images for all regions of the electromagnetic spectrum from X-ray to UV to Visible to Far-IR/Sub-MM. Pre-detection technologies of interest include capabilities to preprocess or analyze an optical wave front or signal to extract time-dependent, spectral, polarization and spatial information from scenes or signals prior to detection. These devices can be placed anywhere within an optical system, between the entrance aperture and the focal plane. A specific technology area of interest is high reflectance UV coatings and uniform polarization coatings for all wavelengths. Collection technologies of interest include capabilities which enable large-baseline segmented-aperture telescopes and sparse aperture telescopes and interferometers that will be needed to obtain high angular resolution observations to support future science goals. This subtopic addresses problems associated with formation flying including development of high-precision, high-stability laser and phase sensors, as well as of techniques to enable the monitoring of the separations of the individual spacecraft and overall orientation of the constellation. Specifically of interest is component-level technology needed to enable the characterization and combination of wavefronts from multiple apertures. Innovative technology to fabricate and test large aperture optical substrates continues to be an interest of this subtopic. Additionally, this interest is specifically extended to include technology to fabricate and test large aperture very lightweight x-ray mirrors. The primary objective of this subtopic is to reduce the mass and volume of advanced telescopes and observatories – either the primary mirror or the relay and science instrument optics. The proposed effort 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.

Proposals in the following areas are specifically solicited:

- Design and construction of UV, optical, infrared or far-infrared beam combiners suitable for wavelength-resolved fringe measurements from a large number of independent apertures with flat response over a broad wavelength range;
- Development of a metrology system suitable for monitoring path lengths in the meter to kilometer range with incremental resolutions of picometers and milliseconds, and sub-micron absolute distance resolution;
- Development and test of low cost laser metrology gauges and optical pathlength control devices for alignment and control in multi-stage, multi-vehicle formations;
- Single frequency, long lifetime (>10 years), visible, IR stable semiconductor lasers in the power range 1 to 10 watt for metrology of optical systems, wavefront sensing and control and interferometry;
- High throughput, radiation hard, large area, X-ray imaging devices such as Fresnel Zone plates and masks;
- Wavelength division demultiplexers, integrated optics waveguide, fiber optic and light pipe devices for spectral analysis of scene information from UV to IR;
- Innovative mirror substrate material/fabrication/test technologies and mounting/support technologies for large aperture lightweight low-cost x-ray, ambient and cryogenic applications in space telescopes;
- Optical coatings: broad-band polarization preserving and polarizing for UV to Far-IR/Sub-MM; high-reflectivity EUV; large area, high acceptance angle narrow-band optical filters; broad-band wide-acceptance angle UV anti-reflection on PMMA substrates; environmentally stable protected silver.
- Components or devices for spectroscopy and imaging applications using hyperspectral, polarometric, Stokes photo-polarimeters, etc. technology for visible to infrared.

TOPIC: S4 Exploration of the Universe Beyond Our Solar System

The Universe division of the NASA/GSFC is charged with exploring the universe beyond the solar system – out to its very edges. To do this requires ever more sophisticated instruments (surpassing Chandra, Spitzer, and Hubble) with larger and better optics and more sensitive detector systems. Future mission may include spacecraft in formation-flyin; optics that fold and deploy and can be assembled on orbit; as well as larger arrays of detectors: bolometers, microcalorimeters, and room temperature semiconductors. Some of these arrays may contain billions of pixels. Our missions cover the full range of the electromagnetic spectrum (from sub-mm to gamma-rays) and gravitational waves. Some of our major science goals are to identify dark matter, to understand dark energy, to produce a census of black holes, to image material in the accretion disks around black holes and to measure gravitational waves from a wide range of sources. In addition, we are exploring new technologies for terrestrial sub-orbital platforms including long duration balloons, tethered balloons, and airships. We are soliciting ideas and concepts in six areas covering optical systems, UV, visible, IR and sub-mm detectors, x-ray and gamma-ray detectors, lasers for gravitational wave measurements, and sub-orbital platforms. The subtopics in this area are described in detail in each subtopic section.

S4.01 Sensor and Detector Technology for Visible, IR, Far IR and Submillimeter
Lead Center: JPL
Participating Center(s): GSFC

NASA astrophysics missions currently under development, such as the Herschel and Planck, (http://science.hq.nasa.gov/missions/phase.html) have been enabled by improvements in detectors. Beyond 2007, advances are expected in detectors, readout electronics, and other technologies, particularly those enabling polarimetry and large format imaging arrays for the visible, near IR, IR and far IR/submm and spectroscopy with unprecedented sensitivity. These advances may enable future mission concepts such as the Single Aperture Far Infrared (SAFIR) Observatory (http://safir.jpl.nasa.gov/technologies/index.asp), SPICA (http://www.ir.isas.ac.jp/SPICA/), CMBPOL, and SNAP (http://snap.lbl.gov). Space science sensor and detector technology innovations are sought in the following areas:

Future space-based observatories in the 10 – 40 micron spectral regime will be passively cooled to about 30 K. They will make use of large, sensitive detector arrays with low-power dissipation array readout electronics. Improvements in sensitivity, stability, array size, and power consumption are sought. In particular, novel doping approaches to extend wavelength response, lower dark current and readout noise, novel energy discrimination approaches, and low noise superconducting electronics are applicable areas. Future space observatories in the 40 micron to 1 mm spectral regime will be cooled to even lower temperatures, frequently < 10 K, greatly reducing background noise from the telescope. In order to take advantage of this potentially huge gain in sensitivity, improved far infrared/submillimeter detector arrays are required. The goal is to provide noise equivalent power as low as 10^{-20} W $Hz^{-1/2}$ over most of the spectral range in a 10,000 pixel detector array with low-power dissipation array readout electronics. The ideal detector element would count individual photons and provide some energy discrimination. For detailed line mapping (e.g., C+ at 158 micron), heterodyne receiver arrays are desirable, operating in the same frequency range near the quantum limit.

In addition to technologies specific to the astrophysics missions previously mentioned, the following cross-cutting technologies are also of interest:

- Large (4 meter), lightweight, deployable antennas for frequencies between 180 to 660 GHz. Reflectors for such antennas with surface densities of 10 kg/m^2 or less.
- Broadband (> 2 GHz, 4 GHz preferred), modest resolution (10 MHz), low power (< 5 watt) digital spectrometers for submillimeter spectroscopy. This may include enabling technologies such as:
  - Efficient FPGA firmware for spectral analysis including polyphase filterbanks;
  - High speed, low power, space qualifiable digitizers with analog bandwidths of > 5 GHz and preferably up to 18 GHz, sample rates > 5 Gs/s, 4 to 6 bit resolution, and simple interface to present FPGAs;
  - Hardware (ex. ASICs) for low power implementation of digital signal processing.
- Broad bandwidth, low power, flight qualifiable spectrometers. Band of interest is 6 to 18 GHz or higher with ~200 MHz resolution.
- Reliable, tunable, spurious free, and flight qualifiable local oscillators for SIS mixers covering 190 to 270 GHz and 600 to 660 GHz.
- Broadband cryogenic isolators covering 6 to18 GHz.

While focused technology and instrument developments are progressing for missions in the development phases such as the Space Interferometry Mission (SIM) and the James Webb Space Telescope (JWST), ambitious mission concepts are being pursued for future opportunities to address cosmology questions, galactic/stellar astrophysics and extrasolar planet finding quests. Innovative concepts that will significantly advance the state of the art in sensitivity, spectral coverage, array format, power dissipation, and other instrument critical parameters are sought. Also solicited are proposals that address key improvements in current techniques and devices in terms of performance, reliability and technology maturity. In such efforts, the proposer must demonstrate expertise and capability with respect to the existing technique/device/process/system. Optical/electronic devices that enhance or complement the detector function in an instrument are also of interest. Examples are micro shutter arrays to select objects across a focal plane for spectroscopy, timing and analog to digital converters for large focal plane instruments. The optical and near-IR requirements include giga pixel arrays, exceptionally stable sensitivity and precision calibration.

Spectral Coverage	Detector Functionality	Parameters to Push
0.1 um – 1.0 um	Improving silicon response in UV and NIR, smart pixel arrays, solar blind response detector arrays, energy resolving calorimeter arrays	Sensitivity, array format size, high purity silicon processes
1.0 um – 4.0 um	New sensor materials, Large format cryogenic readout multiplexers, Large format (>1kx1k) array hybridization techniques	Sensitivity, array format size
4.0 um – 40 um	Low power cryo operated multiplexers, new sensor materials (e.g., novel dopants for extrinsic Si detectors)	Sensitivity, array format size (~megapixels)
40 um – 200 um	Monolithic focal plane arrays (BIB technologies, new sensor materials)	Sensitivity, array format size (~megapixels)
200 um – 1000 um	Photometric imaging arrays, spectroscopy arrays, THz coherent receiver arrays (mixers, sources, precision packaging)	Photometric imaging arrays (NEP~1e-18 $W/Hz^{0.5}$, 10,000 pixels); Spectroscopic arrays (NEP~1e-20 $W/Hz^{0.5}$, 1,000 pixels)

Supporting Device Categories

Spectral Coverage / Function	Technology	Parameters to Push
mm wave	MMIC packaging	Cost, cryo operation
Digital spectrometer (back-end for coherent receivers)	Autocorrelation spectrometers, high resolution FFT spectrometers	15 GHz or greater bandwidth (auto-correlation), 2 GHz or greater bandwidth (FFT >32K points); low power, compact configurations
Shutter arrays for multi-object spectrographs	Micro-electromechanical shutter arrays or new technologies to do the same thing better	Reliability, low off state scatter or leakage, cryo operability
Infrared optical filters	Thin film or other technologies to realize ~1" aperture filters	High out of band rejection, well defined passbands (especially in 4-40um), cryo operation
Array hybridizing techniques	New, high yield bump bonding techniques	Yield, format size

S4.02 Detector Technologies for UV, X-Ray, Gamma-Ray and Cosmic-Ray Instruments
Lead Center: GSFC
Participating Center(s): MSFC

The next generation of astrophysics observatories for the infrared, ultraviolet (UV), X-ray, and Gamma-ray bands require order-of-magnitude performance advances in detectors, detector arrays, readout electronics, and other supporting and enabling technologies. Although the relative value of the improvements may differ among the four energy regions, many of the parameters where improvements are needed are present in all four bands. In particular, all bands need improvements in spatial and spectral resolutions in the ability to cover large areas and in the ability to support the readout of the thousands to millions of resultant spatial resolution elements. Innovative technologies are sought to enhance the scope, efficiency, and resolution of instrument systems at all energies and wavelengths:

- The next generation of gravitational missions will require greatly improved inertial sensors. Such an inertial sensor must provide a carefully fabricated test mass, which has interactions with external forces (i.e., low magnetic susceptibility, high degree of symmetry, low variation in electrostatic surface potential, etc.) below 10^{-16} of the Earth's gravity, over time scales from several seconds to several hours. The inertial sensor must also provide housing for containing the proof mass in a suitable environment (i.e., high vacuum, low magnetic and electrostatic potentials, etc.);
- Advanced Charged Couple Device (CCD) detectors, including improvements in UV quantum efficiency and read noise, to increase the limiting sensitivity in long exposures and improved radiation tolerance. Electron-bombarded CCD detectors, including improvements in efficiency, resolution, and global and local count rate capability. In the X-ray, we seek to extend the response to lower energies in some CCDs, and to higher, perhaps up to 50 keV, in others;
- Significant improvements in wide band gap (such as GaN and AlGaN) materials, individual detectors, and arrays for UV applications;
- Improved microchannel plate detectors, including improvements to the plates themselves (smaller pores, greater lifetimes, alternative fabrication technologies, e.g., silicon), as well as improvements to the associated electronic readout systems (spatial resolution, signal-to-noise capability, and dynamic range), and in sealed tube fabrication yield;
- Imaging from low-Earth orbit of air fluorescence, UV light generated by giant airshowers by ultra-high energy (E >1019 eV) cosmic rays require the development of high sensitivity and efficiency detection of 300 – 400 nm UV photons to measure signals at the few photon (single photo-electron) level. A secondary goal minimizes the sensitivity to photons with a wavelength greater than 400 nm. High electronic gain (~106), low noise, fast time response (< 10 ns), minimal dead time (< 5% dead time at 10 ns response time), high segmentation with low dead area (< 20% nominal, < 5% goal), and the ability to tailor pixel size to match that dictated by the imaging optics. Optical designs under consideration dictate a pixel size ranging from approximately 2 x 2 mm^2 to 10 x 10 mm^2. Focal plane mass must be minimized (2 g/cm^2 goal). Individual pixel readout. The entire focal plane detector can be formed from smaller, individual sub-arrays.

For advanced X-ray calorimetry improvements in several areas are needed, including:

- Superconducting electronics for cryogenic X-ray detectors such as SQUID-based amplifiers and their multiplexers for low impedance cryogenic sensors and superconducting single-electron transistors and their multiplexers for high impedance cryogenic sensors;
- Micromachining techniques that enhance the fabrication, energy resolution, or count rate capability of closely-packed arrays of X-ray calorimeters operating in the energy range from 0.1 – 10 keV; and
- Surface micromachining techniques for improving integration of X-ray calorimeters with read-out electronics in large-scale arrays.

Improvements in readout electronics, including:

- Low-power ASICs and the associated high-density interconnects and component arrays to interface them to detector arrays;
- Superconducting tunnel junction devices and transition edge sensors for the UV and X-ray regions. For the UV, these offer a promising path to having "three-dimensional" arrays (spatial plus energy).

Improvements in energy resolution, pixel count, count rate capability, and long wavelength rejection are of particular interest:

- Techniques for fabrication of close-packed arrays, with any requisite thermal isolation, and sensitive (SQUID or single electron transistor), fast, readout schemes and/or multiplexers;
- Arrays of CZT detectors of thickness 5 – 10 mm to cover the 10 – 500 keV range, and hybrid detector systems with a Si CCD over a CZT pixelated detector operating in the 2 – 150 keV range.

For improvements to detector systems for solar and night-time UV and EUV (approx. 20-300nm) observing, the following areas are of interest:

- Large format (4 K x 4 K and larger); high quantum efficiency;
- Small pixel size;
- Large well depth;
- Low read noise;
- Fast readout;
- Low power consumption (including readout);
- Intrinsic energy and/or polarization discrimination (3D or 4D detector);
- Active pixel sensors (back-illumination, UV sensitivity); and
- High-resolution image intensifiers, UV and EUV sensitive, insensitive to moisture.

Space spectroscopic observations in the UV, visible, and IR requiring long observation times would be much more sensitive with high quantum efficiency (QE) and zero read noise. Techniques are sought which improve the QE of photon counters, or eliminate the read noise of solid-state detectors; and X-ray and Gamma-ray imaging with higher sensitivity, dynamic range and angular resolution requires innovations in modulation collimators and detection devices. The energy range of interest is from a few kilo-electron Volts to hundreds of milli-electron Volts for observations of solar flares and cosmic sources. Collimators with size scales down to a few microns and thicknesses commensurate with photon absorption over a significant fraction of this energy range are required. Low-background detectors capable of <~keV energy resolution, with or without spatial resolution, are required to record the modulated photon flux. The ability to measure fluxes over a wide dynamic range. The capability to determine the polarization of the photon flux is also desirable.

S4.03 Cryogenic Systems for Sensors and Detectors
Lead Center: GSFC
Participating Center(s): ARC, JPL, MSFC

Stored cryogenic systems have long been used to perform cutting edge space science, but at high cost and with a limited lifetime. Improvements in cryogenic system technology 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 coolers for cooling detectors for scientific instruments and sensors on advanced telescopes and observatories as well as lunar and planetary exploration. The coolers should have long life, low vibration, low mass, low cost, and high efficiency. Specific areas of interest include:

- Highly efficient coolers in the range of 4 – 10 Kelvin as well as at 50 milli-Kelvin and below, and cryogen-free systems, which integrate these coolers together;
- Highly reliable, efficient, low-cost Stirling and pulse tube cooler technologies in the 15 Kelvin and 35 Kelvin regions;
- Essentially vibration-free cooling systems such as reverse Brayton cycle cooler technologies;
- Highly efficient magnetic and dilution cooling technologies, particularly at very low temperatures;
- Hybrid cooling systems that make optimal use of radiative coolers; and
- Miniature, MEMS, and solid-state cooler systems.

S4.04 Optics Manufacturing and Metrology for Telescopes
Lead Center: GSFC
Participating Center(s): JPL, MSFC

This subtopic focuses on optics manufacturing, metrology of optical surfaces, and mitigation of optical surface errors through direct manipulation of the optical surface and/or wavefront sensing and control techniques and technologies.

Optics manufacturing includes all areas associated with generation and maintenance of the optical surface, including both mirror and grating surfaces (and volumes). Improvements in substrate materials, hybrid structures, replication from masters, lightweighting techniques, and figuring and polishing (especially near-edge for segmented optics) are all sought.

Metrology of optical surfaces includes test methods and hardware to measure the surface to fractional wave tolerance, especially for large, aspheric optics and/or while the part is still mounted on the figuring/polishing apparatus or spindle. Metrology systems with artificial intelligence that can deterministically feed back to the polishing instrument, e.g., with a map of dwell times for subaperture polishing.

Mitigation of optical surface errors includes phase retrieval and wavefront sensing and control techniques and instrumentation, optical systems with high-precision controls, active and/or adaptive mirrors, shape control of deformable telescope mirrors, and image stabilization systems.

S4.05 Data Analysis Technologies for Potential Gravity Wave Signals
Lead Center: GSFC

NASA is developing the Laser Interferometer Space Antenna (LISA) mission to search for gravitational waves from astrophysical phenomena such as the Big Bang, mergers of super massive black holes, and galactic binary inspirals. Detection of gravitational waves would open a new astrophysical window on the universe, with great potential for unexpected discoveries. A number of gravitational wave follow on missions to LISA are also under study.

The disturbance caused by the passage of a gravitational wave is expected to be very small and will be measured with laser interferometry. Technologies are sought to deal with the data analysis of the gravitational wave signals in these measurements. Background information on LISA along with preliminary data analysis discussions can be found in the Proceedings of the 5th International LISA Symposium, Estec, Noordwijk, The Netherlands, 12-15, July 2004, published in the Classical and Quantum Gravity Journal, Vol 22, Number 10, 21 May 2005.

Software development for application of the Hilbert-Huang Transform to gravitational wave data analysis: The Hilbert-Huang Transform (HHT) is a new method of time-series analysis which is specifically target to the analysis of non-linear, transient signals (N. Huang, et al., "*The empirical mode decomposition and the Hilbert spectrum for non-linear and non-stationary time series analysis*", Proceedings of the Royal Society of London, A (1998) v. 454, 903-995). It will have a direct application to data analysis for LISA, Big Bang Observer (BBO), and other space-based gravitational wave missions in particular, and more generally to any mission with non-linear, transient data. For this task the vendor will be asked to build a software package that will provide a full HHT analysis of the data, using as an example a NASA-provided simulated LISA data stream, and incorporating a user-friendly interface. The vendor will need to familiarize himself with the HHT algorithm, and show relevant experience in the development of related software packages.

S4.06 Terrestrial Balloon Technology
Lead Center: GSFC

Innovations in materials, structures, and systems concepts have enabled buoyant vehicles to play an expanding role in NASA's Science Mission Directorate and Exploration Systems Mission Directorate. A new generation of large, stratospheric balloons, based on advanced balloon envelope technologies, will be able to deliver payloads of several thousand kilograms to above 99.9% of the Earth's absorbing atmosphere and maintain them there for months of continuous observation. NASA is seeking innovative and cost-effective solutions in support of terrestrial balloons in the following areas:

- Innovative concepts for trajectory control and/or station keeping for effectively maneuvering large terrestrial balloons in either the horizontal latitude or vertical altitude plane or both;
- Innovative floatation systems for water recovery of NASA's scientific payloads;
- Innovative guided or gliding parachutes systems for use in thin atmospheres.

TOPIC: S5 Instrument Technologies for Solar Science

We live in the extended atmosphere of an active star. While sunlight enables and sustains life, the Sun's variability produces streams of high energy particles and radiation that can harm life or alter its evolution. Under the protective shield of a magnetic field and atmosphere, the Earth is an island in the Universe where life has developed and flourished. The origins and fate of life on Earth are intimately connected to the way the Earth responds to the Sun's variations. Understanding the Sun, Heliosphere, and Planetary Environments as a single connected system is the goal of the Science Mission Directorate's Heliophysics Research Program. In addition to solar processes, our domain of study includes the interaction of solar plasma and radiation with Earth, the other planets, and the Galaxy. By analyzing the connections between the Sun, solar wind, planetary space environments, and our place in the Galaxy, we are uncovering the fundamental physical processes that occur throughout the Universe. Understanding the connections between the Sun and its planets will allow us to predict the impacts of solar variability on humans, technological systems, and even the presence of life itself. There are three primary objectives that define the multi-decadal studies needed:

- To understand the changing flow of energy and matter throughout the Sun, Heliosphere, and Planetary Environments;
- To explore the fundamental physical processes of space plasma systems; and
- To define the origins and societal impacts of variability in the Earth-Sun System.

A combination of interrelated elements is used to achieve these objectives. They include complementary missions of various sizes; timely development of enabling and enhancing technologies; and acquisition of knowledge through research, analysis, theory, and modeling.

S5.01 Voltage Supplies and Charge Amplifiers for Solar Science Missions
Lead Center: GSFC

For success of future solar science missions, it is critical to develop future enabling technologies which are modular, compact and efficient. This subtopic focuses on innovations for two technology areas: (1) The first area is compact, sealed and efficient high voltage supplies for space use; (2) The second technology area is high gain, wide dynamic range charge amplifiers. Specific module details are provided as below.

High voltage power supplies can be divided into 3 kilovolt categories: low (< 1kV DC), medium (1 to 5kV DC) and high (5 to 50kV DC). These supplies vary in current capacities, with around 100 mA current for low voltage to around 1 mA for high voltage supplies. The power supplies shall be modular, compact and efficient. These supplies shall be designed with output short circuit protection and other advanced features.

The charge amplifier ASIC shall be of low power, high gain and low noise. The ASIC shall be developed for at least 16 channels, with capability to daisy chain the amplifiers. Individual channels shall contain offset correction, gain correction and input capacitance tuning. The ASIC shall be designed for optimum operating temperature, radiation tolerance and ESD safe inputs.

The proposer shall describe the innovation and specific improvement over the current state of the art.

S5.02 Sensors for Measurement of Particles and Fields
Lead Center: GSFC

Understanding the connections between the Sun and its planets will allow us to predict the impacts of solar variability on humans, technological systems, and even the presence of life itself. This requires remote and in situ sensing of upper atmospheres and ionospheres, magnetospheres and interfaces with the solar wind, the heliosphere, and the Sun. Improving our knowledge and understanding of these requires accurate in situ measurements of the composition, flow, and thermodynamic state of space plasmas and their interactions with atmospheres, as well as the physics and chemistry of the upper atmosphere and ionosphere systems. Remote sensing of neutral atoms is required for the physics and chemistry of the Sun, the heliosphere, magnetospheres, and planetary atmospheres and ionospheres. Because instrumentation is severely constrained by spacecraft resources, miniaturization, low power consumption, and autonomy are common technological challenges across this entire category of sensors. Specific technologies are sought in the following categories:

Plasma Remote Sensing (e. g., neutral atom cameras)
This may involve techniques for high-efficiency and robust imaging of energetic neutral atoms covering any part of the energy spectrum from 1 eV to 100 keV, within resource envelopes less than 5 kg and 5W.

- Miniaturized, radiation-tolerant, autonomous electronic systems for the above, within resource envelopes of 1 – 2 kg and 1 – 2 W.

In Situ Plasma Sensors

- Improved techniques for imaging of charged particle (electrons and ions) velocity distributions as well as improvements in mass spectrometers in terms of smaller size or higher mass resolution;
- Improved techniques for the regulation of spacecraft floating potential near the local plasma potential with minimal effects on the ambient plasma and field environment;
- Low power, digital, time-of-flight analyzer chips with sub-nanosecond resolution and multiple channels of parallel processing; and
- Miniaturized, radiation-tolerant, autonomous electronic systems for the above, within resource envelopes of 1 – 2 kg and 1 – 2 W.

Fields Sensors

- Improved techniques for measurement of plasma floating potential and DC electric field (and by extension, the plasma drift velocity), especially in the direction parallel to the spin axis of a spinning spacecraft;
- Measurement of the gradient of the electric field in space around a single spacecraft or cluster of spacecraft;
- Improved techniques for the measurement of the gradients (curl) of the magnetic field in space local to a single spacecraft or group of spacecraft;
- Direct measurement of the local electric current density at spatial and time resolutions typical of space plasma structures such as shocks, magnetopauses, and auroral arcs; and
- Miniaturized, radiation-tolerant, and autonomous electronic systems for the above within resource envelopes of 1 – 2 kg and 1 – 2 W.

Electromagnetic Radiation Sensors

- Radar sounding and echo imaging of plasma density and field structures from orbiting spacecraft; and
- Miniaturized, radiation-tolerant, and autonomous electronic systems for the above within resource envelopes of 1 – 2 kg and 1 – 2 W.

TOPIC: S6 Earth Science Instrument and Sensor Technology

NASA's Earth Science (ES) Division is committed to studying how our global environment is changing. Using the unique perspective available from spaceborne and airborne platforms, NASA is observing, documenting, and assessing large-scale environmental processes with emphasis on atmospheric composition, climate, carbon cycle and ecosystems, the Earth's surface and interior, the water and energy cycles, and weather. A major objective of ES instrument development programs is to implement science measurement capabilities with small 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. Consequently, the 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 Earth observing instruments and to enable new Earth observations measurements. The following subtopics are concomitant with this objective and are organized by measurement technique. For more on science and technology needs, visit http://estips.nasa.gov.

S6.01 Passive Optics and Stepping Motors for Spaceborne and Airborne Platforms
Lead Center: LaRC
Participating Center(s): GSFC

Passive optical remote sensing generally requires that deployed devices have large apertures and large throughput. NASA is interested primarily in instrument technologies suitable for aircraft or space flight platforms, and these inherently also prefer low mass, low power, fast measurement times, and a high degree of robustness to survive vibrations in flight or at launch. Wavelengths of interest range from ultraviolet through the far infrared. Development of techniques, components and instrument concepts that can be developed for use in actual deployed devices and systems within the next few years is highly encouraged.

Technologies and components that are not clearly suitable for use in high throughput remote sensing instruments are not applicable to this subtopic. The technology areas of primary interest are described below:

- Technology leading to significant improvements in capability, availability, or cost of large format (> 2.5 cm diameter), very narrow band (<5 cm^{-1} full-width at half-maximum [FWHM]), polarization insensitive, high throughput infrared (6 – 15 µm) optical filters. These filters must be able to operate in vacuum at cryogenic temperatures.
- High performance four-band two-dimensional (2D) arrays (128x128 elements or more) in the 0.4 – 2.5 µm wavelength range with high quantum efficiencies (60%–80% or higher) in all spectral bands, low noise, and ambient temperature operation.
- Detector arrays with unusual 3-dimensional geometries. Of particular interest is the development of a photon counting system with multiple cylindrical detecting elements (detecting surface on the outside edge) formed into a stack connected through one end to the cable leading to the readout electronics. The stack should be 2 to 5 cm in length with at least 12, and up to 48, individual elements. The diameter of the stack/elements should be minimized and on the order of 0.5 cm or less. Each detector element should have a clear field of view for most of the 360 degrees perpendicular to the stack. Exact details for the sensitivity are negotiable at this early stage, but applications are for fluorescence type measurements.
- High performance 2-color array detectors (128x128 or higher) covering the 3 – 15 micron spectral range with high efficiencies, low noise and operating at relatively high temperatures (>150K desired, 80K minimum).

- Improved cryogenic stepping motors with high running torques at 80K. The motors must operate in vacuum and at temperatures at or below 80K. It is desired that these motors have minimal size and power requirements, and especially important that they use minimal current. Typical torque values desired are in the range of 10 – 20 oz-inches. Proposed motors should have at least 200 steps per revolution of the axis.

S6.02 Lidar System Components for Spaceborne and Airborne Platforms
Lead Center: LaRC
Participating Center(s): GSFC

High spatial resolution, high accuracy measurements of atmospheric parameters from ground-based, airborne, and spaceborne platforms require advances in the state-of-the-art lidar technology with emphasis on compactness, reliability, efficiency, low weight, lifetime, and high performance. Innovative technologies that can expand current measurement capabilities to airborne, Unmanned Aerial Vehicle (UAV), or spaceborne platforms are particularly desirable. Development of components that can be used in actual deployed systems within the next few years is highly encouraged. Technologies and components that are not clearly suitable for effective lidar remote sensing or field deployment are not applicable to this subtopic. This subtopic considers components that enable Earth-sun system measurements such as:

- Cloud and aerosols with emphasis on aerosol optical properties;
- Wind profiles using direct-detection (noncoherent) lidar, or coherent-detection (heterodyne) lidar, or both;
- Land topography (vegetation, ice, land use); and
- Molecular species (carbon dioxide, ozone, and water vapor).

Innovative component technologies that directly address the measurement needs above will be considered. Dual-use technologies addressing Planetary Exploration are highly desirable. This subtopic is soliciting only the specific component technologies described below.

1. Pulsed, single frequency, diode laser or fiber laser based seeded MOPA systems are desired due to inherent robustness, efficiency, thermal and alignment stability. If the cost per unit is reasonable, and the size is small, then many of these can be installed on a spacecraft for either parallel operation or as backup units to lengthen the life of the mission. Systems with the following specifications are solicited:

    - Stable single frequency operation at 1047nm, 1064 nm, or 1570 nm;
    - Small, integrated assemblies that can generate CW powers in the 100's of mW to several Watts range and higher peak power pulsed operation yielding at least 10 to 500 nJ pulse energies;
    - Fiber laser and amplifier designs with high SBS suppression;
    - Gaussian pulsewidths between 100 ps and 50 ns;
    - MOPA design configuration is desired where the pulse production cavity is short and more readily impedance matched for the fast rise times, gain switching, etc.;
    - A semiconductor amplifier, or possibly a small cm-scale rare Earth doped fiber amplifier, can be coupled to the oscillator chip's output, itself contained in a hermetic butterfly or similar package;
    - Repetition rates as low as 100 Hz and as high as 10 kHz are needed, with pulsed lifetimes in the trillion shot regime (10^{12});
    - Single mode, polarization maintaining (PM) fiber output is needed;
    - Short term drift less than 1 MHz;
    - Second and third harmonic generation techniques that can be packaged with the CW and pulsed diode or fiber laser sources to produce additional wavelengths in the visible or ultraviolet.

2. High speed fiber multiplexers for single and multimode fiber. A 1-to-10, or greater, multiplexer that is capable of switching on the order of 10 to 100 kHz with low insertion losses is required. Unit must be small, lightweight, and use little power. Single mode fiber version must be capable of handling high power (>100

microJoules at 10 kHz at 1064 nm). Multimode version will be used in low power applications and must be compatible with 0.22 NA fiber with 100 to 600 micron core size. Switching speeds faster than 10 microseconds are required.

3. Efficient and compact single frequency 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 2 mJ to 100 mJ, repetition rate 10 Hz to 200 Hz, and pulse duration of approximately 200 nsec.

4. Single element, low noise, high quantum efficiency, HgCdTe avalanche photodiode detector (APD) capable of photon counting at rates >10 MHz for use in the 1570 nm range. Should be suitable for operation with a thermal electric cooler.

5. Lightweight compact lidar telescopes operating at one or more of the primary laser wavelengths in 1.0 to 2.0 micron wavelength region. The general requirements are: optical quality better than 1/6 wave at 632 nm, mass density less than 12 kg/m^2, and aperture diameter from 10 cm to 30 cm. Proof of scalability to 50 to 75 cm diameter for deployment in space is required.

6. Interferometric lidar aft-optics receiver subsystems/components to separately derive aerosol and molecular backscatter via High Spectral Resolution Lidar (HSRL) technique. The subsystem/component is to be implemented into a HSRL system with the goal of independently derive aerosol backscatter and extinction. Subsystems/components are needed at 355 and 532 nm wavelengths. Architectures could be based on Fabry Perot, Mach Zehnder, or other interferometric implementations. Resolving power of the order of 1 GHz and high frequency stability of pass/stop bands are required. Concepts must address issues associated with etendeau of large-aperture (1 – 1.5 m) lidar receivers with field of view of the order of 200 micro-radians.

7. CCD detectors with high quantum efficiency at 355 and 532 nm for spaceborne lidar instruments measuring cloud and aerosol backscatter and extinction. CCD detectors are needed to replace single element PMT detectors for imaging fringes from interferometric elements of a HSRL instrument. Clocking schemes to move charge on the CCD to achieve on-chip profile averaging and reduce dark current and readout noise should be considered.

S6.03 Earth In Situ Sensors
Lead Center: GSFC

Proposals are sought for the development of in situ measurement systems. These systems are sought for use on radiosondes, dropsondes, tethered balloons, kites, mini-Unmanned Airborne Vehicles (UAVs), Unmanned Undersea Vehicles (UUVs), or Unmanned Surface Vehicles (USVs). Data acquisition methods should be included. Technology innovation areas of interest include:

- Measurements of atmospheric properties including temperature, humidity, solar radiation, clouds, liquid water, ice, precipitation, carbon dioxide, methane, and sulfur dioxide;
- Measurements of three-dimensional atmospheric winds near the Earth's surface, and within the troposphere and lower stratosphere, with high spatial resolution and accuracy. Of particular interest are systems intended for measurements of atmospheric fluxes as well as those for convection;
- Measurements of oceanic properties including inherent and apparent optical properties, ocean temperature and salinity, and sea surface height.

S6.04 Passive Microwave
Lead Center: GSFC

Proposals are sought for the development of innovative passive microwave technology in support of Earth System Science measurements of the Earth's atmosphere and surface. These microwave radiometry technology innovations are intended for use in the frequency band from about 1 GHz to 1 THz. The key science goal is to increase our understanding of the interacting physical, chemical, and biological processes that form the complex Earth system. Atmospheric measurements of interest include climate and meteorological parameters-including temperature, water vapor, clouds, precipitation, and aerosols; air pollution; and chemical constituents such as ozone, NOX, and carbon monoxide. Earth surface measurements of interest include water, land, and ice surface temperatures, land surface moisture, snow coverage and water content, sea surface salinity and winds, and multi-spectral imaging.

Technology innovations are sought that will provide the needed concepts, components, subsystems, or complete systems that will improve these needed Earth System Science measurements. Technology innovations should address enhanced measurement capabilities such as improved spatial or temporal resolution, improved spectral resolution, or improved calibration accuracies. Technology innovations should provide reduced size, weight, power, improved reliability, and lower cost. The innovations should expand the capabilities of airborne systems (manned and unmanned) as well as next generation spaceborne systems. Highly innovative approaches that open new pathways are also an important element of competitive proposals under this solicitation.

Specific technology innovation areas include:

Electronics Technologies

- Imaging radiometers, receivers, or receiver arrays on a chip;
- Microwave and millimeter-wave frequency sources as an alternative to Gunn diode oscillators. Compact (<10 cm^3) self-contained oscillators with output frequency between 40 GHz and 120 GHz, low phase noise <125 dBc/Hz at 10 kHz, high output power (>100 mW), and low power consumption (<10 W);
- Wideband and ultra-wideband sensors with >15dB cross-pole isolation across the bandwidth;
- Low noise (<1000 K) with low conversion loss (< 6 dB), compactly designed (< 8 cm^3), heterodyne mixers requiring low local oscillator drive power (<2 mW) with RF input frequency range between 100 GHz and 1 THz;
- Undersampling, multibit, analog-to-digital converters with Multigigahertz RF input bandwidth, low power consumption, and associated digital signal processing logic circuit;
- Low power, lightweight microwave with DC power consumption of less than 2 W;
- Electronic design approaches and subsystems that can be incorporated into microwave radiometers to detect and suppress RFI within or near the reception band of the radiometer, thus insuring higher data quality;
- Innovative new designs for highly stable noise-diode or other electronic devices as additional reference sources for onboard calibration. Of particular interest are variable correlated noise sources for calibrating correlation-type receivers used in interferometric and polarimetric radiometers;
- Monolithic microwave integrated circuit (MMIC), low-noise amplifiers (LNA). Of particular interest are LNAs covering the frequency range of 165 to 193 GHz with low 1/f noise, and having a noise figure of 6.0 dB or better; and
- GPS receiver systems for application as bi-static altimeters and scatterometers.

Antenna Technologies

- Sensor elements with low mutual coupling allowing close spacing within large arrays;
- Large format, millimeter wave, focal plane array modules for large-aperture passive imaging applications; and
- Large aperture, deployable antenna concepts. Such large apertures can be real or synthetic. Of particular interest are highly compact launch configurations.

Calibration Technologies

- New technology calibration reference sources for microwave radiometers that provide greatly improved reference measurement accuracy. Of particular interest are high emissivity (near-black-body) surfaces for use as onboard calibration targets for microwave radiometers-which will significantly reduce the weight of aluminum core target designs, while reliably improving the uniformity and knowledge of the calibration target temperature; and
- New approaches, concepts, and techniques for microwave radiometer system calibration over or within the 1-300 GHz frequency band-which provide end-to-end calibration to better than 0.1K, including corrections for temperature changes and other potential sources of instrumental measurement drift and error.

S6.05 Active Microwave
Lead Center: JPL
Participating Center(s): GSFC

Active microwave sensors have proven to be ideal instruments for many Earth science applications. For global coverage and the long-term study of Earth's eco-systems, space-based radar is of particular interest to Earth scientists. Radar instruments for Earth science measurements include Synthetic Aperture Radar (SAR), scatterometer, sounder, altimeter and atmospheric radar. The life-cycle cost of such radar missions has always been driven by the resources – power, mass, size, and data rate – required by the radar instrument, often making radar not cost competitive with other remote sensing instruments. Order-of-magnitude advancement in key sensor components will make the radar instrument more power efficient, much lighter weight and smaller in stow volume, leading to substantial savings in overall mission life-cycle cost by requiring smaller and less expensive spacecraft buses and launch vehicles. On-board processing techniques will reduce data rates sufficiently to enable global coverage. Technologies that may lead to advances in instrument design, architectures, hardware, and algorithms are the focused areas of this subtopic. In order to increase the radar remote sensing user community, this subtopic will also consider radar data applications and post processing techniques. Specific areas in which advances are needed include:

- L-band SAR for surface deformation, topography, soil moisture measurements:
  - Lightweight, electronically steerable, dual-polarized, L-band phased-array antennas;
  - Lightweight deployable antenna structures and deployment mechanisms suitable for very large aperture systems (e.g., 2x100m antennas);
  - Rad-hard, high-efficiency, low-cost, lightweight L-band T/R modules;
  - L-band MMIC single-chip T/R modules;
  - High-power L-band transmitters (2KW to 10KW);
  - Integrated (e.g., ASIC) arbitrary waveform generators;
  - High performance, low power, rad-hard, real-time SAR processors and SAR data processing algorithms and data reduction techniques;
  - Thin-film membrane compatible electronics. This includes: Reliable integration of electronics with the membrane, high performance (>1.2GHz) transistor fabrication on flex material including identifying new materials, process development and techniques that have potential to produce large area passive and active flexible antenna arrays.
- Ku-band and Ka-band interferometers for snow cover measurement over land (Ku-band) and wetland and river monitoring (Ka-band):
  - Large, stable, lightweight, deployable structures (10-50 meter interferometric baseline);
  - Phase-stable Ku-band and Ka-band electronically steered phased arrays and multi-beam antennas;
  - Lightweight deployable reflectors (Ku-band and Ka-band);
  - Phase stable Ku-band and Ka-band receive electronics and T/R modules;
  - High-power Ka-band transmitters (2KW to 10KW);
  - High performance, low power, rad-hard, real-time radar processors and SAR data processing algorithms and data reduction techniques.
- X-band to W-band doppler radars for precipitation and cloud measurements:
  - High efficiency RF power amplifier (Ku-, Ka-, and W-band);

  - Compact, low loss phase shifters (Ka- and W-band);
  - High power and low insertion loss transmit-receive switches (Ka-,W-band);
  - Wide dynamic range low noise amplifiers (Ka- and W-band);
  - Low sidelobe (-90 dB) pulse compression technology (W-band);
  - Compact frequency synthesizer (Ku- and Ka-band);
  - High power, low sidelobe, compact antennas for high altitudes (X-Ka-band).
- Low Frequency (HF, VHF and UHF) airborne sounders:
  - Technology for creating large Ground Penetrating Radar (GPR) baselines with wireless phase lock loops;
  - High Power (800W), linear amplifiers;
  - Innovations in system design or hardware improvements to minimize the effect of the transmit signal leakage into receiver.

TOPIC: S7 Science Spacecraft Systems Technology

The Science Mission Directorate will carry out the scientific exploration of our Earth, and 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 with small or more affordable spacecraft so development programs can meet multiple mission needs and therefore, make the best use of limited resources. NASA is fostering innovations in cross-cutting technologies that can be leveraged by spacecraft and other platforms to enable new investigations of Earth space, the solar system, and the universe. These missions all require propulsion, power, and guidance and navigation systems that must be implemented at minimal mass and cost to maximize the scientific return for a given budget. To this end, innovations are sought in the areas of Guidance, Navigation and Control, Command and Data Handling, Electric Propulsion, Advanced Chemical and Propellantless Propulsion, Platform Power Management and Distribution (including power electronics and packaging), and Thermal Control Technologies for Science Spacecraft. These technologies need not be limited to spacecraft, but can also be applicable to other platforms such as piloted and unpiloted aircraft, balloons, drop sondes, and sounding rockets. These application examples are given to illustrate the wide diversity of possibilities for acquiring Earth and Space Science data consistent with the future vision of the Science Mission Directorate for which technology development is required. For this solicitation, related science spacecraft system technologies like energy conversion, energy storage, and extreme environment electronics can be found under S2 Robotic Exploration Throughout the Solar System and X8 Energy Generation and Storage.

S7.01 Guidance, Navigation and Control Beyond Low Earth Orbit (LEO)
Lead Center: GSFC
Participating Center(s): JPL

Envisioned NASA science missions will increasingly use large, and/or distributed, observatories in orbits beyond LEO. Advanced Guidance Navigation and Control (GN&C) technology is required for these platforms to address high performance and reliability requirements while simultaneously satisfying low power, mass, volume and affordability constraints. In particular, there are many technology gaps in challenging orbital environments, including highly elliptical Earth orbits, libration point orbits, and lunar and planetary orbits. A vigorous effort is needed to develop guidance, navigation and control methodologies, algorithms, and sensor-actuator technologies to enable revolutionary science missions. Of particular interest are highly innovative GN&C technology proposals directed towards enabling scientific investigators to exploit new vantage points, develop new sensing strategies, and implement new system-level observational concepts that promote agility, adaptability, evolvability, scalability, and affordability. Specific areas of research include:

Precision Pointing
Innovative GN&C solutions for scientific instrument and laser communication system pointing, tracking, and stabilization are sought. Proposals that exploit and combine recent advances in attitude determination and control, lasers, advanced electro-mechanical packaging are encouraged. Proposed NASA science missions provide applications with pointing accuracies of 3 microradians or less with jitter of 30 nanoradians or less.

Formation Flying
Novel approaches to autonomous sensing and navigation of multiple distributed space platforms are sought. Of particular interest are sensing systems for formation, relative navigation and attitude. Proposed NASA science missions provide applications with relative range accuracies of 1 cm or less over formation scales of several km.

Low Impact Sensors and Actuators
GN&C sensors and actuators such as Sun sensors, Earth sensors, star/celestial object trackers, fine guidance sensors, gyroscopes, accelerometers, magnetometers, reaction/momentum wheels, control-moment gyros, magnetic torquers, tethers, attitude control thrusters, etc are sought. Of particular interest are technologies that will provide a sensing or actuation function, having performance (e.g., dynamic range, stability, accuracy, noise, sensitivity, bandwidth, control authority, etc.) consistent with the state-of-the-art, but with significantly reduced impact (mass, power, volume, and cost) to the host spacecraft. These resource reduction improvement factors should be quantified in the proposal and show a minimum factor of 2 with a goal of 10 or greater.

S7.02 Long Duration Command and Data Handling for Harsh Environments
Lead Center: GSFC

NASA's space based observatories, fly by spacecraft, orbiters, landers, and robotic and sample return missions, require robust command and data handling system capabilities. Advances in command and data handling technologies are sought to support the NASA's goals for improved investigations of Earth space, the solar system, and the universe.

The subtopic goal is to develop high-performance processors and architectures and reliable electronic systems that can operate effectively for long periods of time in harsh environments. The subtopic objective is to elicit novel architectural concepts and component technologies that are realistic and have credible applications to NASA missions.

A proposal's ideas should reflect (1) that the final end product(s) lead to usable hardware that can be integrated into NASA programs within 5 to 7 years, (2) effective and sustainable hardware and software development environments, (3) sustainability (affordable, reliable and effective), and (4) applicability to deep space missions (i.e., resource efficient and reliable over extreme environments of temperature and radiation), and will significantly advance solutions to the challenges of high performance processing, reconfiguration, and fault tolerant operations.

Technology priorities:

High Performance Processing
- Distributed or multi-core processing, with math co-processor or floating point capability that significantly exceeds the present state of the art;
- FPGA-based processing, targeting performance and fault tolerance, based on voting processors implemented as part of a rad-tolerant FPGA fabric

Onboard Networks
- Rad-hard Ethernet physical layer components, fully compatible with the current ground based 10/100 Ethernet. The board side interface would have the Ethernet MII and RMII interface standards;
- Rad-hard multi gigabit fiber optic transceiver to support high data rate network protocols.

Data System Support Electronics

- Radiation hard oscillators (greater than 150 MHz with equal duty cycles);
- Models for analysis of interplanetary radiation and radiation belts, and technologies that enable in-flight radiation measurements such as total dose and single event effects in computing systems.

S7.03 Electric Propulsion
Lead Center: GRC
Participating Center(s): GSFC, JPL, MSFC

Innovations in propulsion technologies are needed to support the Science Mission Directorate (SMD) goals of better understanding the Earth-Sun system, exploring our solar system, and investigating the nature of the universe beyond our solar system. Planetary spacecraft need ever-increasing propulsive performance and flexibility for ambitious missions requiring high duty cycles and years of operation. Satellites and satellite constellations have high-precision propulsion requirements, usually in volume- and power-limited envelopes. Electric propulsion systems also present challenging plasma plume and contamination environments to the host spacecraft and payloads. This subtopic seeks innovations in propulsion technologies to increase the capabilities of SMD spacecraft.

Specifically, technology innovations are sought to improve the capability of low- to medium-power electric propulsion systems, including ion, Hall, and advanced plasma thrusters. Areas where innovations are sought include power processing, long-life, high-efficiency cathodes and neutralizers, electrode-less plasma production, low-erosion materials for ion optics and Hall discharge chambers, high-temperature magnetic circuits, plume mitigation, and next generation thrusters. Innovations sought include, but are not limited to those that improve performance, increase lifetime, reduce mass, decrease cost, and facilitate electric propulsion integration. Improvements are also sought for propellant management system components including storage, distribution, and flow control to support solar electric propulsion applications. Innovations in miniature electrostatic and electromagnetic propulsion devices are sought for miniature (less than 10 kg) spacecraft and for high-precision (impulse bit < 100 milliNewton-second) stationkeeping and attitude control. Modeling techniques and tools may also be considered if they address the unique issues related to life validation, thermal analysis, and wear mechanisms of electric propulsion systems and can show benefit to the electric propulsion hardware currently facing these development challenges.

S7.04 Chemical and Propellantless Propulsion for Deep Space
Lead Center: MSFC
Participating Center(s): GRC, GSFC, JSC

Spacecraft propulsion technology innovations are sought for future deep space science missions. Propulsion system functions for these missions include primary propulsion, maneuvering, planetary injection, and planetary descent and ascent. Innovations are needed to reduce spacecraft propulsion system mass, volume, and/or cost. Applicable propulsion technologies include advanced chemical, emerging technologies, and aerocapture.

Advanced Chemical Propulsion
Innovations in low-thrust chemical propulsion system technologies are sought for robotic, deep-space, scientific, mission applications. Delta Vs for the missions of interest range from 1000 m/sec to 3000 m/sec. Advanced chemical propulsion technologies of interest are:

- Advanced material and component technology to enable development of bipropellant engines with Isp greater than 360 seconds, both pressure-fed and pump-fed, with chamber pressures ranging from 100 to 500 psia systems;
- Non-catalytic ignition technology and critical component materials (e.g., tank bladders, valve seats, and filters) for power-limited spacecraft using high-performance (Isp >275 s), high-density (>1 g/cc) monopropellant formulations.

Tether Technologies

Focus on technologies that support the development of tethers that can survive in the space environment. The near-Earth environment contains a significant amount of atomic oxygen (AO) formed by photo-dissociation of atmospheric oxygen. This AO attacks the chemical bonds of polymeric materials, which are desirable for their high specific tensile strength. Furthermore, ultraviolet radiation also attacks tether materials. A coating for a polymeric tether must be able to protect the tether against both effects. Coatings that can be uniformly applied after the fabrication of a multi-strand tether structure are especially desirable, because of the requirement that a space tether have a multitude of separate load paths in the event of a cut by an orbital debris particle. Certain materials (such as titanium oxide/zinc oxide) offer both ultraviolet radiation protection as well as atomic oxygen resistance. Tether technologies of interest are:

- Techniques and processes to coat and protect polymeric tether materials from offer both ultraviolet radiation protection as well as atomic oxygen resistance effects. Such coatings must be as thin as possible because of the importance in maintaining a high specific tensile strength in tether materials, although they must be able to adhere uniformly and reliably to tether materials, even in the face of winding and ground handling. Degradation to the strength characteristics of the tether generated by the coating process must be absolutely minimized.

Aeroassist (Aerocapture)

Aerocapture relies on the exchange of momentum with an atmosphere to achieve a decelerating thrust leading to orbit capture. This technique permits spacecraft to be launched from Earth at higher velocities, thus providing a shorter overall trip time. At the destination, the velocity is reduced by aerodynamic drag within the atmosphere. The aerocapture maneuver can be accomplished by utilizing either rigid or inflatable deceleration systems.

Preliminary analysis has shown that the inflatable decelerator concepts may provide mass reduction and improved packaging efficiency over a rigid aeroshell system. However, the TRL for these inflatable decelerators must be increased before an adequate comparison to traditional rigid aeroshells can be made. Current inflatable decelerator concepts are expected to be manufactured from thin film materials, elastomeric materials, and/or high temperature fabrics, stowed during transport and inflated prior to atmospheric entry for aerocapture applications at planetary destinations. Materials of particular interest include: polyimide thin films, polybenzobisoxazole (PBO) thin films, and ceramic fabrics. Prior to the aerocapture maneuver, the inflatable decelerator will be tightly stowed for many years (up to 10 years) in an uncontrolled space environment (-130°C) during transport to outer solar system destination. Before final atmospheric entry, the inflatable decelerator will be unstowed and inflated (cold GN_2). During the aerocapture maneuver, up to 24 hours after the inflation process is initiated, the inflatable decelerator will experience temperatures to 500°C (or higher).

Low Temperature/High Temperature Structural Materials/Adhesives

Development for Inflatable Deceleration Systems: This task focuses on the development and testing of structural materials/adhesives that can be utilized for aerocapture inflatable decelerator systems. This task should include:

- A thorough survey of the thin film polymer, elastomeric;
- A high temperature fabric trade space for materials that will maintain structural properties during the temperature extremes and long term space exposure experienced by inflatable decelerators.;
- Investigation of the effects of various coatings, surface treatments, or impregnation processes to enhance material properties, which may include optical, mechanical, thermal or physical properties;
- A thorough survey of the adhesives trade space for materials that will maintain bond strength during the temperature extremes of long term space exposure and atmospheric entry experienced by inflatable decelerator systems must also be included.

Final deliverables should include selection criteria for final materials/adhesives, an evaluation of technology readiness levels (TRL) of candidates, technology development and testing of candidates that require further TRL advancement.

S7.05 Power Electronic Devices, Components and Packaging
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

NASA science missions employ Earth orbit and planetary spacecraft, along with terrestrial balloons, surface assets, aircraft, and marine craft as observation platforms. Advanced electrical power technologies are required for the electrical components and systems on these platforms to address the issues of size, mass, efficiency, capacity, durability, and reliability. Advancements are sought in power electronic devices, components, and packaging.

Power Electronic Components
Advanced inductors, transformers, capacitors, micro batteries, semiconductor switches, diodes, and current sensors are of interest. Proposals must address improvements in energy density, speed, efficiency, or wide temperature operation (-125°C to 200°C) with a high number of thermal cycles.

Power Conversion, Motor Drive, Protection, and Distribution
Technologies that provide significant improvements in mass, size, power quality, reliability, or efficiency in electrical power conversion, motor drives, and protective switchgear components are of interest. Candidate applications include solar array regulators, battery charge and discharge regulators, battery by-pass switches, power conversion, power distribution, fault protection, high-speed motors/generators, magnetic bearing drivers, and integrated flywheel energy storage and attitude control electronics.

Electrical Packaging
Thermal control technologies are sought that are integral to electrical devices with high heat flux capability and advanced electronic packaging technologies which reduce volume and mass or combine electromagnetic shielding with thermal control.

S7.06 Thermal Control Technologies for Science Spacecraft
Lead Center: GSFC
Participating Center(s): GRC, JPL, MSFC

Future Spacecraft and instruments for NASA's Science Mission Directorate will require increasingly sophisticated thermal control technology. Innovative proposals for thermal control technologies are sought in the following areas:

1. Optical systems, lasers, and detectors require tight temperature control, often to better than +/- 1°C. Some new missions require thermal gradients held to micro-degree levels. Methods of precise temperature measurement and control to this level are needed.

2. Heat flux levels from lasers and other high power devices are increasing, with some projected to go as high as 100 W/cm^2. They will require thermal technologies such as spray and jet impingement cooling. Also, high conductivity, vacuum-compatible interface materials will be needed to minimize losses across make/break interfaces.

3. Future missions will use large structures, like mirrors and detector arrays, at both ambient and cryogenic temperatures. Some anticipated technology needs include: advanced thermoelectric coolers capable of providing cooling at ambient and cryogenic temperatures, high conductivity materials to minimize temperature gradients and provide high efficiency light-weight radiators, and advanced thermal control coatings such as variable emittance surfaces and coatings with a high emissivity at ambient and cryogenic temperatures.

4. The push for miniaturization also drives the need for new thermal technologies approaching the MEMS level. Miniaturized heat transport devices, especially those suitable for cooling small sensors, devices and electronics are of interest.

5. Future robotic missions and reconfigurable spacecraft present engineering challenges requiring systems which are more self-sufficient.

Some of the technology needs are:

- Single and two-phase mechanically pumped fluid loop systems which accommodate multiple heat sources and sinks, and long life, lightweight pumps for these systems;
- Efficient, lightweight 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 system 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.

TOPIC: S8 Advanced Modeling, Simulation, and Analysis for Science

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.

S8.01 Automation and Planning for Complex Tasks
Lead Center: ARC

This subtopic solicits proposals for technologies and systems that allow spacecraft and ground systems to robustly perform complex tasks in dynamic environments with minimal human direction. Areas of interest include support of decision support systems, distributed sensor webs and component systems, and the creation of automation loops connecting scientific modeling and analysis to mission planning, data collection, processing and operations. NASA is moving from a stove-pipe observational architecture to one that permits data interoperability and dynamic coordination of observational assets to generate desired data products. Technology innovations include, but are not limited to:

- Automation and autonomous systems that support high-level command abstraction;
- Efficient and effective techniques assessing gaps in data collection to assure complete coverage;
- Intelligent searches of distributed data archives, and data discovery through searches of heterogeneous data sets and architectures; and
- Automation of routine, labor intensive tasks to that either increase reliability or throughput of current process.

Specific areas of interest include the following:

- Search agents that support applications involving the use of NASA data using emerging interoperability such as Sensor Model Language;
- Methods that support the planning and scheduling of sensor webs in support of data product processing when given a set of high-level goals and constraints;

- Autonomous data collection including the coordination of space or airborne platforms while adhering to a set of data collection goals and resource constraints;
- System and subsystem health and maintenance, both space- and ground-based;
- Distributed decision making, using multiple agents, and/or mixed autonomous systems;
- Automatic software generation and processing algorithms; and
- Control of Field Programmable Gate-Arrays (FPGA) to provide real-time products.

S8.02 Distributed Information Systems and Numerical Simulation
Lead Center: ARC

This subtopic seeks advances in tools, techniques, and technologies for distributed information systems and large-scale numerical simulation. The goal of this work is to create an efficient and effective information and computing environment that enables NASA scientists to work naturally with distributed teams and resources to dramatically reduce total time-to-solution (i.e., time to discovery, understanding, or prediction), vastly increase the feasible scale and complexity of analysis and data assimilation, and greatly accelerate model advancement cycles. Areas of interest are described below.

Distributed Information Systems

- Supercomputing environment simulation, to identify or anticipate bottlenecks in the environment and to effectively engage all supercomputing program resources. The simulation could include models of application behavior, the full computing and data workload, computing and data systems, local and wide area networks, data analysis and visualization systems, the interface to various facility and user services personnel, and the interface to the remote user at their desktop.
- Services (autonomous software systems) for automated, scalable, and reliable management of distributed, dynamic, and heterogeneous computing, data, and instrument resources. Services of interest include those for authentication and security, resource and service discovery, resource scheduling, event monitoring, uniform access to compute and data resources, and efficient and reliable data transfer.
- Science portals for cross-disciplinary discovery, understanding, and prediction, encapsulating services for single sign-on access, semantic resource and service discovery, workflow composition and management, remote collaboration, and results analysis and visualization.

Large-Scale Numerical Simulation

- Tools for automating large-scale modeling, simulation, and analysis, including those for managing computational ensembles, performing model-optimization studies, interactive computational steering, and maintaining progress in long-running computations in spite of unreliable computing, data, and network resources.
- Tools for computer system performance modeling, prediction, and optimization for real applications.
- Techniques and tools for supercomputing application porting, parallelization, debugging, scaling, performance analysis, and optimization.
- Tools for effective load balancing, and high reliability, availability, and serviceability (RAS) in commodity clusters and other large-scale computing systems.
- Novel supercomputing approaches using FPGAs, graphics processors, and other novel architectures and technologies.

S8.03 On-Board Science for Decisions and Actions
Lead Center: ARC

The focus of this subtopic is enhanced capabilities for NASA observatories in the sensor or platform, or early in the data stream, that can prioritize data for transmission and analysis, or summarize the data for future use. NASA's vision of a sensor-web capability will demand more onboard autonomy and content based data management to support rapid decision making and re-tasking. This subtopic is interested in methods to autonomously understand data as part of a sensor web system capable of rapid redirection and configuration.

Onboard Satellite Data Processing and Intelligent Sensor Control
Software technologies that support the configuration of sensors, satellites, and sensor webs of space-based resources. Examples include capabilities that allow the reconfiguration or re-targeting of sensors in response to user demand or in significant events seen in other sensors. Included are software that supports the reasoning and modeling of such capabilities for demonstration and mission simulation. Also included in this category is onboard analysis of sensor data that could run on reconfigurable computing environments as well as technologies that support or enable the generation of data products for direct distribution to users.

Onboard Satellite Data Organization, Analysis, and Storage
Software technologies that support the storage, handling, analysis, and interpretation of data. Examples include innovations in the enhancement, classification, or feature extraction processes. Also included are data mining, intelligent agent applications for tracking data, distributed heterogeneous frameworks (including open system interfaces and protocols), and data and/or metadata structures to support autonomous data handling, as well as compaction (lossless) or compression of data for storage and transmission.

Simulation and Analysis of Sensor Webs for Improving Science Models or Mission Operations
Software that allows for the simulation of a sensor web of varying platform types producing a variety of data streams. These platforms could be in various orbits (L1, L2, NEO, LEO, etc.) and suborbital (UAV) that are automatically assigned different temporal and spatial coverages. Data streams would be assigned to these platforms and the system computes how the sensor web would cover of events (e.g., volcanic eruption, fires, and crop monitoring) at user designated, particular, geospatial locations (or areas).

S8.04 Spatial and Visual Methods for Search, Analysis and Display of Science Data
Lead Center: SSC
Participating Center(s): ARC

This subtopic seeks technical innovation and unique approaches to exploit spatial tools in order to increase the use of NASA research data, models, simulations, and visualizations. The goal is to facilitate NASA's Science and Exploration Missions, and outreach to the interested public. The tools should be easy to use by non-specialists, from scientists and policy makers to the general public. Tools and services will be prototyped for accessing and fusing (or mashing) image and vector data with popular Web-based or stand-alone applications. Tools can be plug-ins or enhancements to existing software or on-line services. Tools and the products might be used for broad public dissemination or for communicating within a narrower scientific community.

For example, an authoring tool may help a non-GIS expert to map a National Weather Service modeled hurricane path over a background of NASA MODIS sea surface temperatures, in turn draped on a visualization of the globe served by GoogleEarth.

To promote interoperability, tools shall use industry standard protocols, formats, and APIs. For example a tool may manipulate XML of various types, such as GML, SensorML, KML; or use standard services, such as WSDL and UDDI. Applications may subset, filter, merge, and reformat existing spatial data; provide links to attribute data; or visualize results. Combining NASA research data with popular geospatial services is encouraged. Examples of popular applications and services currently include:

- Imagery servers: e.g., NASA DAACs, OGA servers (USGS, NOAA, DOI), Microsoft Terraserver, Google Maps;
- Mapping platforms: e.g., Google Earth, NASA WorldWind;
- Map servers: e.g., Census Bureau, EPA Maps, Google Maps, MapQuest, Yahoo Maps.

S8.05 Science Data Management and Visualization
Lead Center: GSFC

This subtopic focuses on supporting science analysis through innovative approaches to 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:

3D Virtual Reality Environments

- 3D virtual reality environments for scientific data visualization that make use of novel 3D presentation techniques that minimize or eliminate the need for special user devices like goggles or helmets;
- Software tools that will enable users to 'fly' through the data space to locate specific areas of interest.

Distributed Scientific Collaboration

- Tools that enable high bandwidth scientific collaboration in a wide area distributed environment;
- Novel tools for data viewing, real-time data browse, 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.

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.

9.1.4 SPACE OPERATIONS

In 2004, President Bush announced a new space exploration vision for America's civil space program. "*A Renewed Spirit of Discovery: The President's Vision for U. S. Space Exploration"* included four objectives and the fifth objective added later:

1. Implement a sustained and affordable human and robotic program to explore the solar system and beyond;
2. Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
3. Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration;
4. Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests; and
5. Study the Earth system from space and develop new space-based and related capabilities for this purpose.

In support of the NASA Vision for Space Exploration, the Space Operations Mission Directorate will marshal its efforts around a key transformation to enable the President's vision. The role of the directorate will continue to involve operational capabilities for the agency and synergistically guide the development of certain operational systems such as communication systems. The Space Operations Mission Directorate provides the foundation for NASA's space programs — space travel for human and robotic missions, in-space laboratories, and the means to return data to Earth. We provide space access for our customers with a high standard of safety, reliability, and affordability. The focus of the Space Operations Mission Directorate SBIR activity is to provide affordable communications for exploration and science and space access services. We go forward as explorers and as scientists to understand the universe in which we live.

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

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, navigation and timing, reprogrammable communications systems, communications systems for EVAs, advanced antenna technology and transmit array concepts, communications in support of launch services including space based assets are very important to the future of the exploration and science activities of agency. Also 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.

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

Power and spectrum efficient solutions are needed for both near-Earth and deep-space science and exploration applications. Channel coding efficiency from 50% to 87%, combined with good bit-error/burst-error correction property will provide solutions to multiple missions. A high-speed, digital receiver capable of demodulating coded modulations in addition to un-coded modulations is needed for future missions. In compression, implementation of a high-speed decoder for decoding a standard embedded bit-stream offering tunable lossy compression to lossless compression is desired. Proposals are sought in the following specific areas:

Compression
High-speed decoder capable of decoding coded bit stream conforming to CCSDS 122.0-B-1 Image Data Compression standard (www.ccsds.org) is solicited. The decoder has to provide over 640 Mbits/sec decoding for up to 16-bit image data coded in an embedded bit stream. The decoder shall not consume more than 5 watts of power at the specified speed. The implementation technology shall point to potential space-use feasibility.

Coding
Special emphasis is placed on a channel coding design suitable for near-Earth missions, operating at least at over 80% coding rate with an error floor lower than Bit-Error-Rate (BER) of $10e^{-10}$, and at least 8-bit burst-error correction property, with encoder/decoder complexity consistent with implementations at data rates close to 1 Gbps and power consumption smaller than a few watts. The new design when compared with current CCSDS Reed-Solomon (255,223) coder at BER of $10e^{-5}$ shall have over 2dB Eb/No gain. The preferred code block frame length is from 4K to 16K bits. Proposed implementation technology shall point to potential space-use feasibility.

High-Rate Receiver
High-rate receiver capable of decoding coded and un-coded modulation suite (8-PSK, GMSK, filtered OQPSK) specified by CCSDS 413.0-G-1 April 2003 (www.ccsds.org) and 16-PSK, 16-QAM, 16-APSK with processing throughput greater than 300 Mbits/sec is desired. A desirable feature for the receiver output is 7 bits/sample that can be used as input to channel decoding algorithms based on soft-decision decoding.

O1.02 Precision Spacecraft Navigation and Tracking
Lead Center: GSFC

This call for proposals is meant to serve NASA’s ever-evolving set of missions, which require precise tracking of spacecraft position and velocity in order to achieve mission success. The call seeks evolutionary improvements in modularity, sustainability, cost, and performance for current space navigation concepts that support the Vision for Space Exploration. This includes Projects Constellation, Prometheus, robotic servicing, and robotic Earth and space science missions. NASA also seeks disruptive navigation concepts that might not match the modularity, sustainability, cost, and/or performance of current technologies and their near-term evolution, but have convincingly demonstrable potential to overtake the evolution of current technologies within the future development of Projects Constellation and Prometheus, and Earth and space science missions, in the 2015 – 2020 timeframes.

While the definition of "precise" depends upon the mission context, typical interplanetary scenarios have required Earth-based radiometric ranging accuracies of order 1-2m at 1 AU, Doppler to 0.03 mm/sec, and plane-of-sky angles to 2.5 nano-radians. While some legacy applications remain at 2.3 GHz, most current tracking is being done at 8.4 GHz. Forward looking demonstrations are being planned at 32 GHz. These radiometric techniques have been complimented by optical techniques which achieve ~1.5 micro-radian angular accuracy upon target approach. The accuracy of radio-based techniques is typically limited by one's ability to calibrate the path delay through intervening media (troposphere, ionosphere) and by the phase stability of electronics in both the spacecraft and ground systems. For both media and electronics, the stability goal is to achieve Allan standard deviations of $4e^{-15}$ at 100 seconds and $1.5\ e^{-15}$ at $1e^{3}$ to $1e^{4}$ seconds while maintaining, or improving upon, current levels of reliability.

Space navigation technology concepts should support launch and return to Earth, including range safety, early orbit operations, in-space assembly, cis-lunar and interplanetary transit, lunar and planetary approach and orbit, ascent and descent from lunar and planetary surfaces, including precision landing, lunar and planetary surface operations, automated rendezvous and docking, and formation flying spacecraft forming synthetic apertures for science imaging and interferometry. NASA considers applicability to multiple operational regimes through modularity and/or missionization of common components a key element in its exploration strategy. Space navigation systems must produce accurate long-term trajectory predictions as well as definitive epoch solutions. Where applicable, proposed concepts should be interoperable with and/or leverage the resources of NASA's space communications architecture. All navigation systems should be compatible, where applicable, to continuous or near-continuous trajectory perturbations generated by onboard spacecraft systems. All concepts must show some significant advantages over current techniques in at least one of the following areas: accuracy, cost, reliability, modularity, sustainability, or for onboard systems, mass, power, and volume.

Innovative technologies are sought in the following areas:

- Highly phase-stable RF ground systems are critical to high accuracy radiometric tracking. Present systems rely upon analog transmission over 0.5 to 10 km distances of a broadband (100 – 600 MHz) spectrum. Transmission induced phase errors could be greatly reduced by developing highly phase stable digital sampling and time tagging systems that can be placed near (~10m) to the RF feedhorn without measurably degrading the RF signal capture with spurious tones and noise. Phase stability goals are given above. The sampler should Nyquist sample the 100 – 600 MHz band with at least 8-bit resolution and be capable of digitally transmitting the resulting samples over fiber optic lines;
- The VLBI parameter estimation software used to build the radiometric reference frames used for precise tracking relies on a Square Root Information Filter that makes use of Householder transformation techniques. These solutions often take several days of CPU on a modern workstation. Block matrix techniques have the potential to optimize the interaction of the CPU and cache memory thereby greatly reducing the CPU time needed for solutions. The goal is a factor of three improvement in total solution time for problems with 7 million data points and 500,000 parameters, which include at least 5000 parameters that are active over the entire data set;
- Microwave radiometry of atmospheric emission lines (22 GHz H_2O, 60 GHz O_2) has been successful in demonstrating 1 mm level calibration of tropospheric path delay. However, the usefulness of this technique has been limited by the large mass and size of the instrument packages. Identifying/developing low mass, low cost implementations of this technique without significantly sacrificing accuracy would greatly enhance precise tracking;
- Develop low mass, (Less than 1 kg) low cost onboard radio frequency standards for generating highly phase-stable onboard radio signals which achieve Allan standard deviations of 1×10^{-15} at 1000 seconds and drift of less than 10^{-15}/day;
- Develop innovative tracking technologies using new wavelengths (X-ray, Infra-red, etc.), such as systems using celestial and planetary emissions and reflections (not limited to the visible spectrum) that can produce three-dimensional absolute and relative position and velocity in regions where Earth-based GPS measurements are not available, The technologies can exploit either ground based or on-board techniques;
- Develop innovative technologies for improving the state of the art in terms of cost and performance in making spacecraft-to-spacecraft measurements, such as omni-directional range and bearing sensors and robotic-vision-based systems; and

- Develop innovative navigation algorithms and software supporting analysis, design, and mission operations that will reduce operations costs and support multiple systems in simultaneous, tightly-coupled, non-quiescent operations, such as robotic servicing and formation flying.

O1.03 Communication for Space-Based Range
Lead Center: GSFC
Participating Center(s): DFRC, KSC

Metric tracking of launch vehicles for range safety purposes is currently based on redundant radars, telemetry receivers, and uplink command transmitters at the launch site with additional assets deployed downrange in order to maintain line-of-sight communications with the vehicle as it passes over the horizon to orbital insertion.

The vision of space-based range architecture is to assure public safety, cut the costs of launch operations, decrease response time, and improve geographic and temporal flexibility by reducing, or eliminating, these assets. In order to achieve this, a number of advancements in tracking and telemetry are required. Some of NASA's needs are:

GPS/IMU Metric Tracking and Autonomous Systems
Realization of a space-based range requires development of GPS receivers that incorporate:
- Low power consumption;
- Low mass/volume;
- Compliance with range safety standards;
- Flexible tracking loop programmability;
- Programmable output formats; and
- Operability in high G environments.

Other highly desirable GPS specific characteristics include open architecture supported by development software and the capability of being incorporated onto circuit boards designed for multiple functions.

Tactical grade IMUs are needed which can function on spin-stabilized rockets (up to 7 rps) and reliably function during sudden jerk and acceleration associated with launch and engine firings and can be coupled with GPS receivers.

Also needed are approaches to processing the outputs of navigation sensors and combining them with rule-based systems for autonomous navigation and termination decision making.

Space-Based Telemetry
Small, lightweight, low cost transceivers capable of establishing satellite communications links for telemetry and control during the launch and assent stages of flight are required to provide unbroken communications throughout the launch phase. These may enable use of the NASA TDRSS, or commercial communications satellites.

Techniques for multiplexing narrow bandwidth channels to permit increased bit rates and improved algorithms for ensuring smooth transition of support between communications satellites are also needed.

GPS Attitude Determination for Launch Vehicles
Investigate using inexpensive arrays of GPS antennas and receivers on small, expendable launch vehicles to determine the attitude angles and their rates of change as an alternative to traditional inertial measurement units.

The system should be contained entirely on the vehicle and not rely on ground-based processing. The attitude accuracy should be comparable to gyroscope-based systems and should be free of drift and gimble lock. The system must be able to maintain attitude output during periods of high dynamics and erratic flight. The attitude must be determined at a rate of least 10 Hz with minimal processing delay and must be output in a format compatible with vehicle telemetry systems.

O1.04 Antenna Technology for Spacecraft and Planetary Surface Vehicles
Lead Center: GRC
Participating Center(s): GSFC, JPL, LaRC

NASA seeks advanced antenna systems for use in spacecraft and planetary surface vehicles used in science, exploration systems, and space operations missions. Future manned missions to the Moon and Mars will have stringent communication requirements. Highly robust communication networks will be established in the vicinity of the planet to support long-term human interplanetary mission. Such networks will consist of a large number of communication links that connect the various network nodes. Some of these nodes must also maintain continuous high data rate communication links between the moon and the Earth. Great demands will be placed on these communication systems to assure crew safety, robustness in harsh environments, and high reliability for long duration manned missions.

Areas of interest include lightweight deployable antenna systems, high-gain antenna architectures, multi-frequency and dual polarized antennas, self-orienting systems, reconfigurable antennas, novel concepts, antennas that can adapt to failed components without compromising performance and operability (e.g., smart antennas that include structural health monitoring and active control). NASA seeks to develop a lightweight scanning phased array antenna system that enables assured communication links for human interplanetary exploration.

NASA is also interested in technologies enabling direct conversion of RF signals to digital and advanced concepts wherein such systems are integrated with novel smart antenna concepts to allow true interoperability and reconfigurability in the sense of software radios.

Antenna systems for novel navigation concepts (e.g. pulsar beacons) as well as integrated communications and navigation architectures are desirable.

Large inflatable membrane antennas to significantly reduce stowage volume, provide high deployment reliability, and significantly reduced mass (i.e. <1kg/square meter) to provide communication link from Moon/Mars surface to relay satellite or Earth. NASA is interested in large Gossamer antennas for future exploration scenarios. These membranes antennas are deployed from small package via some inflation mechanism. For example, 20 meter class inflatable apertures may enable deep-space relays from a Jupiter Lagrange point, and 10 meter class apertures may be sufficient for Mars relay satellites. It is desirable to rigidize these membranes antennas along with their supporting structures so that make up gas is not required. In particular, this topic is interested in techniques for rigidizing these membranes antennas (e.g., ultraviolet curing), as well as thin-membrane tensioning and support techniques to achieve precision and wrinkle-free surface, in particular for Ka-band applications. In addition, this topic is also interested in novel materials (including memory matrix materials) and approaches to construct large, deployable or inflatable reflective and RF focusing surfaces for use as large aperture antennas. Structural health monitoring systems and sensors needed to assure appropriate deployment as well as continued reliability of the overall communication systems are also desirable.

High efficient, miniature antennas with smaller than lambda square aperture size, to provide astronauts and robotics communications for surface to surface and surface to orbit for lunar, Mars, and planetary exploration missions. Recent new antenna research and development has shown that it is possible to design and build aperture antennas with smaller than the minimum effective apertures size of dipoles. This new class of antennas can provide higher antenna gains (> 2.5 dBi) than the dipole antenna in much smaller aperture size (< .13 lambda square). Because of its size and higher gain these antennas can be use reliably in astronauts and robotics communication equipments in the UHF, VHF, and S- frequency bands for 3 lunar or Mars exploration missions. This topic is interested in novel antenna concepts that address the aforementioned requirements.

The architecture for lunar exploration as defined by the Space Communication Architecture Working Group (SCAWG) is expected to involve a layered communications and navigation network. This network may include lunar vicinity relay satellites at L1 and L2 Lagrange points as well as lunar polar orbiting satellites. The lunar proximity network must be able to access dedicated assets such as Malapert Station and eventually include human assets, such as crewed rovers, as relay nodes. Consequently there is an interest in antenna technologies that enable low cost but reliable reconfigurable and agile antennas at frequencies up to 38 GHz. Another component technology that shows high interest in the area of Earth and planet science is thin-membrane mountable T/R modules, phase shifters, beam former, control circuitry, etc. for future deployable/inflatable large-aperture phased array application. This topic seeks novel smart antenna concepts to address the aforementioned requirements.

There is also interest in space-to-surface links at 25.5 GHz and 37 GHz. The size of reflector antennas is limited by the accuracy of the reflector surface that can be achieved and maintained on-orbit. Development of special materials and structural techniques to control their environment, etc., reduces environmentally induced surface errors and increases the maximum useable reflector size. Distortions caused by thermal gradients are inherently a large scale phenomenon. The reflector surface is usually sufficiently accurate over substantially large local areas but these areas are not on the same desired parabolic surface. An array of feed elements can be designed to illuminate the reflector with a distorted spherical wave. This distortion can be used to compensate for large scale surface error introduced by thermal gradients, gravitational and other forces, and manufacturing. Topics of interest include but are not limited to: Compensating Feed System for an Antenna Reflector Surface With Large Scale Distortions; Techniques for the remote Measurement of Satellite Antenna Profile Errors; Determination of Orbiting S/C Antenna Distortion by Ground-Based Measurements; Measuring and Compensating Antenna Thermal Distortions; Reflector Measurements and Corrections using arrays; Reflector Distortion Measurement and Compensation Using Array Feeds.

NASA is interested in low cost phased array antennas for suborbital vehicles such as sounding rockets, balloons, UAV's, and expendable vehicles. The frequencies of interest are S-band, Ku-band, and Ka-band. The arrays are required to be aerodynamic in shape for the sounding rockets, UAV's, and expendable platforms. The balloon vehicles primarily communicate with TDRS and can tolerate a wide range of mechanical dimensions.

Antenna pointing techniques and technologies for Ka-band spacecraft antennas that can provide spacecraft knowledge with sub-milliradian precision (e.g., <250 micro-radians) in order to point large spacecraft antennas (e.g., 10 meter Diameter) at Mars are also desirable under this subtopic. Methods of dealing with extreme latency (e.g., 20 minutes) in beacon and monopulse systems are of interest.

NASA is designing arrays of ground-based antennas to serve the telecommunications needs of future space exploration. Medium-size (12m class) antennas have been selected for receiving, and arrays of hundreds of them are expected to be required. Applications include communication with distant spacecraft; radar studies of solar system objects; radio astronomy; and perhaps other scientific uses. 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 band (X-band) in the near term and may be in the 31.5 – 33.0 GHz band (Ka-Band) 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. It is also desirable to support as many as ten simultaneously-operating deep-space missions from one complex on Earth, and to have at least three geographically separated complexes so communication is possible with a given spacecraft at any time of the day. The major open questions in the uplink array design are:

- Minimizing the life-cycle cost of an array that produces a given EIRP by selecting the optimum combination of antenna size, transmitter power, and number of antennas. This becomes much more difficult if the option of using the same antenna for both uplink and downlink is considered;
- Identifying/developing low-cost, highly reliable, easily serviceable components for key systems. This could include highly integrated RF and digital signal processing electronics, including mixed-signal ASICs. It could also include low-cost, high-volume antenna manufacturing techniques. (For the receiving array, another key component is a cryogenic refrigerator for the 15 – 25K range.) Also, low-cost transmitters (including medium-power of the order of 100s of Watts) amplifiers are key;
- Phase calibration techniques are required to ensure coherent addition of the signals from individual antennas at the spacecraft. 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. These will minimize the need for continuous, extensive and/or disruptive calibrations;
- 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 this is needed; and

- Techniques for integrating a very low-noise, cryogenically-cooled receiver with medium power (1W to 200W) transmitter. If transmitting and receiving are combined on the same antenna, the performance of each should be compromised as little as possible while maintaining low cost and high reliability.

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

O1.05 Reconfigurable/Reprogrammable Communication Systems
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

NASA seeks novel approaches in reconfigurable, reprogrammable communication systems to enable the Vision for Space Exploration, Science, and Space Operations. Exploration of the Moon and Mars 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 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 subtopic seeks advancements in reconfigurable transceiver and component technology, providing flexible, reconfigurable capability while minimizing on-board resources and cost. The use of open standards within the software radio development is desirable while minimizing potential increased resources and inefficiencies. 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 techniques. Complex reconfigurable systems will provide multiple channel and simultaneous waveforms. Areas of interest can be divided as follows:

Signal Waveforms and On-Orbit Reconfiguration

- Multiple waveforms and multiple channel support strive to reduce radio count to reduce power consumption of the overall communication system. Tradeoffs in radio count and radio complexity are considered in the analysis. Reconfiguration for software and firmware upgrades shall provide access control, authentication, and data integrity checks for the reconfiguration process. Partial reconfigurable logic allows simultaneous operation and upload of new waveforms or functions. Upon operator or automated load detection failure, capability to provide access back to a known, reliable operational state is needed. An automated restore capability ensures the system can revert to a baseline configuration, thereby avoiding permanent communications loss do to an errant reconfiguration process. Approaches should minimize size and power consumption for deep space transceivers incorporating fault tolerant, reprogrammable digital signal processing devices.
- Implementations demonstrating the concept function, and benefits of dynamic or distributed on-board processing architectures to provide maximum reconfigurability and processing capacity are sought. A common processing system capacity for communications, science, and health monitoring is envisioned.
- Demonstration of adaptive modulation and waveform recognition techniques are desired to provide capability to reconfigure to the waveform identified based on an on-board library or enable new waveform upload to the on-board library from the ground.

Software Architecture, Implementation, Modeling and Verification

- Development and demonstration of low overhead, low complexity hardware and software architectures to enable software component or design reuse, or common testing standards that demonstrates cost or time savings. Emphasis on the application of open standards architecture to facilitate interoperability among different vendors to minimize the operational impact of upgrading hardware and software components.

- Methods that enable portability among reconfigurable logic hardware devices among different vendors, different device families and types of digital processing technologies.
- As the use of software and firmware increases with more flexible and portable software defined radio technologies, methods are sought to reduce the complexity and cost to space qualify and verify software operation for use in space yet maintain or increase on-orbit reliability.
- Techniques to ensure reliable software execution and failure detection and self-correction.
- One promise of a software defined radios is software and design reuse maintained in a common repository. The cost or ability to reuse software depends on implementation, development practices, code complexity and other circumstances. This subtopic seeks the development and demonstration of software tools or tool chain methodologies to enable both design and software code reuse.

Fault Tolerance

- 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 caused by charged particles are sought that reduces power consumption and complexity compared to traditional approaches (i.e., voting schemes and constant updates (scrubbing)).
- Techniques and implementations to provide a core waveform 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 or “gold” waveform automatically executed to provide control access to diagnosis system and over-the-air reload operational waveform and control software.

Radio Architectures

- Innovative solutions to provide software defined radio implementations to reduce power consumption and mass. Solutions should promote modularity and common, open interfaces.
- Software defined radio implementations that enable future hardware scalability among different mission classes (e.g., low rate deep space to moderate or high rate near planetary, or relay spacecraft). Operational characteristics range from 1’s to 10’s Mbps at UHF and S-band frequency bands up to 10’s to 100’s Mbps at X, and Ka-band frequency bands.

Component Technology

- Advancements in analog-to-digital converters or digital-to-analog converters to increase sampling and resolution capabilities while reducing power consumption.
- Novel techniques to advance memory densities, reduce power consumption, and improve performance in harsh environments.
- Advancements in reconfigurable logic technology including processing advancements, radiation hardened commercial technology and advancements in advanced computing such as polymorphous computing.

O1.06 Extravehicular (EVA) Radios
Lead Center: JSC
Participating Center(s): GRC

This subtopic focuses on dramatically shrinking the size of the EVA radio by selecting and using micro-machined RF components in the development of a Phase 1 circuit design which demonstrates compact high Q selective devices to propose for Phase 2 to fully fabricate and demonstrate a prototype radio incorporating the compact high Q filter technology developed and demonstrated during Phase 1. This subtopic seeks proposals to close a critical technology gap in the ability to reduce the form factor and power requirements of the EVA Radio while increasing its selectivity and performance, enabling long duration human exploration while simultaneously increasing communications reliability and crew safety.

Miniature EVA Radio
Human exploration demands versatile, lightweight, and miniaturized EVA Radios to enable surface operations and increase astronaut mobility. The size, weight, and power consumption of EVA Radios must dramatically decrease to reduce overall mission costs. These EVA Radios cannot sacrifice performance for weight, power, and form factor requirements – in fact, quite the opposite. While the form factor shrinks, the performance must increase to handle the combination of voice, data, and video needed to support the complex tasks in the next generation of manned mission scenarios.

EVA Radios based on micromachined RF components eliminate the most bulky pieces – the RF components in the diplexers, pre-selectors, and bandpass filters. For example, most high rejection diplexers for space-based radios are almost as enormous as the modern radio package itself. Micro-machined RF elements can complement space radio technology by coupling high-performance and increased reliability with reduction in size.

Besides low spatial volume, a significant mass reduction, and low-power consumption, micro-machined RF devices are also attractive to operate as high Q components to perform frequency selectivity without mass penalties. To build and design high performance, tightly coupled, low volume space radios, compact selectivity-determining devices are a critical enabler. Most high Q filters above 400MHz, such as inter-digital filters and others involving resonant cavities, tend to be wholly mechanical assemblies whose size is generally governed by their frequency and some derivative of their resonate wavelength. By applying micro-machining techniques, the same filter assemblies employing advanced 3D packaging techniques can be “folded” in the design, which is conducive to an order of magnitude improvement in utilization of EVA radio volumetric space.

New EVA Radio Capability
The intent of this subtopic is to develop, apply and demonstrate advantages of micro-machined RF component-based circuitry that proliferate the implementation of next-generation lightweight EVA radios. Areas of investigation may include electromechanically tuned filters, 3D packaged, micro-machined RF resonators, filter configurations consisting of cantilevered structures, as well as carbon nanotube waveguide assemblies. Through application of these fabrication and packaging techniques great strides will be realized in improving functionality, enhancing performance and achieving high reliability for long duration manned space missions. Miniature EVA Radio features include:

- Dramatic reduction of mass;
- Dramatic reduction in power requirements;
- High selectivity components, reducing interference and overlap;
- High reliability through Fault Tolerant design;
- Frequency agility;
- Software defined waveforms and modulation/demodulation.

Technical Approach
The design and use of circuitry using micro-machined RF components to dramatically shrink EVA Radio form factor while increasing operational performance will be supported by investigations and trade studies selecting current and near-term micro-machined RF components, culminating in a circuit design demonstrating their use to make a high Q element. Phase 2 will harness the high Q element as a model; then design an overall EVA Radio architecture compliant with Space Transportation Radio System (STRS) embracing a fault tolerant hardware design. The tradeoffs in sensitivity, selectivity, and packaging will be investigated in the Phase 2 effort.

Commercialization Plan
By providing users with a small size, low power, high performance SDR-based radio platform, the miniature EVA radio has derivative uses far beyond the scope of space exploration. The combination of micro-machined RF assemblies and 3D packaging in the miniature EVA radio has vast implications for both future space exploration and commercial wireless and mobile radio communications:

First Responders: Interoperability among Police, Fire, HazMat, Homeland Security, and Medical personnel
Military: Soldier-centric secure communications, mode switchable on-the-fly
Commercial: Cell phones, pagers, Wi-Fi/Bluetooth/UWB radio integration

O1.07 Transformational Communications Technology
Lead Center: GRC
Participating Center(s): JSC

NASA seeks revolutionary, highly innovative, "transformational" communications technologies that have the potential to enable order of magnitude performance improvements for exploration systems, science, and space operations mission applications. Research focuses on (but not limited to) the following areas:

- Innovative methods of using X-ray or radio pulsar signals for precise navigation or positioning of spacecraft. Small, low mass, reliable detectors, improvements in position accuracy, digital signal processing advances for time of arrival, drift estimation, and position estimation.
- Development of nano-scale communication devices and systems (e.g., FET arrays, nano-antennas, nano-transceivers, etc.) for nano-spacecraft applications.
- Quantum entanglement or innovative breakthroughs in quantum information physics to specifically address curious effects and critical unknowns relevant to revolutionary improvements in communicating data, information or knowledge between independent entities across space-time. Methods or techniques that demonstrate extremely novel means of effectively packaging, storing, encrypting, and/or transferring information or knowledge.
- Breakthrough power-efficiency in communications brought about through the use of natural phenomenon, e.g., soliton pulse/wave/energy propagation.
- Innovative uses of radiofrequency spectrum, planetary atmospheres, or planetary electromagnetic properties for the breakthrough communication of data, information or knowledge directly between independent entities.
- RF Micro Electro-Mechanical Systems (MEMS) devices. Besides low spatial volume, lightweight, and low-power consumption, these devices are also attractive to operate as high Q components and perform frequency selectivity – namely, agile pre-selectors, multi-couplers, and diplexers. Selectivity, or Q, for band pass filters currently comes at an unacceptably high penalty in size and mass. For example, most high rejection diplexers for space-based radios are almost as enormous as the modern radio package itself. To build and design high performance, tightly coupled, low volume space radios, compact selectivity-determining devices are a critical enabler. Most high Q filters above 400MHz, such as inter-digital filters and others involving resonant cavities, are wholly mechanical assemblies which can be "folded" in their design and lend themselves to micro machining techniques
- Other rich areas of investigation may lie within the area between MEMS and Micro-Machined devices, including electromechanically tuned filters, 3D micro machined RF resonators, filter configurations consisting of cantilevered structures, as well as carbon nano-tube waveguides. Develop, apply and demonstrate advantages of RF MEMS circuitry that proliferate the implementation of next-generation lightweight communications systems (e.g. extravehicular activity (EVA) radios).

O1.08 Long Range Optical Telecommunications
Lead Center: JPL
Participating Center(s): GRC, GSFC

This subtopic seeks innovative technologies for long-range optical telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

- Space-qualifiable, efficient (greater than 25% wall plug), lightweight, variable repetition-rate (1 – 60 MHz), tunable (± 0.1 nm) pulsed 1064 nm transmitter sources (diode-pumped fiber amplifier or bulk crystal laser/amplifier) with greater than 1 kW of peak power per pulse (over the entire pulse-repetition rate), and greater than 10 W of average power, and narrow (< 10 pm) spectral width;
- Space-qualifiable, high-peak power (> 1.2 W), average-power (> 300 mW), operating wavelength less than 1000 nm single-mode-fiber pigtailed laser diode transmitters (includes necessary modulator; internal or external driver) with narrow spectral width (< 100 pm) supporting 4-ary pulse-position-modulation for data rates of 0.5 – 1000 Mbps with high wall-plug electrical-efficiency (> 25%);

- Space-qualifiable, photon counting 1064 nm and/or 1550 nm detectors a temperature of 220 K or greater, with the gain greater than 3000, detection efficiency greater than 50%, dark rate < 1 MHz per mm^2 active area, > 0.2 mm in active area diameter, bandwidth greater than 500 MHz, saturation levels > 50 Mcounts/s and non-gated (continuous operation), and lifetime > 3 years at 100 Mega photons /sec continuous photon flux;
- Lightweight, compact, high precision (less than 0.1 micro-radian), high bandwidth (0-2 kHz), inertial reference sensors (angle sensors, gyros) for use onboard spacecraft;
- Novel schemes for stray-light control and sunlight mitigation, especially for large (> 5 m) ground-based optical telescopes that must operate when pointed to within a few (about 3) degrees of the Sun;
- Lightweight, high precision (one micro-radian accuracy) star-trackers for spaceflight application that can be integrated with an optical communications terminal;
- Novel techniques and technologies that will enable very low cost, large aperture (> 5 m equivalent aperture diameter) telescopes for ground or space-borne use;
- High power ground-based, relatively low-cost diode-pumped laser technology capable of reaching 100 kW average power levels in a TEM_{00} mode, for uplink to spacecraft;
- Artificial laser guide-star and beam compensation techniques capable of removing all significant atmospheric turbulence distortions (tilt and higher-order components) on an uplink laser beam;
- Novel techniques to reduce the development cost and risk of future space-borne optical communications transceivers (e.g., automatic focusing or alignment techniques); and
- Systems and technologies relating to sub-microradian pointing, acquisition, and spacecraft vibration.

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

O1.09 Long Range Space RF Telecommunications
Lead Center: JPL
Participating Center(s): GRC, GSFC

This subtopic seeks innovative technologies for long-range RF telecommunications supporting the needs of space missions. Proposals are sought in the following areas:

- Ultra-small, 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 (32 GHz and 38 GHz);
- High-efficiency (> 70 %) Solid-State Power Amplifiers (SSPAs), of both medium output power (10 – 50 W) and high-output power (150 W – 1 KW), using power combining techniques and/or wide-bandgap semiconductor devices at X-band (8.4 GHz) and Ka-band (32 GHz and 38 GHz);
- Traveling Wave Tube Amplifiers (TWTAs), SSPAs, modulators, and MMICs for 26 GHz Ka-band (lunar communication);
- TWTAs operating at millimeter wave frequencies 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 S-, X-, Ka-, and V-band (60 GHz). Of particular interest is Ka-band from 25.5 – 27 GHz and 31.5 – 34 GHz.

O1.10 Surface Networks and Orbit Access Links
Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

NASA is planning a series of short and long duration human and robotic missions to explore the Moon and later Mars. The lunar and Mars surface and access network architectures will enable operational activities in which nodes are simultaneously connected to each other, to Earth, and to the Crew Exploration Vehicle (CEV) via in-space relay orbiters, and wired and wireless networks that provide the bidirectional voice, video, and data services. This subtopic is divided into the surface networks and access link domains (surface to orbiting assets).

Surface Networks
Exploration of lunar and planetary surfaces will require short-range, bidirectional, and robust multi-point links to provide on-demand, disruption tolerant, and autonomous interconnection among surface-based assets. Some of the nodes will be fixed (base stations and relays to orbital assets) and some will be moving (rovers and humans). The ability to meet the demanding environments presented by lunar and planetary surfaces will encompass the development and integration of a number of communications and networking technologies and protocols, including:

- Low mass/power (100's of milliwatts) transceivers for very short range interfaces with sensors and other small devices to enable communications among humans, robots, and access network terminals;
- Reconfigurable, directionally selectable, steerable, multi-frequency switched patch or multiple-in multiple-out [MIMO] antenna arrays for human helmets, robots, and fixed structures (e.g. habitats);
- Miniaturized planar, omni-directional, dual-polarized, self-orienting, and sector antennas for surface-to-surface communications among mobile and fixed nodes;
- Low power space rated ASICs and FPGAs for wireless network products; short (< 1km) range access point, base stations, or wireless router bridges for extending surface network coverage;
- Fixed, long (up to 50km) range, wireless network terminals for extending high data rate communications over large distances;
- Integrated, autonomous tracking and navigation architectures and technologies;
- Self-healing, ad-hoc, disruption tolerant network protocols for intelligent, autonomous link management and reliable throughput.

Access Links
Lunar and planetary surface networks will need to seamlessly interface with communications access terminals and orbiting relays that can provide autonomous and disruption tolerant 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:

- High rate, efficient solid state amplifiers capable of very high data rates over 1,000 – 10,000 km distances with ranging signal embedded;
- Very low power, data rate, and cost inter-spacecraft S-band transceivers for inexpensive spacecraft;
- Optical transceiver capable of very high data rates over 1,000 – 10,000 km distances;
- Agile, multi-beam antennas; mesh or other material flexible reflector unfurlable antennas for Ka-band and lightweight scanning phased array antenna systems;
- SEU and solar flare tolerant transponder capable of programmable wide carrier frequency range from S-band to Ka-band, taking GPS measurements, and handling IP at the digital level;
- Micro software radio technology for autonomous and intelligent space applications;
- Low mass, volume, power, and cost stable oscillators to provide accurate time and frequencies for autonomous operations;
- Autonomously reconfigurable receivers capable of automatic link configuration and management;
- Microwave ranging hardware built into communication system for rendezvous and collision avoidance;
- Ad-hoc, long-range spacecraft to spacecraft network protocols to set up links on demand such that each node can route data through to another node.

O1.11 Software for Space Communications Infrastructure Operations
Lead Center: JPL
Participating Center(s): ARC, GSFC

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.

New technology is sought to improve resource optimization and the user interface of planning and scheduling tools. The software created should have a commercialization approach with the new modules fitting into an existing or in-development planning and scheduling tool. Proposals are sought in the following three areas:

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 by determining what decisions should 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.

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.

The proposal should explicitly include an operations scenario of before and after the inclusion of the new technology.

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 US 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, automated tracking and identification of objects, and instrumentation for space transportation system testing are all required. The following subtopics are required secure technologies for these capabilities.

O2.01 Automated Optical Tracking and Identification of Tumbling 3D Objects
Lead Center: KSC
Participating Center(s): DFRC, GSFC

Tracking and Identification of 3D Tumbling Objects
Develop techniques to track and construct 3-dimensional views of tumbling objects in the atmosphere or space using digital optical tracking images for a variety of missions. These views will be used to determine the objects' approximate geometric sizes and shapes. The potential application is to help track and identify debris quickly after an accident or flight anomaly. The data will be provided by sequential digital images from one or more tracking cameras, ideally operating autonomously. The goal is to track and identify between 50 to 100 objects with typical cross-sections varying from tens of square meters down to one square meter or less within several minutes after an accident. The initial investigation will determine the minimum size that can be imaged using current technology, the probability of correctly estimating an object's size and shape, the processing speed, and the means for transmitting analyzed data to the command center.

GPS or Radar-aided Autofocus
Investigate using range information from radar, GPS, or other sources, for autofocusing long-range optics systems. Optical tracking provides valuable data during aerospace operations, but large distances between the target and the optical system can lead to distortions caused by atmospheric disturbances. Range information might be useful for a computer-controlled optical focusing system to decrease this distortion. The initial investigation will determine if this approach could be useful using one or multiple cameras, how it might be implemented, and if range information could be combined with other distortion–reduction techniques.

New Optical Tracking Systems
Investigate innovative and unconventional ways to use optical or hyperspectral imaging systems to visualize and track vehicles during launch and landing operations. Possibilities might include, but are certainly not limited to, unmanned aerial vehicle platforms or balloons. The system must be implemented unobtrusively in a spaceport environment. The initial investigation should result in a proof-of-concept demonstration in an appropriately scaled environment.

O2.02 Space Transportation Propulsion System and Test Facility Requirements and Instrumentation
Lead Center: SSC
Participating Center(s): GRC, MSFC

Ground testing of propulsion systems continues to be critical in meeting NASA's strategic goals. Relevant ground testing technologies and capabilities are crucial to the development, qualification, and acceptance process of validating cargo launch vehicles and human rated vehicles including Crew Exploration Vehicles (CEV), CEV Launch Systems, Cargo Launch Vehicle (CLV), and Lunar Surface Access Modules propulsion systems. The ability to quickly and efficiently perform system certification greatly impacts all space programs.

Instrumentation and Sensors
NASA's SSC is concerned with expanding its suite of non-intrusive 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. Current capabilities include non-intrusive optical methods of monitoring plumes for metallic contamination from erosion and wear, measuring the radiative and acoustic energies and as well as measuring the concentrations of environmentally sensitive species. SSC also requires facility health management technologies to monitor the physical health of testing infrastructure to improve the sustainability and reliability of the test facilities and components.

- 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 species, temperature, density, velocities, combustion stability and O/F measurement.
- 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, thermal radiation and final exhaust species that will effect the environment.
- Facility Monitoring: Advanced instrumentation and sensors for process monitoring in high pressure 12,000 psi and high flow rate 100 lb/sec gas and cryogenic environments. Applications include; cryogenic level sensing, fast response/high accuracy cryogenic temperature sensors. Facility response and analysis capabilities for monitoring facility structure, process systems and test article interaction. These include dynamic response, structural fatigue and pipe system health.

Computational 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 result 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.

- Plume Environments: Improved capabilities to predict and model acoustic and thermal energy produced by exhaust plumes and interaction/coupling with facilities. Exhaust constituents and far field buoyant plume modeling for environmental impact assessment.
- 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. This capability is required for modeling components in high pressure 12,000 psi, high flow 100 lb/sec cryogenic environments and must address two-phase flows.
- Process System Design, Prediction and Modeling: Improved capabilities to predict and model process systems. The capability should incorporate the previous two areas to accurately model the process systems and test articles.

O2.03 Automated Collection and Transfer of Launch Range Surveillance/Intrusion Data
Lead Center: KSC
Participating Center(s): GSFC

Range surveillance is a primary focus of launch range safety and often cost and schedule drivers as well. Launch delays due to difficulty in verifying a cleared range are common and will increase as development encroaches on existing spaceports and as spaceports are built in new areas. Proposals are sought for innovative sensors, instrumentation platforms, and communication technologies which expedite range clearance by providing real-time situational awareness for range operations such as launches, hazardous processing, and recovery.

- Instrumentation platforms will provide mobile or transportable surveillance assets for broad area coverage to meet range needs. These platforms should be capable of a high degree of self-sufficiency and autonomy for unattended, long-term operations. During operations the platform must maintain stability so that instruments are not required to compensate for unique environmental characteristics surrounding the operations. Platforms may include, but are not limited to, Unpiloted Aerial Vehicles (UAV), High Altitude Airships (HAA), buoys, etc.
- Instrumentation and sensors would include but not be limited to a wide spectrum of optical, infrared, Radio Frequency (RF), and millimeter wave. These would provide for the detection, recognition, and identification of persons and objects that have intruded areas of the range that must be cleared in order to conduct safe launch operations. In addition, multiple sensors and instruments may be used, or combined through the use of neural networks and data fusion, for accurate identification, and time and position of entities.
- Centric and integrated communications schemes that adhere to widely accepted standards will enable a scalable architecture for range instrumentation that supports launch operations. Data rates and bandwidth requirements may vary greatly depending on instrumentation and sensors that are incorporated on a range. These constraints and the distributed nature of a range dictate the need to include multiple communication media such as free-space optics, Wi-Fi, and terrestrial and space-based communications links in order to transport the collected data. Novel and innovative approaches to this architecture are sought.

9.2 STTR Research Topics

Each STTR Program Solicitation topic corresponds to a specific NASA Center. Two subtopics per topic reflect the current highest priority technology thrusts of that Center.

TOPIC: T1 Ames Research Center

Ames Research Center stands at the epicenter of the most prolific and prosperous cluster of high technology businesses, universities, and research laboratories in the world. Ames is internationally recognized as a pre-eminent research institution with an enduring research culture. Innovative design concepts and breakthrough technologies developed here over the last 60 years are legendary. They include the blunt body concept, the first manmade object to leave the Solar System (Pioneer), the supersonic area rule, hypersonic ranges, arc jets, the chemical origins of life, computational fluid dynamics, massively parallel computing, air traffic management, airborne science, exploration of the outer planets, infrared astronomy, and the discovery of water on the moon. Ames today seeks innovative breakthroughs in a 21st Century arena. Ames' pioneering research in information technology, biotechnology, and nanotechnology will enable development of innovative sensors to probe Earth, other planets, and other solar systems, and dramatically increase the ability to communicate large volumes of information across space. It could also lead to stronger materials, ultra-small electronic devices, and new space missions with lower-weight components requiring less power and fuel. With leading-edge capabilities in high-end computing, Ames can fully exploit these emerging technologies and interdisciplinary research, which many see as the most likely source of breakthrough technologies in the coming decades.

T1.01 Information Technologies for System Health Management, Autonomy, and Scientific Exploration
Center: ARC

Information technology is a key element in the successful achievement of NASA's strategic goals. Modern tools and techniques have the capability to redefine many design and operational processes as well as enable grand exploration and science investigations. This subtopic seeks innovative solutions to the following information technology challenges:

- Onboard methods that monitor system health and then automatically reconfigure to respond to failures and sustain progress toward high-level goals. Special emphasis will be on computational techniques for coordinating multi-agent systems in the presence of anomalies or threats. Proposals should focus on data analysis and interpretation rather than development of new sensors;
- Onboard, real-time health management systems that perform quickly enough to monitor a flight control system (including spacecraft and fixed or rotary wing aircraft) in a highly dynamic environment and respond to anomalies with suggested recovery or mitigation actions;
- Integrated software capabilities that allow automated science platforms, such as rovers, to respond to high-level goals. This could include perception of camera and other sensor data, position determination and path planning, science planning, and automated analysis of resulting science data;
- Data fusion, data mining, and automated reasoning technologies that can improve risk assessments, increase identification of system degradation, and enhance scientific understanding;
- Techniques for interconnecting and understanding large heterogeneous or multidimensional data sets or data with complex spatial and/or temporal dynamics;
- Computational and human/computer interface methodologies for inferring causation from associations and background knowledge for scientific, engineering, control, and performance analyses;
- Innovative communication, command, and control concepts for autonomous systems that require interaction with humans to achieve complex operations.

T1.02 Space Radiation Dosimetry and Countermeasures
Center: ARC

As NASA embarks on its Exploration agenda the study of the Cosmic, Solar, Lunar, and Van Allen Belt space radiation environments will continue to guide new biologically related innovation and mitigation needs at NASA. Understanding Space Radiation induced effects on biological organisms is a vital component for future manned spaceflight mission success. Development of support technologies to protect astronaut crew health will be essential for successful long-term mission operations. Our current understanding of the space radiation environment interaction with humans, space rated materials, and technological systems is limited. Specifically, information on radiation events with high atomic number, high energy particles (HZE particles), and energetic protons is lacking compared to our understanding of gamma and x-rays. NASA has established a space radiation laboratory at Brookhaven National

Labs capable of generating HZE particles and protons. NASA also supports a facility at Loma Linda University Medical Center capable of generating energetic protons to enable research studies and technology development. NASA is seeking innovative technologies in the areas described below.

Advanced Space Radiation Dosimeters

NASA seeks the development of a small, low power suite of dosimeters to measure the biologically significant range of space radiation on board manned spacecraft, planetary habitats, or on astronaut extravehicular activity (EVA) suits. The devices must be able to measure the absorbed dose/linear energy transfer (LET) based dose equivalent from electrons, photons (X-rays and gamma rays), protons, heavy ions (HZEs) and secondary neutrons. Both real-time dose/dose equivalent rate and cumulative dose/dose equivalent over selected time intervals, e.g. a day or a mission, are required, along with an alarm system based on fluence rate, dose rate, or cumulative dose (e.g. during Solar Particle Events). The suite of dosimeters should provide time resolved LET data or a suitable surrogate (e.g. lineal energy (y) as measured by a gas filled microdosimeter) and have embedded linear energy transfer-based quality factor algorithms for determining dose equivalent. The devices should be sensitive down to 0.05 milliGray/0.1 mSv and should be able to measure a maximum dose of 1 Gy/3 Sv. The LET of charged particles of interest ranges from 0.2 keV/μm to 1000 keV/μm. The National Council on Radiation Protection and Measurements Report 142 includes a detailed description of the radiation field to be assessed for radiation protection of astronauts. NASA acknowledges the difficulty in measuring secondary neutrons from interactions of protons and heavy ions with spacecraft structures and has particular interest in this area. If possible, the response of candidate dosimeters to protons, heavy ions, and neutrons should be characterized. For absorbed dose calibrations, the devices should be calibrated to National Institute of Standards and Technology (NIST) traceable absorbed dose standards. Prototype hardware or technology developed must be capable of being converted to robust and reliable space flight hardware in the future. This means that all hardware and software must be capable of being fully documented in the future, and that interface software must be compatible with current operating systems.

High Throughput Genomic Analysis Techniques

Following low dose irradiation of cells by protons and heavy ions, damage is localized to only a very few cells. The ability to separate cells with or without genetic changes in an automated manner is of interest. Current technologies are inefficient in identifying smaller-scale genetic changes (less than a million base-pairs (Mbp)) under these conditions. Technologies of interest are:

- Technologies to rapidly score small-scale genetic changes (<1 Mbp), that would be complementary to fluorescence in-situ hybridization (FISH) and other methods used to score large scale (> 1 Mbp) genetic changes to chromosomes following low dose irradiation;
- Imaging techniques to rapidly identify with high accuracy undamaged cells from a cell population irradiated at low doses.

High Throughput Countermeasure Evaluation Techniques

NASA seeks the development of high throughput techniques for the evaluation of countermeasures that can be used by astronauts to ameliorate the effects of ionizing radiation in space, including Solar Particle Events, secondary radiation particle events, and continuous low dose radiation exposure. Techniques to evaluate currently available pharmaceuticals to counteract radiation effects are of interest.

TOPIC: T2 Dryden Flight Research Center

Flight Research separates "the real from the imagined" and makes known the "overlooked and the unexpected." – Hugh L. Dryden. The Dryden Flight Research Center, located at Edwards, California, is NASA's primary installation for flight research. Projects at Dryden over the past 50 years have lead to major advancements in the design and capabilities of many civilian and military aircraft. The history of the Dryden Flight Research Center is the story of modern flight research in this country. Since the pioneering days after World War II, when a small, intensely dedicated band of pilots, engineers, and technicians dared to challenge the "sound barrier" in the X-1, Dryden has been on the leading edge of aeronautics, and more recently, space technology. The newest, the fastest, and the highest – all have made their debut in the vast, clear desert skies over Dryden.

T2.01 Flight Dynamic Systems Characterization
Center: DFRC

This subtopic solicits proposals for innovative, linear or non-linear, aerospace vehicles dynamic systems modeling and simulation techniques. In particular:

Research and development in simulation algorithms for computational fluid dynamics (CFD), structures, heat transfer, and propulsion disciplines: Emphasis is placed on the development and application of state-of-the-art, novel, and computationally efficient solution schemes that enable effective simulation of complex practical problems such as modern flight vehicles, like X-43 and F-18-AAW, as well as more routine problems encountered in recurring atmospheric flight testing on a daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered an important part of this topic.

Aeroelasticity and aeroservoelasticity, linear and non-linear: Vehicle stability analysis is an important aspect of this topic. Primary concern is with the development and application of novel, multidisciplinary, simulation software using finite element and other associated techniques.

T2.02 Advanced Concepts for Flight Research
Center: DFRC

This subtopic is intended to be broad and to solicit and promote technologies for the following:

- Automated online health management and data analysis;
- 21st Century air-traffic management with Remotely Operated Aircraft (ROA) within the National Air Space; and
- Modeling, identification, simulation, and control of aerospace vehicles in-flight test, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts.

Proposals in any of these areas will be considered.

Online health monitoring is a critical technology for improving transportation safety. Safe, affordable, and more efficient operation of aerospace vehicles requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local and wide area networks. Online health monitoring is a general concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of online emphasizes algorithms that minimize the time between data acquisition and decision making.

The challenges in Air Traffic Management (ATM) are to create the next generation systems and to develop the optimal plan for transitioning to future systems. This system should be one that seamlessly supports the operation of ROAs. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.

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 test 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-testing. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. 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, 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 test experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment. The emphasis of this subtopic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and that require a demonstration in an actual-flight environment to fully characterize or validate advances.

TOPIC: T3 Glenn Research Center

The NASA Glenn Research Center at Lewis Field, in partnership with other NASA Centers, U.S. industries, universities, and other Government institutions, develops critical technologies that address national priorities for space and aeronautics applications. NASA Glenn's world-class research and technology development is focused on space power, space flight, electric and nuclear space propulsion, space and aeronautic communications, advanced materials research, biological and physical microgravity science, and aerospace propulsion systems for safe and environmentally friendly skies. NASA Glenn has two sites in northern Ohio. Situated on 350 acres of land adjacent to the Cleveland Hopkins International Airport, the Cleveland site in northeast Ohio comprises more than 140 buildings including 24 major research facilities and over 500 specialized research and test facilities. Plum Brook Station is 50 miles west of Cleveland and has four major world-class facilities for space research available for Government and industry programs. The staff consists of over 2000 civil service and support service contractor employees. Scientists and engineers comprise more than half of our workforce with technical specialists, skilled workers, and administrative staff supporting them. Over 60 percent of our scientists and engineers have advanced degrees, and 25 percent have earned Ph.D. degrees.

T3.01 Space Power and Propulsion
Center: GRC

Development of innovative technologies and systems are sought that will result in robust, lightweight, ultra-high efficiency, lower cost, power and in-space propulsion systems that are long-lived in the relevant mission environment and that enable future missions. The technology developments being sought would, through highly-efficient generation and utilization of power and in-space propulsion, significantly increase the system performance.

Innovations are sought that will significantly improve the efficiency, mass specific power, operating temperature range, radiation hardness, stowed volume, flexibility/reconfigurability, and autonomy of space power systems. In power generation, advances are needed in photovoltaic cell structure including the incorporation of nanomaterials; module integration including monolithic interconnections and high-voltage operation; and array technologies including ultra-lightweight deployment techniques for flexible, thin-film modules, and concentrator techniques as well as dynamic power generation systems for nuclear power conversion. In energy storage systems, advances are needed in batteries-primary and rechargeable-regenerative fuel cells, and flywheels. 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 solar electric propulsion technology, advances are needed for ion, Hall, and advanced plasma thrusters 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. Also, advances are sought for chemical, electrostatic, or electromagnetic miniature and precision propulsion systems and nano- and autonomous systems that include nanomaterials, high temperature shape memory alloys, and piezoelectric materials as well as control systems for autonomous, adaptive engine control and sealing.

T3.02 Bio-Technology and Life Support
Center: GRC

The new Vision for Space Exploration (VSE) entails the eventual presence of humans on the planetary surfaces of both the Moon and Mars. The physiological effects of prolonged space exposure (to both the microgravity environment of interplanetary space as well as the reduced gravity environments of the moon and mars) need to be quantified in order minimize mission risk, as well as insure the general health of astronauts both in space and upon their return to earth. Biomedical sensors to monitor astronaut health that maximize diagnostic capability while reducing up-mass and power requirements are of significant interest for exploration missions. For longer duration missions on the Moon and the journey to Mars, the astronaut's continued health maintenance and fitness evaluation for mission critical activities will need to be performed routinely. Similarly, medical diagnostics are required to evaluate acute events like fatigue fractures. As a result, there is an acknowledged need for compact, robust, multi-function diagnostic biomedical sensors to reduce levels of risk in exploration class missions. To fully quantify space-normal physiology, these biomedical sensors must be supplemented by advanced analytical tools, such as high-resolution microscopy and lab-on-a-chip instrumentation (for blood or urine analysis). In addition, computational models (incorporating the direct physiological data) are needed that allow comparison to 1G values and determination of secondary physiological quantities (e.g., cardiac dysrthymia and renal stone formation, as related to measured calcium levels). These computational models will also enable physicians to predict, diagnose and treat pathologies that are either not present in a 1G environment or are induced by synergies with spaceflight stressors. Specific innovations required for this task include:

- Noninvasive or minimally invasive sensors to detect health parameters such as: metabolic rate, heart rate, ECG, oxygen consumption rate, CO_2 generation rate, core and/or skin temperature, radiation monitoring, oxygen saturation level, intra-cranial pressure, and ocular blood flow rates;
- Novel analytical capabilities such as high resolution microscopy and lab-on-a-chip analysis of blood and urine;
- Technologies for IV fluid mixing and medical grade water generation from the onboard potable water supply;

- Novel approaches to noninvasive measurement of cephalad fluid shift and bone density measurements on astronauts in space is desired to understand and mitigate adverse effects of space environment on astronaut health and performance.

Although the Moon and Mars differ vastly in their origins and near-surface environments, common to both is the ubiquitous presence of fine particulates in the surface regolith. The objectives of the VSE specify missions of unprecedented duration and complexity, posing new classes of technical and operational challenges. One such challenge is managing the effects arising from the finest particulate fractions, commonly referred to as dust. The detailed experiences afforded by the series of Apollo missions provide valuable insights into the problems attributable to Lunar dust. Both anecdotal descriptions provided in situ by the crew members and analysis after the fact provide a lengthy testimony to the numerous technical issues associated with dust. Innovative technologies are needed to monitor the presence of dust, separation of dust from the cabin environment, removal of dust from EVA suit and mitigation of any adverse effects on astronaut health. Specific innovations required include:

- Novel approaches (and instrumentation) for detecting the presence of fine particulates in the cabin and airlock environments and effective regenerative technologies for removing them are required;
- Technologies to effectively and safely remove dust particles from EVA suits and from the surface of any equipment that needs to be transported from the Lunar surface into the cabin environment are needed;
- Technologies and novel approaches to mitigate any adverse effects of dust on the performance of life support equipment and processes are also needed.

Low mass, high reliability, robustness, low power consumption, long life, ease of usage and easy interface with the onboard data acquisition and control system are highly desirable attributes for all candidate technologies.

TOPIC: T4 Goddard Space Flight Center

The mission of the Goddard Space Flight Center is to expand knowledge of the 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 Earth Science Sensors and Instruments
Center: GSFC

As part of its mission, NASA seeks to develop a scientific understanding of the Earth system and its responses to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. By using breakthrough technologies for terrestrial, airborne, and spaceborne instrumentation, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

This subtopic is to help provide advanced remote sensing technologies to enable future Earth Science measurements.

Active Remote Sensing Instruments (Lidar)
Lidar remote sensing systems are required to meet the demanding measurement requirements for future Earth Science missions. Instruments are solicited that enable or support the following Earth Science measurements:

- High spatial and temporal resolution observations of the land surface and vegetation cover (biomass);
- Profiling of clouds and aerosols;
- Wind measurements (direct-detection technology only);
- Tropospheric and stratospheric ozone and CO_2 (profiling and total column);
- Measurement of the air/sea interface and mixed layer.

Systems and approaches will be considered that demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV or aircraft). New systems and approaches are sought that will:

- Enable one of the Earth Science measurements listed above;
- 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.

Passive Remote Sensing Instruments for Unmanned Aerial Vehicles (UAVs)
Spectral imaging devices for remote sensing onboard UAVs are also desired. In particular, uncooled infrared and thermal spectral imager instruments with the following specifications are solicited:

- Instrument must be less than 2 lbs and no larger than 0.05 m^3 in volume;
- Must operate autonomously in coordination with the onboard flight plan;
- Must have a built-in data acquisition system;
- Spectral bands must all be coregistered and the data must be GPS time tagged;
- Spectral bands should be centered at 3.75, 3.96, and 11 microns as well as a band in the visible at 0.6 microns; and
- Quantization bit resolution should be 10-bit minimum.

Active Remote Sensing Instruments (Radar) for Aircraft and Unmanned Aerial Vehicles (UAVs)
Active microwave remote sensing instruments are required for future Earth Science missions with initial system concept development and science measurements on aircraft and UAVs. New systems, approaches, and technologies are sought that will enable or significantly advance the capability for:

- Tropospheric wind measurements within precipitation and clouds (X- through W-band);
- Large Ground Penetrating Radars (GPR) (P-band and lower);
- Rain measurements using differential or dual-frequency approaches (X- through Ka-band).

Data Compression
New approaches to data compression, also known as source coding, are needed to assist in transporting science instrument data within constrained communication channels, and/or to reduce the requirements for onboard data storage. Additional benefits of data compression include more science data return and facilitating the direct broadcast of science data to ground stations. To target multiple missions, implementations should conform to the Consultative Committee for Space Data Systems (CCSDS, www.ccsds.org) recommendation CCDDS 121.0-B 1. This solicitation seeks development of new data compression processors that:

- Can process science instrument data at over 50 Msamples/sec and take science data input from 1-bit/sample and preferably up to 32 bits/sample;
- Can demonstrate radiation tolerance required for both near-Earth and deep space missions; and
- Consume less than 2 watts of electrical power at 50 Msamples/sec.

T4.02 Space Science Sensors and Instruments
Center: GSFC

Sensors and Instruments for space science applications are:

Analytical Instrumentation
Technical innovations are sought for sensitive, high-precision, analog electronics for measurements of low voltages, currents, and temperatures. Work on cryogenic transition edge detection techniques for X-ray astronomy in particular, and IR sensors with high quantum efficiency. New robust, efficient integration techniques that are scalable to commercial manufacturing efforts are sought.

- High-resolution IR sensors with high quantum efficiency, especially novel ion-implanted silicon devices, and arrays with sensitivities better than 10-16 W per root Hz;

- Cryogenic devices, such as SQUID amplifiers and SQUID multiplexers, superconducting transition-edge temperature sensors, and miniature, self-contained low-temperature He refrigerators;
- Analog application-specific integrated circuits (ASICS) with large dynamic range (> 105) and low power (< 100 microwatts per channel); and
- Novel packaging techniques and interconnection techniques for analog and digital electronics.

Optics
Larger telescopes in space (compared to the 6 m James Webb Space Telescope [JWST]) demand lighter weight materials and new concepts. For example: designs including inflatable structures for lenses, mirrors, or antennas. Order of magnitude increases are envisioned. Applications of new materials could bring a new dimension to astronomy.

Goals for Future NASA Optical Systems

	X-ray Mirrors	UV Mirrors	Visible Scanning	Lidar Telescope	NIR* Earth Science Systems	Far Infrared to submillimeter Wavelength
Energy Range	0.05 – 15 keV	100 – 400 nm	400 – 700 nm	355 – 2050 nm	0.7 – 4 mm	20 – 800 mm
Size	1 – 4 m	1 – 2 m	6 – 10+ m	0.7 – 1.5 m	3m – 4 m	10 – 25 m
Areal Density	< 0.5 kg/m^2/grazing incidence	< 10 kg/m^2	< 5 kg/m^2	< 10 kg/m^2	< 5 kg/m^2	< 5 kg/m^2
Surface Figure	l/150 at l = 633 nm	Diffraction Limited at l = 300 nm	l /150 at l = 500 nm	l/10 at l = 633 nm	l /75 at l = 1 mm	l /14 at l =20 mm

* Near-infrared

- Large-area, lightweight (< 15 kg/m^2) focusing optics, including inflatable or deployable structures;
- Novel laser devices (e.g., for lidars) that are tunable, compact, lower power and appropriate for mapping planetary (and lunar) surfaces. Future lidar systems may require up to ~1.5 m optics and novel designs; and
- Fresnel-zone X-ray focusing optics to form large X-ray telescopes with small apertures but high angular resolution-better than 1 milli-arc-second. Besides newly developed optics, these missions will require formation flying of spacecraft to an unprecedented level.

Mars and Lunar Initiative Technologies
The new Exploration Initiative (Code T) will embark upon an ambitious plan of robotic and human exploration of Mars with intermediate work to be done on the Moon. A broad program of analysis and resource identification is being planned, including X-ray and Gamma-ray spectroscopy. Exploiting the existing resources will be an important part of these initiatives rather than moving resources from place to place. These resource investigations will be conducted from orbit and from landers, both of which have differing requirements. On missions to Mars and other planets, instruments are typically limited to ~5 – 10 kg maximum.

- Low-weight, high throughput X-ray diffraction systems at 60 keV so that sample spectra can be accumulated in minutes or hours, not days;
- Laser-based X-ray generators (up to 60 keV), both compact and lightweight;
- Improved scintillator resolution for Gamma-rays up to 10 MeV; and

- High spatial resolution X-ray detectors, for producing ~50 meters or less maps from orbiting spacecraft, also with high throughput.

Computing
Massively parallel computer clusters for more complicated problems (in General Relativity, electrodynamics and "space weather," for example) are becoming more important. Ways to increase performance and reliability and lower cost are called for.

- Novel computing techniques for simulations (including hydrodynamics, stellar evolution, general relativity calculations, etc.);
- New high-performance, low-cost, reliable massively-parallel computers (i.e., Beowulf clusters); and
- Validation tools and software for space weather simulations and modeling.

UAV and Balloon-Craft Technologies
Both remotely piloted (unmanned airborne vehicles [UAVs]) and balloon instrumentation technologies are sought. New techniques and materials for forming "super-pressure" balloons and ways of formation flying or station-keeping with balloons would enable new science from this inexpensive platform, especially in the unmanned exploration of other planets.

- Super-pressure balloon manufacturing technologies;
- Station-keeping and trajectory control devices for balloons;
- New architectures and technologies for remote sensing applications; and
- Trajectory simulation tools and software.

TOPIC: T5 Johnson Space Center

Innovative technologies and approaches are needed to support human surface exploration on the Lunar/Martian surfaces, and means to better understand and reduce the risk to manned missions from ascent, orbital and interplanetary debris sources. The new technologies being solicited include means to improve operational capabilities; increase human productivity; develop advanced extravehicular activity hardware; provide better debris impact structural modeling and damage prediction; new techniques or solutions for detecting, locating and quantifying potential for damage; better and improved repair techniques; and abilities to enhance the success of future human exploration missions. The anticipated proposed technologies shall have a dramatic impact on achieving the agency goals of the Space Exploration Vision.

T5.01 Advanced Extravehicular Activity (AEVA)
Center: JSC

Complex missions require innovative approaches for maximizing human productivity and for providing the capability to perform useful work tasks. Requirements include reduction of system hardware weight and volume; increased hardware reliability, durability, operating lifetime, and increased human comfort. Specific areas of interest are as follows:

- Lightweight Structural and Protective Materials: proposals are sought for development of lightweight structural and protective materials for use in space suits to provide integral shell structure strength, impact, and puncture protection from shape edges, micrometeoroids and orbital debris, radiation protection, and prevention of abrasion, adhesion, and mitigation from Lunar and Martian dust;
- Protective Suits for Hazardous Environments: proposals are sought for development of a protective suit based on EVA technologies and concepts for Homeland Security and hazmat applications including hazardous materials handling and minimizing exposures to chemical and biological agents;
- Airlocks with minimum gas loss and volume: proposals are sought for development of both in-space and surface vehicle airlocks that minimize gas loss during depressurization and repressurization operations and also require minimum volume for airlock hatch and EVA crewmembers.

- Nanomaterials Applications: proposals are also solicited for development of technologies for Advanced Extravehicular Activity that utilize unique properties of nanomaterials that are not possible with conventional materials with special emphasis on applications using single wall carbon nanotubes; and
- Direct Energy Conversion and Storage: proposals are sought on advanced concepts that can provide significant increases in specific energy and energy density (Wh/kg and Wh/L), in operating temperature range, in specific power and power density (W/kg and W/L), and in calendar life while improving or maintaining safety commensurate with in-cabin and exterior applications in crewed vehicles.
- Space suit mounted monocular displays for use inside a space suit with a small screen of view similar to that of a mobile computer screen and a binocular display with a panoramic field of view similar to that of immersive VR display systems. The monocular must display text, graphics, imagery and video with multiple windows and overlays as well as support all mission profiles with a multi-function display that enables situational awareness. The binocular must display wide field imagery with overlays, enable 3D or stereoscopic visualization, and provide vision enhancement as a low light navigational aid when combined with image intensification sensors.
- Dust and abrasion mitigating materials, seals, bearings, techniques, and mechanisms for space suits and EVA equipment are solicited. This includes materials and systems that prevent lunar dust from adhering to the outer layer of the suit or removes the dust prior to entry into an airlock. Seals, bearings, and mechanisms that preclude the migration of dust particles into bearings and the space suit life support system and pressure garment are also sought.

T5.02 Impact Detection and Evaluation for Man-Rated Space Vehicles
Center: JSC

There is significant risk to manned missions from ascent, orbital and interplanetary debris sources. Various NASA programs have chosen to treat the ascent debris and Micro-meteoroid and Orbital Debris (MMOD) impact risk with different intensity and concern. Since the STS-107 accident, NASA has become more concerned about understanding and compensating for this threat. This requires (1) predicting and correlating impacts with structural damage levels; (2) predicting and correlating impact damage levels with structural-dynamic/shock wave responses; (3) efficient systems for detecting, locating and quantifying impacts; (4) inspecting, repairing and performing Non-Destructive Evaluation (NDE) on damaged areas; and (5) efficient systems for detecting, locating and quantifying leaks to vacuum. The scope includes direct application of technology and techniques to Space Shuttle, International Space Station Modules, Inflatable-rigidizable habitats and structures, and Constellation Program man-rated vehicles. Critical areas, such as thermal protection systems and pressurized modules are of primary concern. Awareness of current, state-of-the-art methods and technologies available to and/or applied by NASA is important. Technology development areas are as follows:

Debris impact structural modeling and damage prediction: The developer will use impact test data and design/materials properties to develop models that predict under what conditions impacts will cause damage and what is the extent of the damage. Certain existing flight and ground test data and current analytical techniques can be made available.

- Space Shuttle and International Space Station – develop modeling improvements to critical areas of Orbiter thermal protection system which can more accurately predict failure modes and levels of damage for various ascent debris and MMOD in low Earth orbit.(Orbiter – ascent and on-orbit, ISS on-orbit only).
- Inflatable-rigidizable habitats and structures – develop methods to model potential damage from ascent vibration, earth orbit MMOD and/or lunar surface applications for various candidate inflatable structural material configurations and suggest improvements which reduce risk of damage, more observable damage signatures, incorporate weight savings or other benefits, such as thermal insulation, radiation protection, or longer life. Impact modeling for lunar surface applications will include analysis of free-standing, shielded (separately deployed “umbrella”) and covered (layers of regolith for protection).
- Constellation Program vehicles – develop and evaluate structural models of various candidate and actual vehicle concepts as they evolve for their susceptibility to damage from ascent and Earth orbit MMOD impacts as well as trans-lunar, lunar surface, and trans-Martian impacts.

Debris impact structural-dynamic/shock wave modeling for detection, location and quantification potential for damage: Analytical routines and techniques to optimize prediction accuracy and decrease uncertainties using impact test data, actual flight data, existing and proposed sensor systems and modeling will be developed. Each type of structure in item is a candidate for either improvements in existing structural-dynamic and shock wave prediction models (Space Shuttle Orbiter and International Space Station) or development of these models (inflatable habitats/structures and Constellation vehicles). Limited ground test and flight data can be made available for some structures, but proposals that include instrumented impact testing are encouraged which validate proposed modeling techniques.

Debris impact sensors/sensing systems for critical areas: The developer will recommend practical sensor system solutions for future installations to not only provide impact detection, location and quantification of damage, but also to validate structural models. The sensor/system solutions must account for optimizing the typical factors for space missions: system cost, weight, performance, power, integration, operations time, complexity/reliability, reconfigurability/maintainability, autonomy from Earth-based support, etc. Sensing systems should reduce the vehicle and communication architecture overhead needed for functional redundancy and reliability by considering methods to store and process impact data such that answers are the primary information needed to be transferred within the vehicle but raw data is available on request. No-power Radio Frequency Identification (RFID)-like sensors, very low power standalone sensor systems with scavenge or very long-life power sources, remote sensors and various embedded sensors with a minimum of wired interfaces are examples of what is desired. Other non-contact systems, such as visible or IR flash detection or higher frequency radio frequency (RF) pulse detection may be investigated.

Debris impact structural damage NDE evaluation away from Earth (internal or external environments): Systems and techniques will be developed and tested that can be readily used by astronauts or mobile/robotic systems to evaluate impact-damaged areas and subsequent repairs. Tools and equipment that can provide adequate inspection in hard-to-access areas internally and externally will be especially helpful if it can provide position-awareness of the sensor with respect to the vehicle. Simple human operator interfaces and remote access to data should be considered. NDE systems such as high frequency 3-d imaging, infra-red imagers, eddy current and ultrasound systems will need to evaluated for their effectiveness on new structural composites, inflatable and rigidizable structures – practically applied in both internal and external evaluations. Certain structural health monitoring needs may require remotely operated NDE systems for periods when the vehicles listed above are not man-tended.

Debris impact structural leaks to vacuum detection, location, quantification and repair: The systems must monitor the pressurized vehicle integrity such that catastrophic leaks can be immediately dealt with to provide crew safety and, for smaller leaks, be sensitive enough to avoid loss of precious air resources to vacuum. Low weight, self-sealing structural concepts will be developed that minimize the air lost, but still are able to be located after the sealing has been accomplished for NDE evaluation. Test-validated models of both structural and airborne ultrasonic propagation of sound in the above pressurized modules, as well as sensing above typical background levels will be important to resolving these issues. Systems should be responsive to some or all levels of impact and leak indications through the rate of pressure loss detected requiring:

- Immediate location and isolation with limited access to the evacuated module afterward;
- Limited time to locate and plug the leak; and
- Extended period to locate, inspect, plan and effect repair and perform NDE afterward.

TOPIC: T6 Kennedy Space Center

NASA's launch headquarters, John F. Kennedy Space Center (KSC), is America's gateway to the universe and its busiest launch and landing facility. KSC at the Cape Canaveral Spaceport is NASA's Spaceport Technology Center, a world-class resource for the space transportation industry. KSC is helping to set the standard for future spaceports everywhere. Designers of new space transportation systems and architectures are integrating KSC-developed spaceport and range technologies into those designs to lower not only the costs of building the flight and ground systems but also of maintaining and operating them. Visionary approaches and strategies being developed today at KSC are laying the groundwork for the Cape Canaveral Spaceport and other spaceports and ranges of the future. We want to continue to offer safe and cost-effective space access for our nation and international partners' needs.

T6.01 Predictive Modeling Techniques for the Mechanical Behaviors of Powders, Granular Materials, and Soils
Center: KSC

Developing software models to predict the mechanical behavior of granular materials and powders is an area of on-going and active research and development. NASA has a need for advances in software modeling techniques to support a number of on-going initiatives. One such area is the prediction of stress/strain shearing and compaction response of powder insulation materials located inside the annular space of very large cryogenic dewars (e.g., 80 feet in diameter with a 3 – 4 foot radius in the annular space). This is an area of high interest to KSC due to the use of large cryogenic tanks at the launch pads and the problems associated with the insulation in them. Another area of interest is the mechanical behavior of lunar soil during drilling and digging, during construction and compaction (of berms), or during beneficiation and chemical processing of the soil (e.g., to remove water ice). This area is of interest to KSC due to the need for launch-site facilities to enable the assembly, flight qualification, and final checkout of spacecraft and payloads including the re-testing of last-minute modifications. Modeling the behavior of lunar soil in such facilities and comparing to the expected behavior in the lunar environment is a critical ability for developing launch-site facilities and procedures.

In both areas of interest, it is impossible to perform full-scale testing of the material in the relevant environment, and therefore extrapolation is necessary to compare small-scale or terrestrial experiments against what is expected in the full-scale or lunar environment. Extrapolation from one scale (or one environment) to another is very difficult and currently has a low probability of producing high-fidelity predictions. Unfortunately, without such extrapolation it is impossible to use an affordable small-scale (or terrestrial) test as a means to validate the design of hardware or to validate the expected behavior of the powder or soil in the full-scale (or lunar) case.

The best, presently-known method to do an extrapolation from one scale (or environment) to another is to produce a computer model to realistically simulate the physics of the granular material. The simulation can then be parameterized to make predictions in either scale or in either environment. The simulation can be benchmarked using the accessible scale (or environment), and then the parameterization can be adjusted to the inaccessible scale (or environment) to make the predictive extrapolation. Additional confidence in the extrapolation can be obtained by studying the model’s sensitivity upon its various parameters within some experimentally-accessible range. Furthermore, the model can be used long-term as an engineering tool, iteratively refining it as new data become available from the full-scale application (or from the lunar environment). Thus, the model becomes a method to organize and compare new data as they become available across multiple scales and environments.

Innovations are sought in the area of multi-scale granular material modeling with true extrapolatory, predictive power across scales and environments. These innovations could be in the form of software techniques that integrate Discrete Element Models with Finite Element Models (or other software innovations), benchmarking techniques that integrate experimental methods with modeling methods in new ways, innovative analysis techniques, or any combination of the above. Other innovations will also be considered. The key point to the innovation is that it must extend the state-of-the-art in predicting granular/powder mechanical behavior. Innovations are particularly desired in the ability to model and predict powder shearing and compaction and to model lunar soil geotechnics.

T6.02 Predictive Numerical Simulation of Rocket Exhaust Interactions with Lunar Soil
Center: KSC

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 with 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, 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. On lunar spaceports, the blast protection infrastructure must be constructed (in part) using in-situ materials, such as a berm made with lunar soil. 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. 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, including the erosion rates and trajectories of ejected particulate matter.

Innovations are sought, resulting in the development of a software package to improve the prediction of lunar blast dynamics. The difficulties in developing a flow code to predict these effects include the unique lunar environment, 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). In recent years, researchers have been making significant progress in understanding the interactions of particle assemblages with fluids. Emphasis shall therefore be placed on the research effort extending this progress toward correctly describing the physics of the gas/soil interactions.

TOPIC: T7 Langley Research Center

In alliance with industry, other agencies, academia, and the atmospheric research community in the areas of aerospace vehicles, aerospace systems analysis, and atmospheric science, the Langley Research Center undertakes innovative, high-payoff activities beyond the risk limit or capability of commercial enterprises and delivers validated technology, scientific knowledge, and understanding of the Earth's atmosphere. Our success is measured by the extent to which our research results improve the quality of life of all Americans.

T7.01 Non-Destructive Evaluation and Structural Health Monitoring
Center: LaRC

Innovative concepts are being solicited for the development of non-destructive evaluation (NDE) and health-monitoring technologies for vehicles and structures involved in exploration missions. The highest priority is structural health monitoring systems that provide real time in situ diagnostics and evaluation of structural integrity. Emphasis is focused on highly miniaturized, lightweight, compact systems that deliver accurate assessment of structural health. The sensors, data acquisition and analysis systems and associated electronics must perform in high stress and hostile conditions expected on launch vehicles and space environments. Diagnostic systems intended for external inspection of space vehicles and structures will be highly autonomous, remotely operated and preferably non-contacting.

Evaluation sciences include ultrasonics, laser ultrasonics, optics and fiber optics, video optics and laser metrology, thermography, electromagnetics, acoustic emission, X-ray and terahertz radiation. Innovative and novel evaluation approaches are sought for the following materials and structural systems:

- Adhesives and bonded joints, sealants, bearings, coatings, glasses, alloys, laminates, monolithics, material blends, wire insulating materials, and weldments;
- Thermal protection and insulation systems;
- Complex composite and hybrid structural systems; and
- Low-density and high-temperature materials.

Proposals should address the following performance metrics as appropriate:

- Characterization of material properties;
- Assessment of effects of defects in materials and structures;
- Evaluation of mass-loss in materials;
- Detection of cracks, porosity, foreign material, inclusions, and corrosion;
- Dis-bonded adhesive joints;
- Detection of cracks around fasteners such as bolts and rivets;
- Real-time and in situ monitoring, reporting, and damage characterization for structural durability and life prediction;
- Repair certification;
- Environmental sensing;
- Planetary entry aero-shell validation;
- Micro-meteor and orbital debris impact location and damage assessment;
- Electronic system/wiring integrity assessment;
- Wire insulation integrity and condition (useful life) and arc location for failed insulation;
- Characterization of load environment on a variety of structural materials and geometries including thermal protection systems and bonded configurations;
- Identification of loads exceeding design;
- Monitoring loads for fatigue and preventing overloads;
- Suppression of acoustic loads;
- Early detection of damage; and
- In situ monitoring and control of materials processing.

Measurement and analysis innovations will be characterized by:

- Advanced integrated multi-functional sensor systems;
- Autonomous inspection approaches;
- Distributed/embedded sensors;
- Roaming inspectors;
- Shape adaptive sensors;
- Concepts in computational models for signal processing and data interpretation to establish quantitative characterization;
- Advanced techniques for management and analysis of digital NDE data for health assessment and lifetime prediction; and
- Biomimetic, and nano-scale sensing approaches for structural health monitoring that meet size and weight limitations for long duration space flight.

T7.02 Remote Sensors for Entry, Descent and Landing Applications
Center: LaRC

The NASA Langley Research Center, located in Hampton VA, maintains core competencies in laser/lidar technology development and entry/landing/descent (EDL) applications. Innovative or improved concepts are solicited for the development of sensors supporting human and robotic exploration missions to planetary surfaces. Of immediate interest are technologies enhancing or enabling sensors used in precision guidance and navigation related to surface landings and hazard avoidance. The sensors would be employed from orbit, through descent, and during final approach. The deployed system may require multiple sensors of different fundamental types. Specific sensors/components currently of interest include those associated with:

- 3D lidar systems, including flash lidars and scanning lidars;
- High resolution radars;
- 2D optical imaging devices.

Examples of components desired would include:

- New, highly accurate and robust wide angle scanning systems;
- Moderate power high efficiency lasers;

- Fast detector arrays suitable for use in coherent lidar systems;
- High efficiency long range flash lamps.

Proposals should describe the expected improvements and advantages of proposed deliverables over existing technologies, and should estimate the effects of these improvements on the state-of-the-art EDL guidance, control and hazard avoidance capabilities. Technologies likely to be ready for flight demonstration within the next 2 or 3 years are preferred, but highly innovative longer-term concepts will also be considered.

TOPIC: T8 Marshall Space Flight Center

NASA's Marshall Space Flight Center in Huntsville, AL, develops key space transportation and propulsion technologies including the new exploration crew and cargo launch vehicles; manages space shuttle propulsion elements and science aboard the international space station; and pursues scientific breakthroughs in space that will improve human life here on Earth.

T8.01 Manufacturing Technologies for Human and Robotic Space Exploration
Center: MSFC

Continued technological innovation is critically linked to a strong manufacturing sector in the United States economy. NASA is interested in innovative manufacturing technologies that enable sustained and affordable human and robotic exploration of the Moon, Mars, and solar system. Specific areas of interest in this solicitation include innovative manufacturing, materials, and processes relevant to propulsion systems and airframe structures for next-generation launch vehicles, crew exploration vehicles, lunar orbiters and landers, and supporting space systems. Improvements are sought for increasing safety and reliability and reducing cost and weight of systems and components. Only processes that are environmentally friendly and worker-health oriented will be considered. Proposals are sought, but are not limited to, the following areas:

Polymer Matrix Composites (PMCs)
Large-scale manufacturing; innovative automated processes (e.g., fiber placement); advanced non-autoclave curing (e.g., e-beam, ultrasonic); damage tolerant and repairable structures and self-healing technologies ; advanced materials and manufacturing processes for both cryogenic and high-temperature applications; improved thermal protection systems (e.g., integrated structures, integral cryogenic tanks and insulations) .

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. Advanced CMC, ablative, and insulation materials and processing technologies are of interest which have low volume at low cost and are repeatable and scalable to large sizes. Applications of interest include, but not limited to: solid propulsion nozzles and throats, liquid propulsion nozzles and thrust cells with integral injectors, and ancillary hardware components necessary for earth-to-orbit and in-space transportation.

Metals and Metal Matrix Composites (MMCs)
Advanced manufacturing processes such as pressure infiltration casting (for MMCs); laser engineered near-net shaping; electron-beam physical vapor deposition; in situ MMC formation; solid state and friction stir welding, which target aluminum alloys, especially those applicable to high-performance aluminum-lithium alloys and aluminum metal-matrix composites; advanced materials such as metallic matrix alloys compositions, which optimize high ductility and good joinability; functionally graded materials for high- or low-temperature application; alloys and nanophase materials to achieve more than 120 ksi tensile strength at room temperature and 60 ksi at elevated temperature above 500° F; 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.

Manufacturing Nanotechnology
Innovations that use nanotechnology processes to achieve highly reliable or low-cost manufacturing of high-quality materials for engineered structures.

Fiber-Based and Inflatable Systems
Fabrics and films may be appropriate materials for some space structures, but significant research is required to investigate the benefits, challenges and failure modes of such systems. Where fiber-based or inflatable structures have been demonstrated as potentially valuable to NASA, quality-controlled manufacture of these structures will be a strong focus and interaction between designers, manufacturing specialists and performance analysts can lead to better products; innovative procedures for manufacturing improvements and concepts are on interest.

Advanced NDE Methods
Portable and lightweight NDE tools that take advantage of nanotechnology for noninvasive, noncontact area inspection and characterization of polymer, ceramic and metal matrix composites. Areas include but are not limited to microwaves, millmeter waves, infrared, laser ultrasonics, laser shearography, terahertz, and radiography.

T8.02 Component Development for Deep Throttling Space Propulsion Engines
Center: MSFC

Implementing certain aspects of the NASA Vision for Space Exploration will require versatile space propulsion engines that can operate over a wide range of thrust levels, a capability known as throttling. The ability of a rocket engine to reliably produce a small fraction of the maximum thrust on command during flight is referred to as deep throttling. High specific impulse deep-throttling space propulsion engines may be required for controlled spacecraft descent to planetary surfaces, and a significant degree of throttling may also be required for ascent and in-space transfer maneuvers.

This subtopic solicits partnerships between academic institutions and small businesses in the development of components, design tools, and performance databases for engines in the 5,000-15,000 pound thrust range that use liquid hydrogen and liquid oxygen as propellants and which can be throttled to as little as 7% of the maximum thrust value. Examples of specific areas where innovations are sought include:

- High-throttle-response engine concepts;
- Low-cost regeneratively cooled chamber designs and demonstrations of such;
- Injectors that can provide stable engine performance with two-phase (gas/liquid) flow of propellants, especially during start-up transients;
- Ignition systems that can operate reliably over a wide fuel/oxidizer mixture ratio;
- Propulsion system or component technologies that do not require thermal conditioning prior to ignition;
- Zero net positive suction pressure pump design concepts, and demonstrations of such;
- Performance databases for small turbopumps and turbomachinery components;
- Design and analysis tools that accurately model small valves and turbopumps, and data required for code validation;
- Alternatives to the use of turbopumps for achieving chamber pressures of 1000 pounds per square inch; and
- Instrumentation for integrated vehicle health management.

TOPIC: T9 Stennis Space Center

The John C. Stennis Space Center (SSC) in south Mississippi is NASA's primary center for testing and flight certifying rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Because of its important role in engine testing for four decades, Stennis Space Center is NASA's program manager for rocket propulsion testing with total responsibility for conducting and/or managing all NASA propulsion test programs. Stennis Space Center tests all Space Shuttle main engines. These high-performance, liquid-fueled engines provide most of the total impulse needed during the Shuttle's eight and one-half-minute-flight to orbit. All shuttle main engines must pass a series of test firings at Stennis Space Center prior to being installed in the back of the orbiter. The Earth Science Applications Directorate is NASA's Program Manager for Earth Science Applications. The Directorate matches NASA's scientific and technical knowledge with issues of national concern and the needs of our partners. Partners include local, state, and tribal governments, commercial industry, with educational and other non-profit institutions. Through the Directorate's co-funded partnerships, public and private sector decision makers learn how to apply new technologies to critical environmental, resource management, community growth, and disaster management issues. The Directorate also provides the remote sensing community with a comprehensive array of manmade and natural ground targets, measurement systems, and benchmark processes to help test airborne and space remote sensing systems against performance specifications and customer needs. Stennis Space Center began "re-inventing Government" decades ago before the concept became popular. Over the years, SSC has evolved into a multiagency, multidisciplinary center for Federal, state, academic, and private organizations engaged in space, oceans, environmental programs, and the national defense. In addition to NASA, there are 30 other agencies located at Stennis. Of approximately 4500 employees, about l600 work in the fields of science and engineering. These agencies work side by side and share common costs related to infrastructure, facility, and technical services which makes it cheaper for each to accomplish its independent mission at SSC.

T9.01 Rocket Propulsion Testing Systems
Center: SSC

Proposals are sought for innovative technologies in the area of propulsion test operations. Proposals should support the reduction of overall propulsion test operations costs (recurring costs) and/or increase reliability and performance of propulsion ground test facilities and operations methodologies. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies
Innovative, non-intrusive sensors for measuring gas velocity, temperature, pressure, molecular and metallic plume constituents, and environmentally sensitive effluent gas detection. Low-millisecond to sub-millisecond response time is required. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH_2) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH_2). Flow rate sensors must have a range of up to 2000 lb/s (82 ft/sec) for LOX and 500 lb/sec (300 ft/s) for LH_2. Pressure sensors must have a range up to 15,000 psi. Rocket plume sensors should be capable of measuring gas species, temperature, and velocity for H_2, O_2, hydrocarbon and hybrid fuels.

Rugged, high accuracy (0.2%), fast response, temperature measuring sensors and instrumentation for very high pressure, high flow rate cryogenic piping systems. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LOX and 34R for LH_2) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/s 82 ft/s for LOX; 500 lb/s 300 ft/s for LH_2). Response times must be on the order of a few milliseconds to sub-milliseconds.

Modeling, sensors, and instrumentation for prediction, characterization, and measurement of rocket engine combustion instability. Sensor systems should have bandwidth capabilities in excess of 100 kHz. Emphasis is on development of non-intrusive optical-based sensors.

Test 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 result in complex relationships and dynamics. It is not realistic to physi-

cally 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. This capability is required for modeling components in high pressure 12,000 psi, high flow 100 lb/sec cryogenic environments and must address two-phase flows.

Process System Design, Prediction and Modeling - Improved capabilities to predict and model process systems. The capability should incorporate the previous two areas to accurately model the process systems and test articles.

T9.02 Field Sensors, Instruments, and Related Technologies
Center: SSC

Coastal environments and their natural resources are vital to our Nation's economy, security, commerce and recreation. These environments are strongly impacted by severe weather and other natural hazards. Because most of the world's population lives in coastal regions, these important and dynamic environments are also significantly impacted by human-induced events. Moreover, they are also especially sensitive to the initial effects of global climate change.

This subtopic solicits innovative field measurement technologies and analytical tools to support NASA's remote sensing technologies used in coastal research and applications. Specific interests at SSC include the following:

- Coupling of land and ocean processes (run-off, air quality, material flux);
- Coral reef mapping and health;
- Algal blooms (detection and monitoring);
- Sea level rise (measuring and forecasting effects);
- Sediment and contaminant transport (measuring and monitoring);
- Natural disasters such as tropical systems, tsunamis, and floods (planning, impact assessment, mitigation, and recovery).

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-Manuvering 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 Propellents (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

Verification and Validation
- Operations Concepts and Requirements
- Simulation Modeling Environment
- Testing Facilities
- Testing Requirements and Architectures
- Training Concepts and Architectures

Research Topics Index

AERONAUTICS RESEARCH

EXPLORATION SYSTEMS

SCIENCE

SPACE OPERATIONS

STTR

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