SBIR/STTR 2003-1

National Aeronautics and Space Administration

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

Program Solicitations

Opening Date: July 7, 2003
Closing Date: September 9, 2003

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

Cover: NASA inspires future generations. Breakthrough propulsion technologies and bioscience are two innovative research and development arenas, supported in these Solicitations, that will help extend mankind's physical presence beyond his home planet.

Cover design: Dr. James Kalshoven and Debbi McLean of NASA Goddard Space Flight Center

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2003 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 2003 Solicitation period for Phase I proposals begins July 7, 2003, and ends September 9, 2003.

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.

To be eligible for selection, a proposal must be based on an innovation having high technical or scientific merit that is responsive to a NASA need described herein, and which offers potential commercial application. Proposals must be submitted via the Internet (http://sbir.nasa.gov) and include all relevant documentation. Unsolicited proposals will not be accepted.

A proposal directed towards system studies, market research, routine engineering development of existing products or proven concepts and modifications of existing products without innovative changes is considered inappropriate. Selection preference will be given to eligible proposals where the innovations are judged to have significant potential for commercial application.

NASA plans to select for award those proposals offering the best value to the Government and the Nation. Subject to the availability of funds, approximately 300 SBIR and 20 STTR Phase I proposals will be selected for negotiation of fixed-price contracts in November 2003. Historically, the ratio of Phase I proposals to awards is approximately 7:1 for SBIR and 5:1 for STTR, and approximately 40% of the selected Phase I contracts are selected for Phase II follow-on efforts.

1.2 Program Authority

SBIR: This Solicitation is issued pursuant to the authority contained in P.L. 106-554. Government wide SBIR policy is provided by the Small Business Administration (SBA) through its Policy Directive. 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. Government wide STTR policy is provided by the SBA through its Policy Directive. The current law authorizes the program through September 30, 2009.

1.3 Program Management

The Office of Aerospace Technology provides overall policy direction for the NASA SBIR/STTR programs. The Program Management Office is hosted at the Goddard Space Flight Center. The Procurement Management Office is hosted at Glenn Research Center.

The SBIR Program Solicitation is aligned with NASA's five Strategic Enterprises (http://www.nasa.gov). The needs of all Strategic Enterprises are reflected in the research topics identified in Section 9.

The STTR Program Solicitation research areas correspond to the central underlying technological competencies of each participating NASA Center. The Jet Propulsion Laboratory (JPL) does not participate in the management of the STTR Program.

Information regarding the Strategic Enterprises and the NASA Centers can be obtained at the following web sites:

NASA Strategic Enterprises	
Aerospace Technology	http://www.hq.nasa.gov/office/aero
Biological and Physical Research	http://SpaceResearch.nasa.gov
Earth Science	http://earth.nasa.gov
Space Flight	http://www.hq.nasa.gov/osf/
Space Science	http://spacescience.nasa.gov/

NASA Installations	
Ames Research Center (ARC)	http://www.arc.nasa.gov
Dryden Flight Research Center (DFRC)	http://www.dfrc.nasa.gov
Glenn Research Center (GRC)	http://www.grc.nasa.gov
Goddard Space Flight Center (GSFC)	http://www.gsfc.nasa.gov
Jet Propulsion Laboratory (JPL)	http://www.jpl.nasa.gov
Johnson Space Center (JSC)	http://www.jsc.nasa.gov
Kennedy Space Center (KSC)	http://www.ksc.nasa.gov
Langley Research Center (LaRC)	http://www.larc.nasa.gov
Marshall Space Flight Center (MSFC)	http://www.msfc.nasa.gov
Stennis Space Center (SSC)	http://www.ssc.nasa.gov

1.4 Three-Phase Program

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

1.4.1 Phase I. The purpose of Phase I is to determine the scientific, technical, and commercial merit and feasibility of the proposed innovation, and the quality of the SBC's performance with a relatively small NASA investment before consideration of further Federal support in Phase II. Successful completion of Phase I objectives is a prerequisite to Phase II consideration.

Phase I must concentrate on establishing the scientific or technical merit and feasibility of the proposed innovation and on providing a basis for continued development in Phase II. Proposals must conform to the format described in Section 3.2. Evaluation and selection criteria are described in Section 4.1. NASA is solely responsible for determining the relative merit of proposals, their selection for award, and judging the value of Phase I results.

Maximum value and period of performance for Phase I contracts:

Phase I Contracts	SBIR	STTR
Maximum Contract Value	$ 70,000	$ 100,000
Maximum Period of Performance	6 months	12 months

1.4.2 Phase II. The objective of Phase II is to continue the Research or Research and Development (R/R&D) effort from Phase I. Only SBCs awarded Phase I contracts are eligible for Phase II funding agreements. Phase II projects are chosen as a result of competitive evaluations based on selection criteria provided in Section 4.2.

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

STTR: Phase II funding has been increased to $600K from $500K beginning with this Solicitation.

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

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

1.5 Eligibility Requirements

1.5.1 Small Business Concern. Only firms qualifying as SBCs, as defined in Section 2.12, are eligible to participate in these programs. Socially and economically disadvantaged and women-owned SBCs are particularly encouraged to propose.

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

1.5.2 Place of Performance. For both Phase I and Phase II, the R/R&D must be performed in the United States (Section 2.16). 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 that 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. Approval by the Contracting Officer for such specific condition(s) must be in writing.

1.5.3 Principal Investigator The primary employment of the PI must be with the SBC under the SBIR Program, while under the STTR Program the PI may be employed with the 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.

REQUIREMENTS	SBIR	STTR
Primary Employment	PI must be with the SBC	PI may 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 2003 SBIR/STTR Program Solicitation is available via the NASA SBIR/STTR homepage **(http://sbir.nasa.gov)**. SBCs are encouraged to check the SBIR/STTR homepage for program updates. 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 Homepage: **http://sbir.nasa.gov**

(2) Each of the NASA field installations has its own homepage, including strategic planning and program information. Please consult these homepages as noted in Section 1.3 for more details on the technology requirements within the subtopic areas.

(3) Help Desk. For inquiries, requests, and help-related questions, contact via:

e-mail: sbir@reisys.com
telephone: 301-937-0888 between 8:00 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 answered during the Phase I solicitation period. Only questions requesting clarification of proposal instructions and administrative matters will be answered.

2. Definitions

2.1 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.

2.2 Cooperative 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.

2.3 Cooperative Research or Research and Development

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.

2.4 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.

2.5 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.

2.6 HUBZone-Owned SBC

A "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.

2.7 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.

2.8 Intellectual Property

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 this section), 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.

2.9 Research Institution

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.

2.10 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.

2.11 SBIR/STTR Technical Data

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

2.12 SBIR/STTR Technical Data Rights

The rights an SBC obtains in 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.

2.13 Small Business Concern

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

(1) Is independently owned and operated, has its principal place of business located in the United States, and is organized for profit;

(2) Is at least 51 percent owned, or in the case of a publicly owned business, at least 51 percent of its voting stock is owned by United States citizens or lawfully admitted permanent resident aliens; and

(3) Has, including its affiliates, a number of employees not exceeding 500 and meets the other regulatory requirements found in 13 CFR Part 121. Business concerns, other than investment companies licensed, or state development companies qualifying under the Small Business Investment Act of 1958, 15 U.S.C. 661, et seq., are affiliates of one another when, either directly or indirectly, (1) one concern controls or has the power to control the other or (2) a third party controls or has the power to control both. Control can be exercised through common ownership, common management, and contractual relationships. The terms "affiliates" and "number of employees" are defined in greater detail in 13 CFR Part 121.

Small business concerns include sole proprietorships, partnerships, corporations, joint ventures, associations, or cooperatives. Eligible joint ventures are limited to no more than 49 percent participation by foreign business entities.

2.14 Socially and Economically Disadvantaged Individual

A member of any of the following groups: African Americans, Hispanic Americans, Native Americans, Asian-Pacific Americans, Subcontinent-Asian Americans, 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).

2.15 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 Part 124.103 and 124.104.

2.16 Subcontract

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

2.17 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.

2.18 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. An offeror may submit any number of proposals, 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 all such proposals being rejected without evaluation.*

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

End Deliverables. The deliverable item at the end of a Phase I contract shall be a comprehensive report that justifies, validates, and defends the experimental and theoretical work accomplished and may include delivery of a product or service.

Deliverable items for Phase II contracts include products or services in addition to required reporting of further developments or applications of the Phase I results. These deliverables may include prototypes, models, software, or complete products or services. The reported results of Phase II must address and provide the basis for validating the innovation and the potential for implementation of commercial applications.

Reporting shall be submitted electronically via the SBIR/STTR homepage. NASA requests that all deliverable items be submitted in PDF format, and encourages companies to do so. Other acceptable formats are MS Word, MS Works, and WordPerfect.

3.2 Phase I Proposal Requirements

3.2.1 General Requirements

Page Limitation. A Phase I proposal shall not exceed a total of 25 standard 8 1/2 x 11 inch (21.6 x 27.9 cm) pages inclusive of the technical proposal 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. 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 is to be used for text or tables, except as legends on reduced drawings. Proposals prepared with smaller font sizes will be rejected without consideration.

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 proposal will depend on the project chosen and the offeror's approach.

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

(1) Proposal Cover (Form A), electronically endorsed,
(2) Proposal Summary (Form B),
(3) Technical Proposal (11 Parts in order as specified in Section 3.2.4), including all graphics, with a table of contents,
(4) Summary Budget (Form C), and
(5) Briefing Chart (Optional – not included in the 25-page limit).

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 Proposal Cover and Proposal Summary

Page 1: Proposal Cover (Form A). The Proposal Cover 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.

Page 2: Proposal Summary (Form B). The 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. The technical abstract portion is limited to 200 words and shall summarize the implications of the approach and the anticipated results of both Phase I and Phase II. Potential NASA and non-NASA commercial applications of the technology should also be presented. If the technical abstract is judged to be non responsive to the subtopic, the proposal will be rejected without further evaluation.

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

3.2.4 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 proposal shall begin with a brief table of contents indicating the page numbers of each of the parts of the proposal. A sample table of contents is included in Appendix A.

Part 2: Identification and Significance of the Innovation. The first paragraph of Part 2 shall contain:

(1) A clear and succinct statement of the specific innovation proposed, and why it is an innovation, and
(2) A brief explanation of how the innovation is relevant and important to meeting the technology need described in the subtopic. The initial paragraph shall contain no more than 200 words. NASA will reject proposals that lack explanation of the innovation. In subsequent paragraphs, Part 2 may also include appropriate background and elaboration to explain the proposed innovation.

Part 3: Technical Objectives. State the specific objectives of the Phase I 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 I R/R&D plan. The plan should indicate what will be done, where it will be done, and how the R/R&D will be carried out. The plan should address the objectives and the questions cited in Part 3 above. Discuss in detail the methods planned to achieve each objective or task. Task descriptions, schedules, resource allocations, estimated task hours for each key personnel, and planned accomplishments including project milestones shall be included.

STTR: 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. Not less than 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 not less than 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 concise bibliographic references in support of the proposal if they are confined to activities directly related to the proposed work.

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

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

Functions. The functions of the PI are: planning and directing the project; leading it technically and making substantial personal contributions during its implementation; serving as the primary contact with NASA on the project; and ensuring that the work proceeds according to contract agreements. Competent management of PI functions is essential to project success. The Phase I proposal shall describe the nature of the PI's activities and the amount of time that the PI will personally apply on 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 2003 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 Phase II or Future R/R&D. State the anticipated results of the proposed R/R&D effort if the project is successful (through Phase I and Phase II). Discuss the significance of the Phase I effort in providing a foundation for the Phase II R/R&D continuation.

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 I and projected Phase II and Phase III activities. The offeror should describe the relevant facilities and equipment, their availability, and those to be acquired, to support the proposed activities. *NASA will not fund the purchase of equipment, instrumentation, or facilities under Phase I contracts as a direct cost.* Special tooling may be allowed. (Section 5.17)

The capability of the offeror to perform the proposed activities and bring a resulting product or service to market must be indicated. Qualifications of the offeror in marketing related products or services or in raising capital should 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 Small Business Administration (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 a Government facility for successful completion, the offeror must provide 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, other Government, internal) for the effort.

Part 9: Subcontracts and Consultants. 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. The proposal **must** include a signed statement by each participating organization or individual that they will be available at the times required for the purposes and extent of effort described in the proposal. The signed statement should be scanned and included in the technical proposal document. This statement is included in the 25-page limit. Failure to provide certification(s) may result in rejection of the proposal. 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 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 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 Applications. The Phase I proposal shall forecast both the NASA and the non-NASA commercial potential of the project assuming success through Phase II. The offeror, in the Phase II proposal, will be required to provide more detailed information regarding product development and potential markets (Sections 3.3 and 4.2.2).

Part 11: Similar Proposals and Awards. A firm may elect to submit proposals for essentially equivalent work to other Federal program solicitations (Section 2.4). Firms may also choose to resubmit previously unsuccessful 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:

(a) 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 which have been submitted to previous NASA SBIR Solicitations);
(b) Dates of such proposal submissions or awards;
(c) Title, number, and date of solicitations under which proposals have been or will be submitted or awards received;
(d) The specific applicable research topic for each such proposal submitted or award received;
(e) Titles of research projects;
(f) 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;
(g) 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) shall be a single-page document (see example in Section 8) signed by the SBC and the RI. This agreement counts toward the 25-page limit.

3.2.6 Proposed Budget

Summary Budget (Form C). The offeror shall complete the Summary Budget, following the instructions provided with the form (Section 8) and include it and any explanation sheets, if needed, as the last page(s) of the proposal. 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 facility acquisition under Phase I as a direct cost (Section 5.17).

Travel. Travel during Phase I is not normally allowed to prove technical merit and feasibility of the proposed innovation. However, where the offeror deems travel to be essential for these purposes, it is necessary to limit it to one person, one trip to the sponsoring NASA installation. Proposed travel must be described as to purpose and benefits in proving feasibility, and is subject to negotiation and approval by the Contracting Officer. Trips to conferences are not allowed under the Phase I contract.

Profit. A profit or fee may be included in the proposed budget as noted in Section 5.12.

Cost Sharing. See Section 5.11.

3.2.7 Briefing Chart (Optional)

All technically meritorious proposals will be advocated to NASA senior management prior to selection. To assist NASA personnel in preparing information to advocate your proposal, a single-page briefing chart, as described in the on line electronic handbook, is encouraged. Submission of the briefing chart is optional and is not counted against the 25-page limit. An example chart has been provided in Appendix B.

3.2.8 Prior Awards Addendum (Applicable for SBIR awards only)

If the SBC has received more than 15 Phase II awards in the prior 5 fiscal years, submit name of awarding agency, date of award, funding agreement number, amount, topic or subtopic title, follow-on agreement amount, source, and date of commitment and current commercialization status for each Phase II. The addendum is not included in the 25-page limit.

3.3 Phase II Proposal Requirements

3.3.1 General Requirements

The Phase I contract will serve as a request for proposal (RFP) for the Phase II follow-on project. Phase II proposals are more comprehensive than those required for Phase I. Phase II proposals are required to be submitted electronically by utilizing the electronic handbook system hosted on the NASA SBIR homepage (http://sbir.nasa.gov). Submission of a Phase II proposal is strictly voluntary and NASA assumes no responsibility for any proposal preparation expenses.

Page Limitation. A Phase II proposal shall not exceed a total of 50 standard 8 1/2 x 11 inch (21.6 x 27.9 cm) pages. All items required in Section 3.3.2 will be included within this total. 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 is to be used for text or tables, except as legends on reduced drawings. Proposals prepared with smaller font sizes will be rejected without consideration.

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 proposal will depend on the project and the offeror's approach.

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

(1) Proposal Cover (Form A), electronically endorsed
(2) Proposal Summary (Form B)
(3) Technical Proposal (11 Parts in order as specified in Section 3.3.4), including all graphics, and starting with a table of contents
(4) Summary Budget (Form C)
(5) Briefing Chart (Optional – not included in the 50-page limit)

3.3.3 Proposal Cover and Proposal Summary

Page 1: Proposal Cover (Form A). A sample copy of the Proposal Cover 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.

Page 2: Proposal Summary (Form B). A sample copy of the Proposal Summary is provided in Section 8. The offeror shall provide complete information for each item and submit Form B as required in Section 6. The technical abstract portion is limited to 200 words and shall summarize the implications of the approach and the anticipated results of Phase II. Potential NASA and non-NASA commercial applications of the technology should also be presented. If the technical abstract is judged to be non responsive to the subtopic, the proposal will be rejected without further evaluation.

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

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

Part 2: Identification and Significance of the Innovation and Results of the Phase I Proposal. Provide a brief explanation of the specific innovation and describe how it is relevant to meeting NASA’s technology needs. In addition, describe how the Phase I effort has proven the feasibility of the innovation, provided a rationale for both NASA and commercial applications, and demonstrated the ability of the offeror to conduct the required R/R&D.

Part 3: Technical Objectives and Work Plan. Define the specific objectives of the Phase II research and technical approach; and provide a detailed work plan defining specific tasks, performance schedules, project milestones, and deliverables.

Part 4: Company Information. Describe the capability of the firm to carry out Phase II and Phase III activities, including its organization, operations, number of employees, R/R&D capabilities, and experience relevant to the work proposed.

Part 5: Facilities and Equipment. This section shall provide adequate information to allow the evaluators to assess the ability of the SBC to carry out the proposed Phase II 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 II contracts as a direct cost. Special tooling may be allowed. (Section 5.17)

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 a Government facility for successful completion, the offeror must provide 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 sources(s) (private, other Government, internal) for the effort.

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

Part 7: Subcontracts and Consultants. Describe in detail any subcontract, consultant, or other business arrangements involving participation in performance of the proposed R/R&D effort and provide written evidence of their availability for the project. The proposal must include a commitment from each subcontractor and/or consultant that they will be available at the times required for the purposes and extent of effort described in the proposal. Subcontractors' and consultants' work must be performed in the United States. Failure to provide subcontractor/consultant commitments may result in rejection of proposal. Note the following restrictions on subcontracts/consultants:

SBIR Phase II Proposal	**STTR Phase II 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.

Note: The Cooperative Research established with a specific RI in STTR Phase I contracts shall continue with the same RI in Phase II.

Part 8: Potential Applications: Describe both the potential NASA and non-NASA commercial applications of the project assuming successful development of the proposed objectives.

Part 9: Phase III Efforts, Commercialization and Business Planning. Describe plans for Phase III commercialization (including applications/sales back to NASA) in terms of each of the following areas:

(1) Market Feasibility and Competition: Describe the target market of the product or service, the unique competitive advantage of the product, the potential market size (Government and/or non Government), the offeror's estimated market share after first year of sales and after 5 years, and, competition from similar and alternative technologies and/or competing domestic or foreign entities.

(2) Strategic Relevance to the Offeror: Describe the role the product or service has in the company's current business plan and in its strategic planning for the next 5 years.

(3) Key Management, Technical Personnel and Organizational Structure: Describe (a) the skills and experiences of key management and technical personnel in bringing innovative technology to the market, (b) current organizational structure, and (c) plans and timelines for obtaining needed business development expertise and other necessary personnel.

(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 dedicated to development of product or service (both business development and technical development) to date. Describe the expected financial needs and potential sources to meet those needs that will be necessary to bring product or service to market. Provide evidence of current financial condition, e.g., standard financial statements including a current cash flow statement.

(6) Intellectual Property: Describe patent status, technology lead, trade secrets or other demonstration of a plan to achieve sufficient IP protection to realize the commercialization stage and attain at least a temporal competitive advantage.

Part 10: Capital Commitments Supporting Phase II and Phase III. Describe and document capital commitments from non-SBIR/STTR sources or from internal SBC funds for pursuit of Phase II and Phase III. Offerors for Phase II contracts are strongly urged to obtain non-SBIR/STTR funding support commitments for follow-on Phase III activities and additional support of Phase II from parties other than the proposing firm. Funding support commitments must provide that a specific, substantial amount will be made available to the firm to pursue the stated Phase II and/or Phase III objectives. They must indicate the source, date, and conditions or contingencies under which the funds will be made available. Alternatively, self-commitments of the same type and magnitude that are required from outside sources can be considered. If Phase III will be funded internally, offerors should describe their financial position.

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

Part 11: 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.

3.3.5 Proposed Budget

Summary Budget (Form C). The offeror shall complete the Summary Budget, following the instructions provided with the form (Section 8) and include it and any explanation sheets, if needed, as the last page(s) of the proposal. Sufficient 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 facility acquisition under Phase I as a direct cost (Section 5.17).

Travel. Travel during Phase II is not normally allowed to prove technical merit and feasibility of the proposed innovation. However, where the offeror deems travel to be essential for these purposes, it is necessary to limit it to one person, one trip to the sponsoring NASA installation. Proposed travel must be described as to purpose and benefits in proving feasibility, and is subject to negotiation and approval by the Contracting Officer. Trips to conferences are not allowed under the Phase II contract.

Profit. A profit or fee may be included in the proposed budget as noted in Section 5.12.

Cost Sharing. See Section 5.11.

3.3.6 Briefing Chart (Optional)

All technically meritorious proposals will be advocated to NASA senior management prior to selection. To assist NASA personnel in preparing information to advocate your proposal, a single-page briefing chart, as described in the on line electronic handbook is encouraged. Submission of the briefing chart is optional and is not counted against the 50-page limitation. An example chart has been provided in Appendix B.

3.4 SBA Data Collection Requirement

Each SBC applying for a Phase II award is required to update the appropriate information in the Tech-Net database for any of its prior Phase II awards. In addition, upon completion of Phase II, the SBC is required to update the appropriate information in the Tech-Net database and is requested to voluntarily 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

4.1 Phase I Proposals

Proposals judged to be responsive to the administrative requirements of this Solicitation and having a reasonable potential of meeting a NASA need, as evidenced by the technical abstract included in the Proposal Summary (Form B), will be evaluated by evaluators with a knowledge of the subtopic area.

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

4.1.2 Phase I Evaluation Criteria. NASA plans to select for award those proposals offering the best value to the Government and the 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 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 5.17).

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

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 Merit and Feasibility
The proposal will be evaluated for any potential commercial applications in the private sector or for use by the Federal Government.

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 score for Commercial Merit 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 and will rank those proposals recommended for award relative to all other recommended proposals at that Center. Center rankings will be forwarded to the Program Management Office for analysis and presented to the Source Selection Official and Strategic Enterprise Representatives. Final selection decisions will consider the Center rankings as well as overall NASA priorities, program balance and available funding. However, recommendations and relative rankings developed 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 selections will be posted on the NASA SBIR/STTR Homepage **(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 I contract negotiations, but before the contract starts, the offeror shall, if requested, 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 II Proposals

4.2.1 Evaluation Process. The Phase II evaluation process is similar to the Phase I process. NASA plans to select for award those proposals offering the best value to the Government and the 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 uses a peer review panel to evaluate commercial merit. Panel membership will include non-NASA personnel expert in business development and technology commercialization.

4.2.2 Evaluation Factors. The evaluation of Phase II proposals under this Solicitation will apply the following factors:

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

Factor 2. Future Importance and Value to NASA
The eventual value of the product, process, or technology results to the NASA mission will be assessed.

Factor 3. Capability of the Small Business Concern
NASA will assess the capability of the SBC to conduct Phase II based on (a) the validity of the project plans for achieving the stated goals; (b) the qualifications and ability of the project team (Principal Investigator/ Project Manager, company staff, consultants and subcontractors) relative to the proposed research; and (c) the availability of any required equipment and facilities.

Factor 4. Commercial Potential. NASA will assess the proposed commercialization plan in terms of its credibility, objectivity, reasonableness of key assumptions and awareness of key risk areas and critical business vulnerabilities, as applicable to the following factors:

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

(2) Commercial intent of the offeror: This includes assessing the commercial venture 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 success in bringing SBIR/STTR or other innovative technology to commercial application; (b) the offeror's business planning; (c) the likelihood that the offeror will be able to obtain the remaining necessary financial, technical, and personnel-related resources to bear; and (d) the current strength and continued financial viability of the offeror.

In applying these commercial criteria, NASA will assess proposal information in terms of credibility, objectivity, reasonableness of key assumptions, independent corroborating evidence, internal consistency, demonstrated awareness of key risk areas and critical business vulnerabilities, and other indicators of sound business analysis and judgment.

4.2.3 Evaluation and Selection. Factors 1, 2, and 3 will be scored numerically with Factor 1 worth 50 percent and Factors 2 and 3 each worth 25 percent. The sum of the scores for Factors 1, 2, and 3 will comprise the Technical Merit score. Proposals receiving numerical scores of 85 percent or higher will be evaluated and rated for their commercial potential using the criteria listed in Factor 4 and by applying the same adjectival ratings as set forth for

Phase I proposals. Where technical evaluations are essentially equal in merit, cost to the Government may be considered in determining successful offerors.

Each Center will make recommendations for award among those proposals that it evaluates and will rank those proposals recommended for award relative to all other recommended proposals at that Center. The Center Recommendation Report (which includes the Center analysis and ranking) will be forwarded to the Program Management Office for analysis and presented to the Source Selection Official and Strategic Enterprise Representatives. Final selection decisions will consider the Center rankings as well as overall NASA priorities, program balance and available funding, as well as any other evaluations or assessments (particularly pertaining to commercial potential) that may become available. However, recommendations and relative rankings developed 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 Awards

NASA has instituted a comprehensive commercialization survey/data gathering process for companies with prior NASA SBIR awards. Information received from SBIR companies 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 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.

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

4.3 Debriefing of Unsuccessful Offerors

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

Debriefings will not disclose the identity of the proposal evaluators, nor provide proposal scores, rankings in the competition, the content of or comparisons with, other proposals.

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

4.3.2 Phase II Debriefings. To request debriefings on Phase II proposals, offerors must request via e-mail to the SBIR/STTR Program Support Office at sbir@reisys.com within 60 days after selection announcement. The offeror will be contacted by the appropriate Field Center for debriefing. Late requests will not be honored.

5. Considerations

5.1 Awards

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

SBIR

- NASA plans to announce the selection of approximately 300 proposals resulting from this Solicitation, for negotiation of Phase I contracts with values not exceeding $70,000. Following contract negotiations and awards, Phase I contractors will have up to 6 months to carry out their programs, prepare their final reports, and submit Phase II proposals.

- NASA anticipates that approximately 40 percent of the successfully completed Phase I projects from the SBIR 2003 Solicitation will be selected for Phase II. Phase II agreements are fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.

STTR

- NASA plans to announce the selection of approximately 40 proposals resulting from this Solicitation, for negotiation of Phase I contracts with values not exceeding $100,000. Following contract negotiations and awards, Phase I contractors will have up to 12 months to carry out their programs, prepare their final reports, and submit Phase II proposals.

- NASA anticipates that approximately 40 percent of the successfully completed Phase I projects from the STTR 2003 Solicitation will be selected for Phase II. Phase II 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 I and Phase II 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 I model contract and other documents available to the public on the NASA SBIR/STTR homepage (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 I 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 I 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 I contract, identifying the purpose of the R/R&D effort and describing the findings and results, including the degree to which the Phase I objectives were achieved, and whether the results justify Phase II continuation. The potential applications of the project results in Phase III either for NASA or commercial purposes shall also be described. The final project summary is to be submitted without restriction for NASA publication.

All reports are required to be submitted electronically via the SBIR/STTR homepage.

5.3 Payment Schedule for Phase I

Payments can be 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 information (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 Non-NASA Reviewers

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

5.6 Final Disposition of Proposals

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

5.7 Proprietary Information in the Proposal Submission

It is NASA's policy to use information (data) included in proposals for evaluation purposes only. Public release of information in any proposal submitted will be subject to existing statutory and regulatory requirements. If information consisting of a trade secret, proprietary commercial or financial information, or private personal information is provided in a proposal, NASA will treat in confidence the proprietary information provided the following legend appears on the title page of the proposal:

> "For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part, provided that if 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. 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 I or Phase II 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. The Government, for a period of 4 years from acceptance of all items to be delivered under an SBIR/STTR contract, shall use the data, *i.e*., data first produced by the contractor in performance of the contract, where such data are not generally known, and which data without obligation as to its confidentiality have not been made available to others by the contractor or are not already available to the Government, agrees to use these data for Government purposes. These data shall not be disclosed outside the Government (including disclosure for procurement purposes) during the 4-year period without permission of the contractor, except that such data may be disclosed for use by support contractors under an obligation of confidentiality. After the 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 the Government is relieved of all disclosure prohibitions and assumes no liability for unauthorized use 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. SBIR 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 is permitted, but not required for proposals under this Solicitation. Cost sharing, if included, should be shown in the summary budget but not in items labeled "AMOUNT REQUESTED." 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 I and Phase II contracts may include a reasonable profit. The reasonableness of proposed profit is determined by the Contracting Officer during contract negotiations.

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

5.12 Similar Awards and Prior Work

If an award is made pursuant to a proposal submitted under either SBIR or STTR Solicitation, 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 I 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 I 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).

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).

5.15 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 contract. 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. (See Section 3.3.4).

If a proposed project or product demonstration requires a Government facility for successful completion, the offeror must provide 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 sources(s) (private, other Government, internal) for the effort.

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 utilizes a paperless, electronic process for management of the SBIR/STTR programs. This management approach requires that a proposing firm have Internet access and an e-mail address. Paper submissions are no longer accepted.

An Electronic Handbook for submitting proposals via the internet is hosted on the NASA SBIR/STTR Homepage (http://sbir.nasa.gov). The handbook will guide the firms through the various steps required for submitting an

SBIR/STTR proposal. All electronic handbook submissions will be through a secure connection. Communication between NASA and the firm will be via a combination of electronic handbooks and e-mail.

6.2 Submission Process

To begin the submission process, SBCs must first register in the handbook. 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 on line, upload their technical proposal in an acceptable format, and have the Business Official electronically endorse the proposal. Electronic endorsement of the proposal is handled on line with no additional software requirements. The term "technical proposal" refers to the part of the submission as described in Section 3.2.4 for Phase I and 3.3.4 for Phase II.

6.2.1 What Needs to Be Submitted

The entire proposal including Forms A, B, and C must be submitted via the NASA SBIR/STTR home page located at http://sbir.nasa.gov.

a. Forms A, B, and C are to be completed online.
b. The technical proposal is uploaded from your computer via the Internet utilizing secure communication protocol.
c. Firms are encouraged to upload an optional briefing chart, which is not included in the page count (See Section 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 purposes. Therefore, NASA requests that technical proposals be submitted in PDF format, and encourages companies to do so. Other acceptable formats are MS Works, MS Word, and WordPerfect. Unix and TeX users please note that due to PDF difficulties with non-standard fonts, please 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).

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.**

6.3 Technical Proposal Uploads

Firms will upload their proposals using the Submissions electronic handbook. 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:

Sample E-mail for Successful Upload of Technical Proposal

Subject: Successful Upload of Technical Proposal

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

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

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

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

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

IMPORTANT! The Business Official or an authorized representative must electronically endorse the proposal in the Electronic Handbook using the "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 may be considered for review.

6.4 Deadline for Phase I Proposal Receipt

All Phase I proposal submissions must be received no later than 5:00 p.m. EDT on Tuesday, September 9, 2003, via the NASA SBIR/STTR homepage (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.**

6.5 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:

<u>Sample E-mail for Official Confirmation of Receipt of Full Proposal:</u>

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 2003 Phase I xx.xx-xxxx (Title)
Form A completed on:
Form B completed on:
Form C completed on:
Technical Proposal Uploaded on:
File Name:
File Type:
File Size:
Briefing Chart (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 19, 2003, and will be posted via the SBIR/STTR homepage (http://sbir.nasa.gov).

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

NASA SBIR/STTR Program Support Office

6.6 Withdrawal of Proposals

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

6.7 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 SBIR/STTR Homepage

Detailed information on NASA's SBIR/STTR Programs is available at: **http://sbir.nasa.gov.**

7.2 NASA Commercial Technology Network

The NASA Commercial Technology Network (NCTN) contains a significant amount of on line information about the NASA Commercial Technology Program. The address for the NCTN homepage is: http://nctn.hq.nasa.gov/

7.3 NASA Technology Utilization Services

The **National Technology Transfer Center (NTTC)**, sponsored by NASA in cooperation with other Federal agencies, serves as a national resource for technology transfer and commercialization. NTTC has a primary role to get Government research into the hands of U.S. businesses. Its gateway services make it easy to access databases and to contact experts in your area of research and development. For further information, call 800-678-6882.

NASA's network of **Regional Technology Transfer Centers (RTTCs)** provides business planning and development services. However, NASA does not accept responsibility for any services these centers may offer in the preparation of proposals. RTTCs can be contacted directly as listed below to determine what services are available and to discuss fees charged. Alternatively, to contact any RTTC, call 800-472-6785.

Northeast:
Center for Technology Commercialization
Massachusetts Technology Park
1400 Computer Drive
Westboro, MA 01581-5043
Phone: 508-870-0042
URL: http://www.ctc.org

Southeast:
Georgia Institute of Technology
151 6th Street
216 O'Keefe Building
Atlanta, GA 30332-0640
Phone: 800-472-6785
URL: http://www.edi.gatech.edu/nasa/

Mid-Continent:
Mid-Continent Technology Transfer Center
Texas Engineering Extension Service
301 Tarrow Street
College Station, TX 77840-7896
Phone: 800-472-6785
URL: http://www.mcttc.com/

Mid-Atlantic:
Technology Commercialization Center, Inc.
12050 Jefferson Avenue, Suite 340
Newport News, VA 23606
Phone: 757-269-0025
URL: http://www.teccenter.org

Mid-West:
Great Lakes Industrial Technology Center
Battelle Memorial Institute
20445 Emerald Parkway Drive, SW, Suite 200
Cleveland, OH 44135
Phone: 216-898-6400
URL: http://www.battelle.org/glitec

Far-West:
Far-West Technology Transfer Center
University of Southern California
3716 South Hope Street, Suite 200
Los Angeles, CA 90007-4344
Phone: 800-642-2872
URL: http://www.usc.edu/dept/engineering/TTC/NASA

7.4 United States Small Business Administration

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

Office of Innovation, Research and Technology
U.S. Small Business Administration
409 Third Street, S.W.
Washington, DC 20416
Phone: 202-205-7701

7.5 National Technical Information Service

The **National Technical Information Service**, an agency of the Department of Commerce, is the Federal Government's central clearinghouse for publicly funded scientific and technical information. For information about their various services and fees, call or write:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: 703-605-6040
URL: http://www.ntis.gov

8. Submission Forms and Certifications

FORM A – SBIR PROPOSAL COVER

Subtopic Number

1. PROPOSAL NUMBER: **03-** __ __ . __ __ __ __ __ __
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. Woman-owned SBC	Yes	No
e. HUBZone-owned SBC	Yes	No
As defined in Section 3.2.4 Part 11 of the Solicitation, the offeror certifies:		
f. Work under this project has been submitted for Federal funding only to the NASA SBIR Program	Yes	No
g. No 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
ii) If yes, copy of agreement enclosed	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

7. ACN NAME: E-MAIL:
8. ENDORSEMENT BY SBC OFFICIAL:

   NAME:
   TITLE:
   PHONE:
   E-MAIL:
   SIGNATURE:
   DATE:

NOTICE: For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. 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 Proposal Cover

1. Proposal Number: This number does not change even if the firm gets a new phone number. Complete the proposal number as follows:
    1. Enter the four-digit subtopic number.
    2. Enter the four-digit system-generated numbers
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:	City name
State:	2-letter State designation (example VA for Virginia)
Zip:	9-digit Zip code (example 20705-3106)
Phone:	Number including area code
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 $70,000 (see Sections 1.4.1, 5.1.1).

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

6. Certifications: Answer Yes or No as applicable for 6a, 6b, 6c, 6d, 6e, 6f, 6g and 6h (see the referenced sections for definitions).

   6f. SBCs should choose "Yes" to affirm 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.

   ii) If yes, copy of agreement enclosed: By answering yes, the SBC certifies that a copy of any subcontracting or consulting agreements described in Section 3.2.4 Part 9 is included as required. Copy of the agreement may be submitted in a reduced-size format.

   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 5, 5.17). By answering no, the SBC 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 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.

7. ACN Name and E-mail: Name and e-mail address of Authorized Contract Negotiator.
8. Endorsement: An official of the firm must electronically endorse the proposal cover.

FORM B – SBIR PROPOSAL SUMMARY

Subtopic Number

1. Proposal Number **03- _ _ . _ _**

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:
   U.S. Citizen or Legal Resident Yes No

6. Technical Abstract (Limit 200 words or 2,000 characters, whichever is less):

7. Potential NASA Application(s): (Limit 100 words or 1,500 characters, whichever is less)

8. Potential Non-NASA Commercial Application(s): (Limit 100 words or 1,500 characters, whichever is less)

Guidelines for Completing SBIR Proposal Summary

Complete Form B electronically.

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

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

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

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

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

   Note: Offerors are responsible for ensuring that all employees who will work on this contract are eligible under export control and International Traffic in Arms (ITAR) regulations. Any employee who is not a U.S. citizen or a legal resident may be restricted from working on this contract if the technology is restricted under export control and ITAR regulations. Violations of these regulations can result in criminal or civil penalties.

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.

7. **Potential NASA Application(s):** Summary of the direct or indirect NASA applications of the project, assuming the goals of the proposed R/R&D are achieved. Limit your response to 100 words or 1,500 characters, whichever is less.

8. **Potential Non-NASA Commercial Application(s):** Summary of the direct or indirect NASA applications of the project, assuming the goals of the proposed R/R&D are achieved. Limit your response to 100 words or 1,500 characters, whichever is less.

FORM C – SBIR SUMMARY BUDGET

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 I 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 homepage (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 Summary Budget

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, on a budget explanation page immediately following the summary budget in the proposal.

Firm: Same as Proposal Cover.

Proposal Number: Same as Proposal Cover.

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 I 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.

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.

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 5.11 and 5.12. 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 $70,000.

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 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 $70,000. (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 Tuesday, September 9, 2003** (Section 6.4).

FORM A – STTR PROPOSAL COVER

Topic Number

1. PROPOSAL NUMBER: **03-** __ __
2. RESEARCH TOPIC:
3. PROPOSAL TITLE:
4. SMALL BUSINESS CONCERN (SBC)
   NAME:
   ADDRESS:
   CITY/STATE/ZIP:
   PHONE:
   FAX:
   EIN/TAX ID:
   DUNS + 4: CAGE CODE:

   RESEARCH INSTITUTION (RI)
   NAME:
   ADDRESS:
   CITY/STATE/ZIP :
   PHONE:
   FAX:
   EIN/TAX ID:
5. AMOUNT REQUESTED: $____________________ DURATION: _________ MONTHS
6. CERTIFICATIONS: THE ABOVE SBC CERTIFIES THAT:

As defined in Section 2 of the Solicitation, the offeror qualifies as a:		
a. SBC Number of employees: ____	Yes	No
b. Socially and economically disadvantaged SBC	Yes	No
c. Woman-owned SBC	Yes	No
d. HUBZone-owned SBC	Yes	No
As described in Section 2.8 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?	Yes	No
i) If yes, limits on subcontracts/consultants met	Yes	No
ii) If yes, copy of agreement enclosed	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-SBIR funding source identified in Part 8?	Yes	No
As described in Section 3.2.4 of the Solicitation, the offeror certifies:		
l. Work under this project has been submitted for funding only to the NASA STTR Program	Yes	No
m. No funding has been received for work under this project by any other Federal grant, contract, or subcontract	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. ENDORSEMENT BY SBC OFFICIAL:
   NAME: TITLE:
   PHONE: E_MAIL:
   SIGNATURE: DATE:

NOTICE: For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part, provided that, if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. 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 Proposal Cover

1. Proposal Number: This number does not change even if the firm gets a new phone number. Complete the proposal number as follows:
   1. Enter the two-digit Topic number.
   2. The system will generate a unique four-digit number

2. Research Topic: NASA research topic number and title (Section 8).

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:	City name
State:	2-letter State designation (example VA for Virginia)
Zip:	9-digit Zip code (example 20705-3106)
Phone:	Number including area code
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 and 6g (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).

   6i. All eleven parts of the technical proposal included: By answering yes, the SBC/RI certifies that the proposal consists of all eleven parts numbered and in the prescribed order (see Section 3.2.4).

   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.

   ii) If yes, copy of agreement enclosed: By answering yes, the SBC/RI certifies that a copy of any subcontracting or consulting agreements described in Section 3.2.4 Part 9 is included as required. Copy of the agreement may be submitted in a reduced size format.

   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 5, 5.17). 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.

6m. SBCs should choose "Yes" to affirm that work under this project has not been funded under any other Federal grant, contract or subcontract.

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 1.1).

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

FORM B – STTR PROPOSAL SUMMARY

Topic Number

1. Proposal Number **03 - __ __**

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:
   U.S. Citizen or Legal Resident Yes No

7. Technical Abstract (Limit 200 words or 2,000 characters, whichever is less):

8. Potential NASA Application(s): (Limit 100 words or 1,500 characters, whichever is less)

9. Potential Non-NASA Commercial Application(s): (Limit 100 words or 1,500 characters, whichever is less)

Guidelines for Completing STTR Proposal Summary

Complete Form B electronically.

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

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

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

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

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

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

   Note: Offerors are responsible for ensuring that all employees who will work on this contract are eligible under export control and International Traffic in Arms (ITAR) regulations. Any employee who is not a U.S. citizen or a legal resident may be restricted from working on this contract if the technology is restricted under export control and ITAR regulations. Violations of these regulations can result in criminal or civil penalties.

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

8. **Potential NASA Application(s):** Summary of the direct or indirect NASA applications of the project, assuming the goals of the proposed R/R&D are achieved. Limit your response to 100 words or 1,500 characters, whichever is less.

9. **Potential Non-NASA Commercial Application(s):** Summary of the direct or indirect NASA applications of the project, assuming the goals of the proposed R/R&D are achieved. Limit your response to 100 words or 1,500 characters, whichever is less.

FORM C – STTR SUMMARY BUDGET

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 I 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 homepage (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 Summary Budget

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, on a budget explanation page immediately following the summary budget in the proposal.

Small Business Concern - Same as Proposal Cover.

Principal Investigator/Project Manager - Same as Proposal Cover.

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 I 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.

Example: 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.

Other Direct Costs (ODCs) - (Include budget for the Research Institution as a Other Direct Cost.)

- 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.

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 5.11 and 5.12. 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 I activities, at a minimum. If the_______ _______(Proposal Title)_________ Project is selected to continue into Phase II, the agreement may also be binding in Phase II activities that are funded by NASA, then this agreement shall be binding until those activities are completed. The agreement may also be binding in Phase III activities that are funded by NASA.

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

Please direct all questions and comments to _______________(Small Business Concern representative) at _______(Phone Number)________________

_______Signature_____________________

_______Name/title____________________

_______Small Business Concern_________

_______Signature_____________________

_______Name/title____________________

_______Research Institution_____________

SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) PROGRAM
MODEL ALLOCATION OF RIGHTS AGREEMENT

This Agreement between ______________________________, a small business concern organized as a ____________________ under the laws of ______________ and having a principal place of business at ____ ________________, ("SBC") and ____________________________________, a research institution having a principal place of business at ____________________ ______________,("RI") is entered into for the purpose of allocating between the parties certain rights relating to an STTR project to be carried out by SBC and RI (hereinafter referred to as the "PARTIES") under an STTR funding agreement that may be awarded by _NASA________ to SBC to fund a proposal entitled "____________________________ ____" submitted, or to be submitted, to by SBC on or about ____________________, 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, (iii) 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 proposal, use the following checklist to ensure your submission is complete.

1. The entire proposal including any supplemental material shall not exceed a total of 25 8.5 x 11 inch pages, including Cooperative Agreement. (Sections 3.2.2, 3.2.5).
2. The proposal and innovation is submitted for one topic only. (Sections 1.4.1, 5.1.1).
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 3.2.2, 3.2.5).
9. Entire proposal including Forms A, B, and C submitted via the Internet.
10. Form A electronically endorsed by the SBC Official.
11. **Proposals must be received by the NASA SBIR/STTR Program Support Office no later than by 5:00 p.m. EDT on Tuesday, September 9, 2003.** (Section 6.4).

9. Research Topics for SBIR and STTR

9.1 SBIR Research Topics

Introduction

The SBIR Program Solicitation is aligned with the established NASA management structure of the Strategic Enterprises (http://www.nasa.gov).

The Enterprises identify, at the most fundamental level, what NASA does and for whom. Each Strategic Enterprise is analogous to a strategic business unit employed by private-sector companies to focus on and respond to their customers' needs. Each Strategic Enterprise has a unique set of goals, objectives, and strategies. SBIR research topics and subtopics are organized under the NASA Strategic Enterprises:

Aerospace Technology
Biological and Physical Research
Earth Science
Space Flight
Space Science

A sixth Strategic Enterprise has been established in 2003: ***Education***

Education is a crosscutting organization: It works to coordinate with the other Enterprises' in outreach activities for K-12 and universities and colleges. There are subtopics in this SBIR Solicitation that have an outreach and Education focus, matching the needs of one of the five technical Enterprise's missions. In addition, the required involvement of research institutions in the STTR Solicitation, which is announced concurrently with the SBIR Solicitation, adds an additional potential linkage to the Education Enterprise.

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9.1.1 AEROSPACE TECHNOLOGY

NASA's Aerospace Technology Enterprise pioneers the identification, development, verification, transfer, application, and commercialization of high-payoff aeronautics technologies. It seeks to promote economic growth and security and to enhance U.S. competitiveness through safe, superior, and environmentally compatible U.S. civil and military aircraft and through a safe, efficient national aviation system. In addition, the Enterprise recognizes that the space transportation industry can benefit significantly from the transfer of aviation technologies and flight operations to launch vehicles, the goal being to reduce the cost of access to space. The Enterprise will work closely with its aeronautics customers, including U.S. industry, the Department of Defense, and the Federal Aviation Administration, to ensure that its technology products and services add value, are timely, and have been developed to the level where the customer can confidently make decisions regarding the application of those technologies.

http://www.aero-space.nasa.gov/

TOPIC A1 Aviation Safety and Security

The worldwide commercial aviation accident rate has been nearly constant over the past two decades. Although the rate is very low, increasing traffic over the years has resulted in the absolute number of accidents also increasing. Without improvements, doubling or tripling of air traffic by 2017 could lead to 50 or more major accidents a year. This number of accidents would have an unacceptable impact on the aviation system. The goal of NASA's Aviation Safety and Security Program (AvSSP) is to develop and demonstrate technologies that contribute to a reduction in the fatal aviation accident rate by a factor of 5 by 2007. Research and technology will address accidents involving hazardous weather, controlled flight into terrain, human-error-caused accidents and incidents, and mechanical or software malfunctions. The Program will also develop and integrate information technologies needed to build a safer aviation system and provide information for the assessment of situations and trends that indicate unsafe conditions before they lead to accidents. NASA researchers are also looking at ways to adapt aviation technologies already being developed to improve aviation security. The AvSSP is focusing on areas where NASA expertise could make a significant contribution to security: 1) the hardening of aircraft and their systems; 2) secure airspace operation technologies; 3) improved systems to screen passenger and cargo information; and 4) sensors designed to better detect threats. NASA seeks highly innovative proposals that will complement its work in Aviation Safety and Security in the following subtopic areas:

A1.01 Crew Systems Technologies for Improved Airspace Safety and Security
Lead Center: LaRC

NASA seeks highly innovative crew systems technologies to improve airspace safety and security. Such advanced technologies may meet these goals 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; assisting in response planning and execution; and ensuring individuals have access to use of national airspace as appropriate. In addition, NASA seeks tools and methods for measuring and assessing crew and group performance in complex, dynamic systems. Technologies may take the form of 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. Technologies should have a high potential for emerging as marketable products. Examples include:

- Intelligent systems monitoring and alerting technologies for improved failure mode identification, recovery, and threat mitigation.
- Innovative crew systems to improve situation awareness of airspace safety and security concerns.
- Designs for human-error prevention, detection, and mitigation.
- Decision-support tools and methods to improve communication, collaborative and distributive decision-making.
- Data fusion technologies to integrate disparate sources of flight-related information.
- Computational approaches to support response planning and selection by crew and/or automation.
- Computational approaches to monitoring crew health, stress level, state of duress, and performance.
- Computational approaches to modulate appropriate crew engagement, work load, and situation awareness.
- Human-centered information technologies to improve the performance of less-experienced NAS operators.
- Technologies to ensure access to airspace systems and infrastructure only by appropriate persons.
- Avionics designers and/or certification specialist tools to improve the application of human-centered principles.
- Human-error reliability approaches to analyzing flight deck displays, decision aids, and procedures.
- Individual and team performance metrics, analysis methods, and tools to better evaluate and certify human and system performance for use in operational airspace environments, simulation, and model-based analyses.

A1.02 Propulsion and Airframe Failure Data and Accident Mitigation
Lead Center: GRC

NASA is concerned with the prevention of hazardous conditions and the mitigation of their effects when they do occur. One particular emphasis is on the prevention and suppression of fire and explosions. Aircraft fires represent a small number of actual accident causes, but the number of fatalities due to in-flight, post-crash and on-ground fires is large.

A second emphasis is on mitigating the safety risk and collateral damage due to unexpected failures of rotating components. Although the FAA mandates a blade containment and rotor unbalance requirement (FAR Part 33, section 33.94) as part of the airworthiness standards for turbine aircraft engines, there are substantial potential (aircraft-engine) system benefits to be gained by enabling safety assured, lighter weight, lower cost, and more damage-tolerant designs for engine case/containment systems and associated (primary load path) structures.

A third emphasis for this subtopic is on propulsion system health management in order to prevent or accommodate safety-significant malfunctions and damage. Past advances in this area have helped improve the reliability and safety of aircraft propulsion systems. However, propulsion system component failures are still a contributing factor in numerous aircraft accidents and incidents. Advances in technology are sought which help to further reduce the occurrence of and/or mitigate the effects of safety-significant propulsion system malfunctions and damage.

A fourth emphasis is to increase the level of safety for all aircraft flying in the atmospheric icing environment. 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 (aircraft icing protection systems and design tools).

A final emphasis for this subtopic is protection of the aircraft through communication, navigation and surveillance (CNS) systems which are themselves secure, as well as applications that support other aircraft failure or sabotage mitigation systems. Technology is needed to harden the CNS systems, both onboard and air-to-ground, and to provide next-generation airborne, ground- and space-based surveillance systems.

With these emphases in mind, products and technologies are sought which can be made affordable and retrofitable within the current aviation system, as well as for use in the future. These include the following areas:

- Technology for prevention and suppression of potential in-flight fires in fuel tanks, cargo bays, insulation, and other inaccessible locations due to accidents or deliberate acts.
- Technology to provide fuel tank vapor flammability reduction and onboard oxygen generation.
- Technology to minimize fire hazards in crashes and to prevent or delay fires.
- Advanced material/structural configuration concepts to prevent catastrophic failures of engine components, or to ensure fragment containment.
- Computational tools for analyzing blade-loss events and designing structural components/systems accordingly.
- Health management technologies such as instrumentation, ground/on-wing nondestructive inspection, health monitoring algorithms, and fault accommodating logic, that will predict, diagnose, prevent, assess, and allow recovery from propulsion system malfunctions or damage.
- Ground and airborne radome technologies for microwave wavelength radar and radiometers that remain clear of liquid water and ice in all weather situations.
- All-weather, profiling cloud radar that are accurate to -40dBZ at 1 km and that utilize the latest microwave technologies to ensure a final customer cost of less than $100,000, including data acquisition and processing computer.

- Technology capable of real-time assessment of aero performance for clean and ice-contaminated wing surfaces. Concept must be capable of operating in the normal passenger-carrying flight domain and be unaffected by typical flight turbulence.
- 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 ideally cloud particle sizing and phase information. Solutions envisioned would utilize radiosonde-based systems.
- Next generation capabilities for remote monitoring of onboard systems and the aircraft environment
- Secure onboard information processing, computing and air/ground networking
- Technologies to harden aircraft communication, navigation, and surveillance systems against abnormality and deliberate attack.

A1.03 Automated On-Line Health Management and Data Analysis
Lead Center: DFRC

Online health monitoring is a critical technology for improving transportation safety in the 21st century. 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/wide area networks. On-line health monitoring is a general concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. On-line applications emphasizes algorithms that minimize the time between data acquisition and decision-making.

This subtopic seeks solutions for on-line aircraft subsystem health monitoring. Solutions should exploit multiple computers communicating over standard networks where applicable. Solutions can be designed to monitor a specific subsystem or a number of systems simultaneously. Resulting commercial products might be implemented in a distributed decision-making environment such as a virtual flight research center, a disciplinary-specific collaborative laboratory, an onboard diagnostics system, or a maintenance and inspection network of potentially global proportion.

Offerors should discuss who the users of resulting products would be, e.g., research/test/development; manufacturing; maintenance depots; flight crew; airports; flight operations or mission control; air traffic management; or airlines. Offerors are encouraged to discuss data acquisition, processing, and presentation components in their proposal. Examples of desired solutions targeted by this subtopic include:

- Real-time autonomous sensor validity monitors.
- Flight control system or flight path diagnostics for predicting loss of control.
- Automated testing and diagnostics of mission-critical avionics.
- Structural fatigue, life cycle, static, or dynamic load monitors.
- Automated nondestructive evaluation for faulty structural components.
- Electrical system monitoring and fire prevention.
- Applications that exploit wireless communication technology to reduce costs.
- Model-reference or model-updating schemes based on measured data that operate autonomously.
- Proactive maintenance schedules for rocket or turbine engines, including engine life-cycle monitors.
- Predicting or detecting any equipment malfunction.
- Middleware or software toolkits to lower the cost of developing online health-monitoring applications.
- Innovative solutions for harvesting, managing, archival, and retrieval of aerospace vehicle health data.

TOPIC A2 Vehicle Systems

The Vehicle Systems Program is about Outcomes for the Public Good: Environmentally Friendly Aircraft, Air Vehicles for Public Mobility, Superior Air Power, and New Aeronautical Missions. Vehicle Systems does this by looking at three Objectives: Transportation System Concepts, Vehicle Capabilities and Enabling Technologies. The Vehicle Systems Program is developing revolutionary technologies at the laboratory, component or subsystem level. The majority of the resources are allocated for fundamental research to find breakthrough technologies through three projects: Tailored Lightweight Structures, Robust Reliability, and Electric Hybrid Propulsion. These projects develop the fundamental technologies needed to enable the change state in aeronautics. Existing and newfound knowledge is refined through field tests through three more projects: Efficient Aerodynamic Configurations, Ultra-Efficient Engine Technology, and Quiet Aircraft Technology. These projects focus on the integration of these technologies into subsystems and systems that can be developed with industry partners into highly leveraged products. To measure the overall progress, Vehicle Systems accelerates the technology integration and maturation through two Vehicle Sector Integration Projects: Strategic Vehicle Architectures and Flight and System Demonstrations. The Strategic Vehicle Architectures Project conducts system level integration studies, and the Flight and Systems Demonstrations Project conducts concept development and research flight testing.

A2.01 Propulsion System Emissions and Noise Prediction and Reduction
Lead Center: GRC

<u>Emissions</u>: Current environmental concerns with subsonic and supersonic aircraft center around the impact of emissions on the Earth's climate. Carbon dioxide (CO_2) and oxides of nitrogen (NOx) are the major emittants of concern coming from commercial aircraft engines. Current state-of-the-art engines and combustors in most subsonic aircraft are fuel efficient and meet the 1996 ICAO nitrogen oxide (NOx) limits. Recent observations of aircraft exhaust contrails (from both subsonic and supersonic flights) have resulted in growing concern over aerosol, particulate, and sulfur levels in the fuel. In particular, aerosols and particulates from aircraft are suspected of producing high altitude clouds which could adversely affect the Earth's climatology. Advanced concepts research for reducing CO_2 and NOx, and analytical and experimental research in characterization (intrusive and non-intrusive) and control (through component design, controls, and/or fuel additives) of gaseous, liquid and particulates of aircraft exhaust emissions is sought. Specific aircraft operating conditions of interest include the landing-takeoff cycle as well as the in-flight portion of the mission. Areas of particular interest include:

- New concepts for reducing CO_2, oxides of nitrogen (NO, NO_2, NOx), unburned hydrocarbons; carbon monoxide, particulate, and aerosols emittants (novel propulsion concepts, injector designs to improve fuel mixing, catalysts, additives, etc.)
- New fuels for commercial aircraft which minimize CO_2 and NOx emissions
- Innovative active control concepts for emission minimization with an integrated systems focus including emission modeling for control, sensing and actuation requirements, control logic development, and experimental validation are of interest
- New instrumentation techniques are needed for the measurement of engine emissions such as NOx, SOx, HOx, atomic oxygen and hydrocarbons in combustion facilities and engines. Size, size distributions, reactivity, and constituents of aerosols and particulates are needed, as are temperature, pressure, density, and velocity measurements. Optical techniques that provide 2-D and 3-D data; time history measurements; and thin film, fiber optic, and MEMS-based sensors are of interest

<u>Noise</u>: Engine noise reduction technologies are required in the areas of propulsion source noise, nacelle aeroacoustics, and engine/airframe integration. Some of the key technologies needed to achieve these goals are revolutionary propulsion systems for reduced noise without significant increases in cost and emissions. Noise reduction concepts need to be identified that provide economical alternatives to conventional propulsion systems. NASA is soliciting proposals in one or more of the following areas for propulsion system noise reduction:

- Innovative acoustic source identification techniques for turbomachinery noise: The technique shall be described for a relevant source. Plans for a Phase II demonstration should be included for the Phase I proposal. A simple source may be used where the solution is known to demonstrate the technique. A clear explanation on how the technique can be applied to turbofan engines should be included. The technique should be capable of identifying sources contributing to dominant engine components, such as fan and jet noise.
- Fan Noise: The technique shall be capable of separating fan sources such as fan-alone versus fan/stator interaction for both tones and broadband noise. Sufficient resolution is needed to determine the location of the dominant sources on the aerodynamic surfaces. Jet Noise: The technique shall be capable of locating both internal and external mixing noise for dual-flow nozzles found in modern turbofans.
- Innovative turbofan source reduction techniques. Methods shall emphasize noise reduction methods for fan, jet and core components without compromising performance for turbofan engines. A resulting engine system that incorporates one or more of the proposed methods should be capable of reducing perceived noise levels anywhere from 10 to 20 EPNdB relative to FAR 36, Stage 3 certification levels.
- Revolutionary propulsion concepts for lower emissions and noise (proposed as alternatives to turbofan engines). Feasibility studies shall be done that demonstrate the potential for 20 EPNdB engine noise reduction relative to FAR 36, Stage 3 certification levels and 90% reduction in NOx emissions standards relative to current ICAO regulations for commercial aircraft concepts. Enabling technologies shall be identified for future research.

A2.02 Electric and Intelligent Propulsion Technologies for Environmentally Harmonious Aircraft
Lead Center: GRC

With the increased emphasis on safety, enhanced performance and affordability, and the need to reduce the environmental impact of aircraft, there are many new challenges being faced by the designers of aerospace propulsion systems.

Electric aircraft propulsion & power systems have the potential to completely eliminate harmful emissions from aircraft while at the same time doubling fuel efficiency. Major strides have been achieved in the development of electrical systems and components, especially in the automotive field. We now appear to be on the threshold of viable electric flight. There are still major technical advances required to make commercially viable electric aircraft a reality, but the goal does now appear to be achievable, possibly even in the nearer term for smaller family-sized air vehicles. To achieve the implementation of environmentally harmonious twenty-first century air vehicles, innovations are needed to enable highly efficient, low-cost, power-dense (weight and volume) electric aircraft propulsions & power systems.

Intelligent propulsion technologies have the potential to enable the design of extremely safe, high performance propulsion systems that will also meet the stringent affordability and environmental requirements of the future. For turbomachinery-based propulsion systems, the approach has been to design engine components such as combustors, fans and compressors, inlets, nozzles, etc., for optimum component performance within some overall system constraints, the control problem was to transition the operating point of the engine from one set point to another in the most expedient manner without compromising safety. With the advancements in information technologies and various disciplines relevant to aeropropulsion, the component designers are beginning to realize the potential of "Intelligent Engines" in helping them meet more stringent design requirements.

Implementation of intelligent propulsion concepts requires advancements in the area of robust control synthesis techniques and automated diagnostics, and development of advanced enabling technologies such as smart sensors and actuators. Attention will also need to be paid to integration of the active component control and diagnostics technologies with the control of the overall propulsion system. This will require moving from the current analog control systems to distributed control architectures.

Technical areas of interest in electric aircraft propulsion and power include, but are not limited to, fuel cells, power management, power conditioning, power distribution, actuators, motor drive systems, fuel storage (especially hydrogen). Highly integrated dual function components, and systems that have the potential to reduce overall weight are of special interest (e.g., power conductors that are integrated into the airframe structure, motors directly integrated into the fan/propeller structure, etc.). Both component and system level technologies are solicited. Also of interest are aviation Jet-A fuel reformers and desulfurizers that integrate with fuel cell systems. These must provide effluent hydrogen with target sulfur concentrations of 10 ppm or less, minimize the need for water or steam, operate without damaging coke formation, and be compact, lightweight, durable and long life.

Intelligent propulsion technologies that address electric, turbine, jet and/or hybrid aerospace propulsion systems are of interest. Proposals focusing on development of advanced diagnostics, health monitoring and control concepts, and smart sensors, electronics and actuators for enabling self-diagnostic and prognostic, and self-reconfiguration capabilities being sought. Concepts integrating distributed sensing and, actuation and control logic for micro-level control of parameters, such as propulsion system internal flows, that impact performance and environment, are of special interest. Novel instrumentation approaches that provide valuable information for development and validation of technologies for self-diagnosis, prognosis and reconfiguration are also of interest.

A2.03 Revolutionary Technologies and Components for Propulsion Systems
Lead Center: GRC

NASA seeks highly innovative concepts for propulsion systems and components for advanced high-speed aerospace vehicles to support missions, such as access to space, global cruise, and high-speed transports. The main emphasis in this subtopic is on high-risk, breakthrough technologies in order to revolutionize aerospace propulsion over a broad flight spectrum, up to Mach 8. Proposals offering significant advancements in critical components and designs for propulsion systems and subsystems are sought. Specific technical areas include the following:

- Advanced cooling concepts that minimize coolant penalties. This can include innovative cooling systems, fuel cooling of combustor, and endothermic fuels and/or fuel additives to increase the heat-sink capacity or cooling capacity of fuels.
- Innovative concepts relating to combustion process, including fuel injectors, piloting, flame holding techniques for increased performance and decreased emissions, techniques to identify the onset of combustion instability in lean-burn and/or rich-burn, low NOx combustor, ramjet combustion and active and passive combustion controls in order to extend the operability of the combustion components to a wider range of operating conditions.
- New inlet concepts to meet functional airflow needs of high Mach number propulsion. For instance, a variable geometry, supersonic, mixed compression inlet. Compatibility with turbomachinery and mode transition across the speed range should be addressed. Special attention should be given to combustor demands along a realistic flight corridor. This flight corridor must be compatible with turbine engine thermal-structure limits.
- New techniques to improve the aerodynamic performance and operability of the inlet, including highly offset subsonic diffusers and designs for boundary layer control, minimizing engine unstart susceptibility, and techniques to identify and control the onset of mode transition between different propulsion concepts within the same internal flowpath or dual flowpaths.
- New controllable and reliable nozzle concepts with optimum expansion efficiency and thrust vectoring capability, including a computational nozzle design methodology to study various geometries and chemistry effects.
- Enabling technologies of components and subsystems that allow turbomachinery to operate at high-speed flight conditions. Specific examples include 1) a lightweight, high-pressure ratio compressor which must be protected or removed from the extremely high temperature primary air stream; 2) applications of micro-electrical-mechanical systems (MEMS) that demonstrate the potential to enhance the performance and reduce the cost and weight; and 3) innovative inlet flow conditioning.
- New concepts for combined/combination cycles, in particular those including turbine propulsion. Alternate engine cycles that meet a unique mission requirement (e.g., global reach, access to

space, etc.), including pulse detonation, ramjets, scramjets, and rockets. Proposals can also include development of unique components required for the maturation of alternate propulsion cycles, such as inlets, diffusers, nozzles, air-valves, fuel injectors, combustors, etc.

- Innovative integration technologies among components or subsystems which significantly improve the performance or reduce the cost of the overall propulsion system are sought. This includes new collaborative and concurrent engineering tools for analysis and design. These tools could reduce the need for empiricism, thus facilitating early evaluation of interactions among propulsion components. "Intelligent" design tools, based on technologies such as evolutionary algorithms and neural networks, are also of interest. All design/analysis tool proposals must include a propulsion technology development application.

A2.04 Airframe Systems Noise Prediction and Reduction
Lead Center: LaRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, rotorcraft, and advanced aerospace vehicles. Improvements in noise prediction and control are needed for jet, propeller, rotor, fan, turbomachinery, and airframe noise sources to reduce the impact on community residents, aircraft passengers and crew, and launch vehicle payloads. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid-dynamics techniques for aeroacoustic analysis, particularly for use early in the design process.
- Simulation and prediction of aeroacoustic noise sources particularly for airframe noise sources and situations with significant interactions between airframe and propulsion systems.
- Innovative active and passive acoustic treatment concepts for engine nacelle liners and concepts for high-intensity acoustic sources, which can be used to characterize engine nacelle liner materials.
- Concepts for active and passive control of aeroacoustic noise sources for advanced aircraft configurations.
- Reduction technologies and prediction methods for rotorcraft and advanced propeller aerodynamic noise.
- Computational and analytical structural acoustics techniques for aircraft and advanced aerospace vehicle interior noise prediction, particularly for use early in the airframe design process.
- Technologies and techniques for active and passive interior noise control for aircraft and advanced aerospace vehicle structures.
- Prediction and control of high-amplitude aeroacoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue.
- Development and application of flight procedures for reducing community noise impact of rotorcraft and future subsonic and supersonic commercial aircraft while maintaining safety, capacity and fuel efficiency.
- Development of synthesis and auditory display technologies for subjective assessments of interior and exterior aircraft noise.

A2.05 Revolutionary Propulsion Research for Core Technologies
Lead Center: GRC

This subtopic addresses structural and mechanical components and subsystems, and advanced materials for Aerospace Propulsion and Power Systems. Proposals are sought for innovative and commercially viable concepts which address objectives, depending on application, such as enable lighter weight, reduced operational costs, noise or emissions, higher temperature capability, increased efficiency or operational margin, greater safety and reliability, and more time on station for aircraft, satellites, and inflatable platforms.

One focus is on problems related to structural and mechanical components and subsystems that operate at high temperatures, in hostile aero-thermo-chemical environments or space environments, and at high stresses under cyclic loading conditions. Interests include tribological coatings, seals, bearings, gears and transmissions, and approaches to noise attenuation.

A second focus addresses advanced materials, their development, and their application to primary propulsion systems such as aircraft gas turbines, rocket and turbine-based combined cycle engines, and rocket engines as well as auxiliary power sources in aircraft and space vehicles. Materials of interest include any classes especially used in propulsion systems such as high-temperature polymers and composites, metals including titanium alloys and nickel-base superalloys, ceramics and ceramic matrix composites, and coatings for these, and processes for their economical and reliable preparation.

A2.06 Modeling and Control of Complex Flows Over Aerospace Vehicles and Propulsion Systems
Lead Center: LaRC
Participating Center(s): ARC

This subtopic solicits innovative ideas, concepts, and methodologies for the measurement, prediction, modeling and control of unsteady aerodynamic and aerothermodynamic phenomena that may be encountered by aerospace vehicles. Biologically inspired approaches and/or ideas for flow control are also solicited in this subtopic. Also of interest are advanced measurement systems and ground-testing techniques to provide dynamic and global measuring capabilities, higher bandwidth, and improved resolution. Additionally, the subtopic is interested in innovative computational and experimental techniques that account for the complex aerothermodynamic, mixing, and combustion phenomena impacting the design and development of future space transportation vehicles, aero-assist orbital transfer vehicles, planetary entry probes, and hypersonic airbreathing propulsion systems. Unsteady phenomena of interest include, but are not limited to, active and passive flow-control mechanisms; vortical and separated flows; equilibrium and finiterate chemistry; thermodynamic and transport properties of multicomponent mixtures, gaseous radiation, gas-surface interactions, mixing and combustion, shock-wave/boundary-layer interactions; and laminar, transitional, and turbulent reacting and nonreacting flows. Specific areas of interest include:

- Flow-physics modeling and control of transition and/or transitional flows, turbulence, and turbulence-related phenomena such as heat transfer, skin-friction, acoustics, mixing and combustion, with an emphasis on separated flow and the scaling of ground-based experiments to flight Reynolds numbers.
- Design optimization methods for natural laminar flow and/or hybrid (combined natural and active) laminar flow aircraft or aircraft components.
- Control and/or mitigation of separation, vortical flows, and shock wave phenomenon, including their impact on vehicle drag (tubulent skin friction drag, profile drag, drag-due-to-lift, and wave drag).
- Non conventional numerical methods for solving fluid-flow equations that increase computational efficiency, accuracy, speed, and utility, including construction of new algorithms, improved computer languages, efficient and adaptive grid-algorithm interfacing, and applications of automation techniques with discretization error assessments.
- Innovative techniques for robust and reliable handling and sharing of large CFD and experimental data sets.
- Analytical and/or computational models/algorithms applicable to the optimization of integrated hypersonic propulsion/vehicle systems.
- Innovative mixing techniques applicable to hypersonic propulsion, with special consideration placed on the stoichiometric fuel regimes.
- Concepts for small-scale devices that initiate and sustain fuel (hydrogen and/or hydrocarbon) ignition and flame holding in supersonic combustor environments, at conditions relevant to hypersonic airbreathing propulsion flight trajectories.
- Advanced test techniques and flow diagnostics (including non intrusive flow diagnostics and surface diagnostics) for developing definitive databases across speed range from subsonic to hypersonic facilities including shock-expansion pulse facilities.
- MEMS and nanotechnology sensors and interface electronics for flow measurements including flow velocity, pressure, temperature, shear stress, vibration, force, attitude, and/or acceleration.

- A small onboard multichannel intelligent data system and/or a high-speed wireless (optical or radio frequency) data transfer system with 50 mega-bits-per-second or higher data rate for wind tunnel model applications.
- Optical flow diagnostic technologies capable of resolving velocity, density, temperature, etc., in a global sense to provide planar or volumetric data, or at multiple points within the flow to provide temporally dependent cross correlations at sample rates on the order of 100 kHz.

TOPIC A3 Airspace Systems

NASA's Airspace Systems (AS) program is investing in development of revolutionary improvements and modernization for the air traffic management (ATM) system. The AS Program will enable new aircraft, new aircraft technologies and air traffic technology to safely maximize operational efficiency, flexibility, predictability and access into airspace systems. The major challenges are to accommodate projected growth in air traffic while preserving and enhancing safety; provide all airspace system users more flexibility and efficiency in the use of airports, airspace and aircraft; reduce system delays; enable new modes of operation that support the Federal Aviation Administration (FAA) commitment to "Free Flight" and maintain pace with a continually evolving technical environment, and provides for doorstep-to-destination transportation developments. AS Program objectives are: Improve mobility, capacity, efficiency and access of the airspace system; Improve collaboration, predictability and flexibility for the airspace users; Enable modeling and simulation of air transportation systems; Enable runway-independent aircraft and general aviation operations; and Maintain system safety and environmental protection. NASA is working to develop, validate and transfer advanced concepts, technologies and procedures through partnership with the FAA, other Government agencies and in cooperation with the U.S. aeronautics industry.

A3.01 21st Century Air-Traffic Management
Lead Center: ARC
Participating Center(s): DFRC

The challenges in Air Traffic Management (ATM) are to create the next generation system and to develop the optimal plan for transitioning to the future system. This system should be one that (1) economically moves people and goods from origin to destination on schedule; (2) operates without fatalities or injuries resulting from system or human errors or terrorist intervention; (3) seamlessly supports the operation of unmanned aerial vehicles (UAVs); (4) is environmentally compatible; (5) supports an integrated national transportation system and is harmonized with global transportation. 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.

To meet these challenges, innovative and economically attractive approaches are sought to advance technologies in the following areas:

- Decision support tools (DST) to assist pilots, controllers and dispatchers in all parts of the airspace(surface, terminal, enroute, command center)
- Integration of DST across different airspace domains
- Next generation simulation and modeling capability: models of uncertainty and complexity, National Airspace System (NAS) operational performance, economic impact
- Distributed decision making
- Security of advanced ATM systems
- System robustness and safety: sensor failure, threat mitigation, health monitoring
- Weather modeling and improved trajectory estimation for traffic management applications
- Role of data exchange and data link in collaborative decision-making
- Modeling of the NAS

- Distributed complex, real-time simulations: components with different levels of fidelity, human-in-the-loop decision agents
- Environmentally friendly ATM and aircraft operations
- Automation concepts for advanced ATM systems
- Application of methodologies from other domains to address ATM research issues
- Intelligent software architecture
- Runway-independent (e.g., VTOL, STOL, and V/STOL) aircraft technologies required to meet national air transportation needs and to satisfy requirements for airline productivity, passenger acceptance, and community friendliness
- Intermodal transportation technologies
- Technologies fostering the operation of unpiloted aircraft within NAS under control of the ATM system, including, but not limited to, innovative control, navigation, & surveillance (CNS) concepts

TOPIC A4 Next Generation Launch Technologies

The Commission on the Future of the U.S. Aerospace Industry states - "Aerospace is a technology-driven industry. Long-term research and innovation are the fuel for technology. U.S. aerospace leadership is a direct result of our preeminence in research and innovation…. reducing the cost to orbit is an essential ingredient for progress. The expense per pound of lifting humans, cargo and satellites into orbit has effectively limited us to utilizing space for only the most critical national missions. The result has been a narrowing, rather than a broadening, of our space ambitions." NASA's New Integrated Space Transportation Plan (ISTP) implements a long-term investment strategy to increase safety and reliability and reduce the cost of space access. As a component of the ISTP, the Next Generation Launch Technology (NGLT) Program will make launch systems more safe, reliable and affordable, enhance national security, support future NASA exploration needs, and inspire and motivate students to pursue science and math careers. This topic is soliciting technologies that will combine previous Space Launch Initiative research and development efforts with cutting-edge, advanced space-transportation programs to increase the safety, reliability and cost-effectiveness associated with developing the Nation's next-generation launch vehicle. The first step in identifying technologies needed to create a new, safe, cost-effective launch system is to generate an integrated technology plan. The next step is developing and maturing technologies in key areas, such as propulsion, structures and integrated vehicle systems. Emphasis on rocket engine technologies such as a large reusable kerosene engine (in concert with Department of Defense initiatives) and on a variety of launch system technologies, including development of air-breathing hypersonic propulsion systems is of special interest to the NGLT.

A4.01 Space Transportation Architecture Definition
Lead Center: MSFC
Participating Center(s): ARC

Next Generation Launch Technology (NGLT) architecture definition efforts will require innovative system analysis tools to determine the impact of critical technologies on the overall launch system infrastructure. Next generation of launch systems will require high overall vehicle payload mass to lift-off mass ratios, propulsion systems which deliver higher thrust to engine weight ratios, increased trajectory-averaged specific impulse, reliable overall vehicle systems performance, and extended reusability in order to achieve cost and crew safety goals. This subtopic emphasizes innovative launch vehicle architecture definition technology for subsystems, and vehicle system level design and analysis tools to support assessment of the credible physics and technical viability of proposed next generation launch systems. Moreover, such analysis tools are needed to support decisions on the development of key technologies to enable the next generation of launch systems. Design and analysis tools proposed under this subtopic should address a range of technical issues related to propellant tanks, thermal control subsystems, thermal protection systems, structures, guidance, navigation, and control (GN&C), loads and dynamics, fluid dynamics, integrated vehicle health management, turbomachinery, combustion devices, propulsion subsystems integration, vehicle layout, and overall vehicle level systems integration. Specific areas of interest for technology advancement and innovations include the following:

- Innovated analysis tools, and testing techniques applicable to assessment of credible physics associated with NGLT thermal protection system designs, compartment thermal control requirements, cryotank thermal characteristics, and vehicle base heat shield requirements.
- Control and health management of vehicle structural systems by using sensors that have little influence on the structural parameters with the exception of the structural damping parameters. Innovative vehicle preliminary design tools that support the design, analysis, and integration of vehicle systems and propulsions subsystems (such as the ability to assess operability of the overall launch vehicle concept and to model the impacts of design changes on vehicle cost, operations, crew safety, vehicle aerodynamics, and controllability). These tools would significantly enhance the overall systems engineering evaluation of potential reusable launch vehicle architectures.
- Integrated CAD, solid-model, structural, dynamic, thermal, and fluid-flow analysis methods for multidisciplinary analysis and optimization of subsystems, components, and overall launch vehicle systems; and improved vehicle analysis tools in the areas of stress, thermal, structures, fluid dynamics, and acoustics.
- Manufacturing and testing techniques that will allow for significant reduction in the cost and schedule required for wind tunnel aerodynamic testing of candidate NGLT configurations.
- Innovative analysis techniques to assess propellant management systems, feed lines, tank pressurization, fill, drain, and vent requirements.
- Methodologies and analysis tools for investigation and assessment of optimal fault detection and redundancy management strategies; execution software and advanced navigation hardware/software architectures; adaptive GN&C utilizing data from sensors such as GPS; guidance concepts that will reduce operational costs and increase reliability by autonomously reshaping trajectories and retargeting landing sites in the presence of abort/failure situations to satisfy vehicle and control constraints to achieve a safe abort.
- Methodologies and analysis tools for investigation and assessment of advanced control concepts that will reduce operational costs and increase reliability by adapting to changing missions/payloads/vehicle models/failures and abort scenarios without requiring ground effort to retune.
- Methodologies and analysis tools for investigation and assessment of automated mission planning techniques for planning flight operations of NGLT vehicles, including trajectory planning, launch window and timeline determination, generation of initialization loads, and verification that the GN&C will successfully fly the vehicle.
- Analysis and testing techniques for assessment of damage and stress including life cycle predictions, progressive internal damage and dynamic response in structures containing ceramic-matrix, metal-matrix composites, or other composite materials; and nondestructive evaluation of structural integrity of vehicle subsystem and component materials. Methods for efficient characterization of frequency response functions of large structures, and analysis and testing techniques for passive and active vibration isolation devices for launch vehicles and payloads.
- Innovative microwave nondestructive evaluation (NDE) techniques to assess flaws and the integrity of thermal protection system materials.
- Advanced methods and tools for prediction and assessment of unsteady environments applicable to reusable launch vehicle systems and components. Methods to predict and evaluate the internal fluctuating environments of propellant delivery systems, dynamic contributions of cavitating pumps, and vehicle/engine system dynamic stability. Methods to predict and evaluate steady and unsteady external environments of complex vehicle/engine combinations relating to geometrically complex external aerodynamics, engine start/launch overpressures, and noise related to flow dynamics.
- Advanced methodologies for thermal and structural assessment of large integrated composite cryogenic tanks, assessment of efficient and effective tank repair techniques, and technologies associated with modal, acoustic and static testing of large-scale aerospace structural systems.
- Innovative experimental-empirical methods for composite material thermal characterization and response prediction.

A4.02 Propulsion and Airframe Structures, Materials, and Manufacturing
Lead Center: MSFC
Participating Center(s): JSC

The primary interest of the subtopic is innovative manufacturing, materials and processes relevant to propulsion systems and airframe structures for next generation launch vehicles. Improvements are sought for increasing safety and reliability, and reducing cost and weight of propulsion, launch vehicle, and spacecraft systems and components. Only processes which are environmentally friendly and worker health oriented will be considered. Areas of interest include, but are not limited to:

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; advanced materials and manufacturing processes for both cryogenic and high-temperature applications; improved thermal protection systems (e.g., integrated structures, integral cryogenic tanks, aerogels).

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; friction stir and friction plug 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 degrees 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 non-metallic composite materials.

Rapid-prototyping
Rapid-prototyping technologies leading to improved structural integrity, materials for use in end-item component processing; near-net shape hardware from metal or ceramic matrix composites, as well as improved monolithic and alloyed properties for direct hardware fabrication.

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

A4.03 Lightweight Propulsion Components
Lead Center: MSFC

Ceramic matrix composite materials are projected to significantly increase safety and reduce costs simultaneously, while decreasing weight for space transportation propulsion. Innovative material and process technology advancements are required to enable long-life, reliable, and environmentally durable materials. Specific areas of technology development that are of interest include, but are not limited to, the following:

- Development of an environmentally durable fiber-reinforced refractory composite materials and their components,
- Actively cooled, CMC flow path components which contain pressure,
- Development of turbomachinery with inserted CMC blades,
- Development of the means to contain pressure and account for movement due to thermal growth and operation of connecting systems in uncooled CMC piping,
- Development of functionally formed components; CMCs with optimal and hybrid fiber tows and architectures, interface coating systems, inhibitors, matrices (e.g., glass/ceramic), and environmental barrier coatings which best suits function of the component for a specific portion of the

component (e.g., CMC face sheet with PMC backing, high-conductivity material transitioned to low-conductivity material in the same component, embedded CMC thrust chambers in a flow path, integral injector and cooled chamber, etc),

- Sealing and/or joining of CMCs to metals and ceramics for cooled components, manifolding, inserted blades, and end user-specified components accounting for fiber directions, surface conditions of the materials to be seal/joined, system loads and environments, and potential interactions between the materials to be sealed/joined (both during processing and subsequent use),
- Low-cost (with metrics), rapid, scalable, repeatable CMC fabrication process development for the preceding applications. Clearly state how the process quality will be measured and validated from batch to batch or with respect to time. Note any limitations.

Ideally, technology development will include design, analysis, fabrication and testing of components, subsystems, and engine systems to enable full assessment and accountability of the technology product and fundamental findings with respect to their value toward reaching NASA's goals. Composites are desired composed of fibers selected by end users such as high strength carbon fibers, SiC fibers, or hybrid tows or architectures. Environmentally durable fiber interface coating systems yielding optimal composite life and composite performance with respect to cost and time for fabrication are desired. Ceramic-based matrices, containing silicon- and/or refractory compounds are of interest. Where applicable, proposals should include the following:

- Explanation of how aspects of similar, previous efforts are leveraged.
- Identification and explanation of key issues and how they are mitigated within the technology developed.
- Explanation of how the technology developed will address key issues and mitigate risks for targeted/candidate propulsion systems with respect to NASA goals.
- Identification of path to prove assessment and accountability of the technology product with respect to their value toward reaching NASA's goals.
- Identification of potential end users that would integrate the technology product(s) into a propulsion system.
- Listing of all deliverables. When components or systems are delivered to NASA for potential testing and analyses, plans for manifolding (for cooling and gas ducting), attachment and hardware assembly, and technology integration are sought. Desired deliverables include: Components, test data, and material analyses as appropriate, hoop or flat tensile stress-strain curves, interlaminar shear, and other coupon test data, microscopic analysis images, edge-loaded tensile specimens (maximum of nine).
- Justification for selection of matrix material constituents, fibers, interface coatings, fabric architecture, etc.
- For process development, inclusion of a flexible, process-development matrix (e.g., which variables changed and how many processing trials) and ideally a Design of Experiments.
- Correlation of processing variables to flexible, detailed test matrices (include in reports also).
- Verification of processes with microscopic analysis (e.g., microprobe, SEM, XRD, TEM, etc.) and macroscopic analysis (e.g., tensile strength, stress-oxidation, thermal mechanical fatigue, interlaminar shear strength, thermal and physical properties, etc.).
- Verification of specific end-use application by testing for permeability, thermal shock, etc.
- Evaluation of components and/or coupon material using nondestructive characterization techniques.
- Explanation of manufacturing scale-up necessary for the ultimate full-size target components.

A4.04 Launch Vehicle Airframe Technologies
Lead Center: LaRC
Participating Center(s): MSFC

Next generation space transportation systems must address the significant challenge of significantly reducing the cost of space access while providing orders-of-magnitude improvements in safety. To accomplish these goals, the airframes/spaceframes for future launch vehicles and upper stages must be reusable and incorporate advanced technologies in materials and structural concepts, validated, safe structural analysis and design technologies, and improved manufacture of large-scale, advanced structures. The conflicting requirements of low cost and safety must also be balanced with the need for performance sufficient for space transportation vehicles.

Airframe systems of primary interest in this subtopic include innovative concepts in hot structures (i.e., structures that can function without requiring any atmospheric entry thermal protection system), and "integrated thermal structures" (i.e., airframe structures, such as integral cryogenic tanks, intertanks, wings/fins, thrust structures, fairings, control surfaces and leading edges that have the atmospheric entry thermal protection system closely integrated with the structure). Proposals for innovative research in design and mechanics, and in materials technologies addressing these airframe systems, are solicited. Proposals of specific interest in this subtopic include one or more of the following items:

Design and Mechanics

- Specialized modeling, analysis, and design tools for integrated aerothermal, thermal, thermal-structural responses. Innovative measurement and test methods for design validation. Application of methodology to hot aerosurfaces, and to integrated thermal-structural concepts for tanks is of special interest.
- Novel methods for prediction and testing of material and structural durability and damage tolerance, with emphasis on environmental degradation, combined thermal-mechanical loads, and operation beyond nominal design conditions; and related methods to repair damaged structures.

Materials Technologies

- Significant advances in critical properties for high-temperature materials such as nickel, iron, and titanium alloys, intermetallics, refractory metals, MMC's, and CMC's along with their related processing into useful product forms for fabrication into the airframe systems of interest.
- Materials technologies focused on advanced, high-temperature materials compatible with cryogenic and gaseous hydrogen and oxygen, and high-temperature products of combustions such as water vapor.

A4.05 Propulsion Test Technologies
Lead Center: SSC
Participating Center(s): MSFC

The goal of this subtopic is to identify and develop new technologies that can significantly increase the capabilities for improved rocket engine ground testing and safety assurance while reducing costs. Specific areas of interest include the following:

- New, innovative non-intrusive sensors for measuring flow rate, temperature, pressure, rocket plume constituents, and detection of effluent gas. Sensors must not physically intrude at all into the measurement space. 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) and high flow rate conditions (2000 lb/sec, 300 ft/sec) for LH_2. Pressure sensors must have a range of up to 15,000 psi. Rocket plume sensors must determine gas species, temperature, and velocity for H_2 , O_2 , hydrocarbons (kerosene), and hybrid fuels.
- On-line (real-time) sampling and analysis of high-pressure, high flow rate liquid oxygen-nitrogen mixtures. There is a significant need for real-time, totally non-intrusive instrumentation for high-pressure, high flow rate liquid oxygen (LOX) systems, having the capability to detect the presence of other chemical species present in the LOX, which may have been introduced through the pressurization process. An example would be the detection of N_2 in a LOX flow, where N_2 is used to pressurize the LOX delivery system. The technology should be expandable to include other rocket engine propellants.
- On-line particulate contamination sampling for facility propellant (LOX and LH_2) and gas systems (He, H_2 , O_2 , and N_2). A requirement exists for instrumentation that can detect, in real time,

the presence of contaminants in the 30 micron to 100 micron range as these propellants and gases flow through facility piping. Sub millisecond response time and ability to withstand cryogenic temperatures (down to 34R) and high pressures (up to 15,000 psi) are required features.

- Miniature front-end electronics to support embedding of intelligent functions on sensors. Requirements include computational power comparable to a 200 MHz PC with 32 MB of RAM or similar nonvolatile storage, analog I/O (at least two of each, with programmable amplification, anti-aliasing filters, and automatic calibration), digital I/O (at least eight), communication port for Ethernet bus protocol (one high speed and one low speed), support for C programming (or other high-level language), and development kit for PC. Physical size should not occupy a volume larger than 4" x 4" x 2".
- Modeling of the high temperature rocket engine plume radiance and transmittance. Modification of MODTRAN code to include HITEMP database and to include radiance emanating from the engine and the test stand structural materials at high temperatures. Modeling of the engine plume water vapor condensation clouds hovering over and near the test stands. All these effects are required in order to predict radiance effects of the rocket engine testing accurately.
- Methods and instrumentation for rocket plume spectral signature measurements. There are requirements to develop enhanced capabilities in the area of rocket exhaust plume spectral signature measurements. Emphasis is on developing data acquisition, analysis, display software, and systems to support infrared spectrometers, imaging systems, and filter radiometer systems. Overall system concepts should include instrument system calibration methodologies and data uncertainty analysis.
- Materials and components for high-pressure (up to 6000 psi), high-purity (90%+) hydrogen peroxide service. Materials, including seals, valve materials, and coatings that can withstand long-term hydrogen peroxide contact are required. Components for hydrogen peroxide service, including isolation valves, ball valves, and relief valves, which are designed for minimum number of sumps and seals, and clean flush-through, are required.
- Measurements and data are the product of ground testing. High accuracy, precision, uncertainty bands, and error bands are important elements of the data which is generated, and this must be quantified. Techniques and models to determine these parameters for active test facilities are required.

A4.06 Launch Vehicle Subsystems Technology
Lead Center: MSFC

Next generation launch technologies will require high overall vehicle payload mass to lift-off mass ratios, propulsion systems which deliver higher thrust to engine weight ratios, increased trajectory-averaged specific impulse, reliable overall vehicle systems performance, and extended reusability in order to achieve cost and crew safety goals. This subtopic emphasizes innovative propulsion subsystem and component technologies as well as design and analysis tools to support assessment of the technical viability of proposed next generation propulsion subsystems and components. Technologies, design, and analysis tools proposed under this subtopic should address technical issues related to engine and main propulsion system design and integration, turbomachinery, combustion devices, valves, actuators, ducts, lines, solid propellant and hybrid grain design, and overall propulsion systems integration. Specific areas of interest for technology advancement and innovations include the following:

- Innovative technologies, design and analysis tools applicable to assessment of credible physics associated with reusable launch vehicle turbomachinery, combustion devices, and overall engine systems concepts. Design and analysis tools that provide improved understanding and quantification of component, subsystem, and system operating environments are of particular interest.
- Development of fluid/structural interaction simulation tool for assessment of (1) Transient loads in nonlinear valve/actuator hardware, (2) Cracking in engine ducts and flow liners, (3) Dynamic loads on component sensors, (4) Cavitation in engine components, (5) Sloshing in fuel tanks, and others. Complex fluid/structure interaction problems generally entail turbulent flows, complex geometries and/or transient conditions, and disregarding fluid/structure interaction may result in performance degradation or failure. Therefore, the overall objective is to develop a simulation ap-

proach to solve such problems with reduced computational time and improved capability. Related objectives include (a) effective finite element analysis for truly multidisciplinary response analysis of engine and vehicle components; (b) innovative use of high-performance computers, including parallel processing, for integrated systems analysis and multidisciplinary structural response analysis; (c) innovative applications of high-performance computer graphics for visualizing computer models and results; and (d) validation of multidisciplinary structural response modeling with test data, such as engine test fire and vibration data.

- Innovative propulsion system and component preliminary design tools that support the design, analysis, and integration of propulsion subsystems. These tools should significantly enhance the overall systems engineering evaluation of potential reusable launch vehicle concepts such as tools for component/parameter sensitivity analysis, quantification of system benefits to changes, the operability of the overall propulsion system concept, bottoms-up weight estimating, cost estimating, and reliability prediction of propulsion systems.
- Innovative turbomachinery and combustion devices concepts that address fundamental issues such as bearing and turbine blade life, combustion chamber cooling, injector design, sealing, increased thrust to weight ratio, and design features that facilitate manufacturing.
- Manufacturing techniques that will allow for significant reduction in the cost and schedule required to fabricate engine and main propulsion system components for candidate RLV concepts.
- Innovative analysis techniques to assess propellant management systems, feed lines, tank pressurization, fill, drain, and vent requirements.
- Innovative concepts for solid or hybrid rockets that increase mass fraction and decrease the need for thermal insulation and reduce or eliminate the need for staging. Concepts that drastically reduce the required launch complex preparation with the goal of providing a cost-effective launch-on-demand system for spacecraft.
- Innovative approaches using current or emerging processes and manufacturing technologies to design and develop valves, actuators, ducts, lines, flanges, seals, gimbal joints, bellows, and ancillary components that will reduce complexity and increase reliability, and are easier to assemble, install and test when integrated onto the vehicle.
- Integrated Computer aided design, solid-model, structural, dynamic, and thermal & fluid-flow analysis methods for multidisciplinary analysis and optimization of components and subsystems.
- Innovative materials and coatings for more robust valve designs, leading to increased life and extended durability and wear properties.
- Innovative manufacturing and testing techniques that will allow for significant reduction in the cost and schedule required to perform subsystem and component development.
- Utilization of advanced materials to reduce weight and tailor properties such as stiffness for valves, actuators, gimbal joints, ducts and lines.
- Innovative valve seal designs contributing to increased life, reliability, wear, material compatibility and decreased leak rates, friction and cost.
- Valve health monitoring systems and sensor technology which can record, store, and download performance data for monitoring, predicting and trending key parameters such as leak rate, torque, cycles, etc., from ground checkout through flight.
- New and innovative analysis tools or techniques for determining pressure drops and flowrates throughout a gelled propellant feed system. Tools or techniques that can be incorporated into existing analysis or design tools are of particular interest.
- New and innovative designs for pumping gelled propellants to high pressures (>1000 psi). Emphasis is placed on designs that can be adapted for in-space applications.

TOPIC A5 Computing, Information and Communications Technology

NASA's Computing, Information and Communications Technology (CICT) Program will enable scientific research, space exploration, and aerospace technology research greater success at less cost and with increased return through development and use of advanced computing, information and communications technologies. Goal-Directed Systems: smarter more adaptive systems and tools that work collaboratively with humans in a goal-directed manner to achieve NASA's twenty-first century mission/science goals, including: robotic exploration; human-robotic exploration; safe, cost-effective operation of all launch vehicles; Earth-orbiting satellites monitoring relationships associated with planetary phenomena; and development of methodologies to enhance the capacity, safety and security of our National Airspace System (NAS). Seamless Access to NASA Information Technology Resources: seamless access to ground-, air-, and space-based distributed hardware, software, and information resources allow scientists and engineers to focus on make new discoveries in science, design next generation space vehicles, control missions or develop new concepts for the NAS. High Rate Data Delivery: broad, continuous presence and coverage for high rate data delivery from ground, air, and space-based assets directly to the users enabling NASA's twenty-first century missions, including: distributed network of observing spacecraft to provide real-time multi-sensor information directly to users; multi-gigabit Internet-based communications in near-Earth orbit; high rate communications from spacecraft traveling to our outer planets including intra-planetary networks for surface exploration; and development of the NAS Communication, Navigation and Surveillance Architecture to meet 2015 air travel demands. Strategic Research: research, develop, and evaluate a broad portfolio of fundamental information and bio/nanotechnologies for infusion into future NASA missions.

A5.01 Human-Automation Interaction in Aerospace Systems
Lead Center: ARC

Aerospace systems rely increasingly on supervisory monitoring and control of automated systems supporting individual and distributed decision making. Innovative proposals that are relevant to NASA aviation and space missions are sought in the following areas:

- Formal methods of analyzing flight deck and ground control human-automation interaction design
- Large-scale simulation of human-in-the-loop decision-making in the National Airspace System
- Individual and team performance modeling, visualization and prediction for design and operations
- Model-based intelligent tutoring approaches to human-automation interaction
- Data mining and visualization tools that extract causal human factors underlying aerospace mishaps from large amounts of text or quantitative data
- Human-system interaction supporting collaboration among humans as well as between humans and synthetic agents.

A5.02 Nanotechnology
Lead Center: ARC
Participating Center(s): GRC, JPL, JSC, LaRC

Nanotechnology is the science of creating functional materials, devices and systems through control of matter on the nanometer (atomic) scale and the exploitation of novel phenomena and properties (physical, chemical and biological) at that length scale. Control of organization at the atomic level provides the opportunity to create function-specific materials at the micro and macro scales. Nanotechnology is not simply another step toward top-down, miniaturization; it represents a fundamental change in approach that exploits new behaviors dominated by quantum mechanics, material confinement, and large interfaces.

Nanotechnology is expected to have a profound impact on all NASA Enterprises by enabling revolutionary, lighter, smaller spacecraft; powerful, small, low-power consuming computers; radiation-hardened electronics; nanoelectronics; nanosensors and instruments, high-power density fuel cell, biosensors for astrobiology and astronaut health monitoring; biomedical sensors and in-vivo medical devices; novel nanoelectromechanical systems (NEMS); and advanced materials for aerospace vehicles and space launch vehicle structures.

NASA's missions for Space Science, Earth Science and Aerospace Technology development have pushed the state of the art for extraordinary computational speed and memory capacity for at least two decades. The Space Science mission has the added requirement for computing devices that must have low power consumption, unparalleled reliability, and resistance to harsh radiation environments.

Nanotechnology provides radical new approaches to size reduction and speed improvements through materials manipulation at the atomic scale. Possible candidates arising from potential advances in nanoelectronics include molecular computing (e.g., carbon nanotube, nanowire and molecular electronics-based electronics), and artificial quantum-structure systems. These concepts can be realized through the concurrent development and fabrication of the underlying nanoelectronic building blocks (e.g., gates, interconnects), new system architectures and associated algorithms.

Specific interests for the 2003 solicitation include technology developments directed toward the above applications, including:

- Exploiting the extraordinary mechanical, electrical, magnetic, optical, and chemical properties of nanostructures including nanotubes (e.g., carbon, silicon carbide, boron nitride), and nanowires.
- Controlled growth, characterization, dispersion and functionalization of nanostructures (e.g., nanotube and nanowire) for electronics, computing and sensing applications.
- Application of molecular and nanoelectronics devices for chemical, gas, and biosensors.
- Atomic chain electronics and sensors.
- Nanophotonics, including nanowire lasers.
- Fabrication processes (including biomolecular processes) for depositing metals for electrical or other surface properties.
- Design, development, fabrication and low-cost manufacturing processes of nanoelectronic components, connectors, switches and wires.
- Development of fault-tolerant, radiation resistant nanoelectronic and computing devices.
- Fuel cell, batteries, and thermoelectric converters
- Applications of nanomaterials for life support (including gas and water purification) and extravehicular activity.
- Thermal Management nanomaterials (heat rejection, heat management and thermal protection). Interface and packaging technologies which enable nanocomponent and nanosystem development for integration into macro-scale structures and instruments.
- Integration of nanodevices including sensors, communications and processing systems.
- Integration of nanoelectronic components with conventional electronic devices (e.g., CMOS).
- Modeling of nanoelectronic devices and hybrid nanoelectronic-microelectronic technologies.

TOPIC A6 Engineering for Complex Systems

The Engineering for Complex Systems program is part of the Engineering Innovation objective of NASA's Aerospace Enterprise Pioneer Revolutionary Technology goal: To demonstrate advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications. The ECS program, in particular, focuses on the representation, reasoning, and mitigation of risk. Achieving this vision will require infusing new risk mitigation technologies and processes into our standard engineering practices throughout the program lifecycle. The Engineering for Complex Systems program is designed specifically to achieve the following goals: 1) Significantly advance the scientific and engineering understanding of system complexities and failures, including human and organization risk characteristics; and 2) Develop processes, tools, and organizational methods to quantify, track, visualize, and trade-off system designs and/or mission options with an emphasis on risk management throughout the lifecycle of the programs.

A6.01 Modeling and Simulation of Aerospace Vehicles in a Flight Test Environment
Lead Center: DFRC

Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design tools. The goal of this subtopic is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influence of aerodynamics and the control system, in addition to pilot commands. The benefit of this effort will ultimately be increased flight safety (particularly during flight tests), more efficient aerospace vehicles, and an increased understanding of the complex interactions between the vehicle subsystems. This subtopic solicits proposals for novel, multidisciplinary, linear or nonlinear, dynamic systems simulation techniques. Proposals should address one or more of the objectives listed below:

- Prediction of steady and unsteady pressure and thermal load distributions on the aerospace surfaces, or similar distributions due to propulsive forces, by employing accurate finite element CFD techniques.
- Effective finite element numerical algorithms for multidisciplinary systems response analysis with adaptive three-dimensional grid/mesh generation at selected time steps.
- Effective use of high-performance computing machines, including parallel processors, for integrated systems analysis or pilot-in-the-loop simulators.
- Innovative applications of high-performance computer graphics or virtual reality systems for visualizing the computer model or results.
- Correlation of predictive analyses with test data or model update schemes based on measured information.

A6.02 Flight Sensors, Sensor Arrays and Airborne Instruments for Flight Research
Lead Center: DFRC

Real-time measurement techniques are needed to acquire aerodynamic, structural 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 subtopic solicits proposals for improving airborne sensors and sensor-instrumentation systems in subsonic, supersonic and hypersonic flight regimes. These sensors and systems are required to have fast response, low volume, minimal intrusion and high accuracy and reliability, and include wireless technology. Innovative concepts are solicited in the following areas:

Vehicle Environmental Monitoring

- Nonintrusive air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach number, air density, flow angle, and humidity at air temperatures as low as -20 deg. F).
- Off-surface flow field measurement and/or visualization (laminar, vortical, and separated flow, turbulence) zero to 50 meters from the aircraft.
- Boundary layer flow field, surface pressure distribution, acoustics or skin friction measurements or visualization.
- Any of the above measurements in hypersonic flow.

Vehicle Condition Monitoring

- Optical arrays for robust flight control surface position and velocity measurement.
- Sensor arrays for structural load monitoring.
- Robust arrays for engine monitoring and control applications.

Advanced Instrumentation for Aeropropulsion Flight Tests

- Thin film and fiber optic sensors, especially those compatible with advanced propulsion system materials such as ceramics and composites, and capable of withstanding the high temperatures and pressures associated with turbomachinery.
- Onboard processing for data condensation, failed sensor identification or other valuable onboard processing capability.

Vehicle Far Field Environmental Monitoring

- Nonintrusive measurements at range of 2-5 kilometers of environmental data (natural and induced flowfields, turbulence, weather, traffic).
- Onboard processing of sensed and telemetered data for integrated storage and strategic presentation to the flight crew.

A6.03 Knowledge Engineering for Safe Systems in Lifecycle Engineering
Lead Center: ARC

The Knowledge Engineering for Safe Systems area represents a synergy of human organizational modeling and simulation capabilities with knowledge management approaches that address explicitly issues of mission risk and safety in lifecycle engineering. Innovative proposals that are relevant to NASA missions are sought in the following areas:

- Computational organization models of risk management throughout the lifecycle of design, manufacture, operations, and maintenance
- Model-based simulation of the interactions between organizational decision making and hardware and software systems design and engineering that predict issues related to risk and resiliency
- Computational models of human and team performance that include fatigue, stress, workload, and risk-based decision making in a dynamic environment
- Ontologies and architectures for advanced product data management systems that explicitly incorporate the notions of risk, resiliency, and decision-making rationale
- Integration and interoperability of knowledge management, knowledge capture, and design rationale management capabilities into a heterogeneous distributed computing environment
- Immersive virtual environments and geospatial navigation approaches for user exploration of engineering facility and vehicle data

TOPIC A7 Enabling Concepts and Technologies

The ECT Program explores revolutionary concepts for aerospace systems, and performs fundamental research and development of high-payoff technologies to enable the strategic visions of the NASA Enterprises. Program objectives are to identify, develop, and transfer breakthrough technologies that have broad potential across many types of systems to provide increased scientific return at lower cost, and to enable missions and capabilities beyond current horizons. Current projects within the ECT Program are: 1) The Advanced Systems Concepts Project; 2) The Energetics Project; 3) The Advanced Measurement and Detection Project; 4) The Revolutionary Spacecraft Systems Project; and 5) The Large Space Systems Project. Information on the ECT Program can be found at https://erasmus.hq.nasa.gov. New technologies are sought that will enable the future development of Integrated Flight Vehicle System/Airspace Concepts. These integrated concepts will address both vehicle capability and airspace capability issues, and where appropriate, performance, cost, environment and safety/security issues. Flight vehicles or platforms considered here include both Earth and other planetary applications. Research is also sought which supports the future development of autonomic, self-managing vehicle configurations (e.g., self-configuration, self-optimization, self-healing and self-protection). Research activities may involve traditional disciplines, emerging technology areas, such as artificial intelligence, biomimetics and nanotechnologies, or multidisciplinary, synergistic topics.

A7.01 Smart, Adaptive Aerospace Vehicles With Intelligence
Lead Center: LaRC
Participating Center(s): ARC, GSFC

This subtopic emphasizes the roles of aerodynamics, aerothermodynamics, hypersonic airbreathing propulsion, adaptive software, vehicle dynamics in nonlinear flight regimes, and advanced instrumentation in research directed towards the identification, development and validation of enabling technologies that support the design of future, autonomous aerospace vehicle and platform concepts for both Earth and other planetary atmospheric flight applications. Some of the vehicle attributes envisioned by this subtopic include: a) "Smart" vehicle attributes - using advanced sensor technologies, flight vehicle systems are "highly aware" of onboard health and performance parameters, as well as the external flow field and potential threat environments; b) "Adaptive" vehicle attributes - flight avionics systems are reconfigurable, structural elements are self-repairing, flight control surfaces and/or effectors respond to changing flight parameters and/or vehicle system performance degradation; and c) "Intelligent" vehicle attributes - vehicle onboard processing and artificial intelligence technologies, interfaced with advanced vehicle structural component and subcomponent designs and appropriate actuating devices, reacts rapidly and effectively to changing performance demands and/or external threat environments. Future air vehicles with the above attributes will manage complexity, "know" themselves, continuously tune themselves, adapt to unpredictable conditions, prevent and recover from failures, and provide a safe environment.

For Earth atmospheric vehicles and platforms, both military and civil applications are sought, while for other planetary applications, emphasis is placed on configurations that enable the discovery of new science information. Concepts and corresponding enabling technologies are sought which expand the traditional boundaries of conventional piloted vehicles categories such as General Aviation (GA) or Personal Air Vehicles (PAV), as well as significantly advance the State-of-the-Art in remotely operated vehicle classes such as Long-Endurance Sensing Platforms (LESP), Unmanned Aerial Vehicles (UAV) or Unmanned Combat Aerial Vehicles (UCAV). Furthermore, for Earth applications, special emphasis is placed on research proposals that attempt to provide solutions for a future state in which revolutionary vehicles operate in a highly integrated airspace including hub & spoke, point-to-point, long-haul, unmanned aircraft, green aircraft, as well as a future state where air vehicle designs reflect a high level of integration in performance, safety/security, environmental impact and cost factors.

Specific areas of interest are:

- Conceptual flight vehicle/platform designs featuring variable levels of vehicle and airspace requirements integration, and/or smart, intelligent, and adaptive flight vehicle capabilities, as demonstrated by state-of-the-art systems analyses methods to determine enabling technologies and resulting impacts on future system integrated performance, environmental impact, and safety/security issues.
- New algorithms for predicting vehicle loads and response using minimal vehicle state information.
- Novel optimization methodologies to support conceptual design studies for highly integrated flight vehicle/air space concepts and/or smart, intelligent and adaptive flight vehicle capabilities, which demonstrate appropriate design variable selection, scaling techniques, suitable cost functions and improved computational efficiency.
- Physics-based modeling and simulation tools of multiple vehicle classes and corresponding airspace operations aspects to support scenario-based planning and requirements definition of highly integrated vehicle/airspace concepts, including investigations of the potential use of virtual/immersive simulations on future engineering decision making processes.
- Micro-scale wireless communications, health monitoring, energy harvesting and power-distribution technologies for large arrays of vehicle-embedded MEMS sensors and actuators.
- Miniaturized, robust sensor and/or diagnostic hardware for hypersonic vehicle applications, including in-stream, wall or nozzle flow measurements, suitable for subscale models in hypersonic wind tunnels and on subscale/full-size hypervelocity flight vehicles. Parameters of interest include temperature time histories ($70 < T < 3000$ deg. F), heat flux, pressures, forces and moments ($1 < q < 1500$ psf), skin-friction, species composition, velocity components and turbulent flow quantities.
- Test case management including requirements/test case traceability, test case generation, software risk assessment methods including reliability growth model or failure mode analysis, and model-based reasoning over early life-cycle artifacts including Unified Modeling Language (UML), lightweight formal methods, and traceability analysis.
- Static analysis, model checking, and runtime verification of adaptive systems.
- Learning algorithms to determine how effective the learner is given environment changes. Relevant technologies include convergence studies, novelty detection, and temporal data mining.

- Guidance and control for fail-safe adaptivity under adverse and upset conditions, including integrated flight/structural/propulsion control, and/or for highly nonlinear and/or distributed systems. Relevant technologies and methods include detection, identification, and prediction of adverse and upset conditions, flight critical computer systems technologies that provide fail-safe operation, and analytical, simulation-based, and experimental validation methods for adaptive flight systems technologies.

A7.02 Revolutionary Flight Concepts
Lead Center: DFRC

This subtopic 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 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 require a demonstration in the actual flight environment to fully characterize or validate.

The scope of this subtopic is broad and includes advanced flight experiments that accelerate the understanding and development of advanced technologies and unconventional operational concepts. Examples extend to (but are not limited to) such things as inflatable aerostructures (new designs or innovative applications, new manufacturing methods, new materials, new in-flight inflation methods, new methods for analysis of inflation dynamics), innovative control surface effectors (micro surfaces, embedded boundary layer control effectors, microactuators), innovative engine designs for UAV aircraft, innovative approaches to structures, stability, control, and aerodynamics integration schemes, and 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 testing a concept or technology as a necessary means of verifying or proving its worth. The benefit of this effort will ultimately be more efficient aerospace vehicles, increased flight safety (particularly during flight tests), and an increased understanding of the complex interactions between the vehicle or technology concept and the flight environment.

A7.03 Advanced Flight Platforms for Planetary Sciences
Lead Center: LaRC

This subtopic will focus on advanced atmospheric flight system technologies and the integration of these technologies into complete flight platforms to enable future science missions at Earth and other planets. The emphasis of this subtopic is on vehicle systems (rather than vehicle aerodynamics and aeroheating covered under A7.01) and the conception and development of new flight platforms to meet the needs of emerging planetary science objectives.

Advanced flight platforms
- Innovative vehicle configurations (geometry, materials, instrument integration, deployable components)
- Power management and energy storage (solar power, high-energy batteries, compact fuel cells)
- Precision orientation control systems (accurate positioning and feedback of vehicle's spatial attitude)
- Technologies and systems to enable long-duration flight
- Propulsion systems (electric propulsion, advanced motor technologies)
- Robust vehicle systems (high reliability and high resiliency)
- System integration and performance (prototyping, testing, flight demonstration)

Advanced science instruments and sensors (ground sensing, atmospheric analysis, astrophysics)
- Small, low-mass instrument technologies (miniaturized multi-purpose sensors)
- Data storage and transmission

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9.1.2 BIOLOGICAL AND PHYSICAL RESEARCH

NASA's Biological and Physical Research Enterprise conducts basic and applied research to support human exploration of space and to take advantage of the space environment as a laboratory. It creates unique cross-disciplinary research programs, bringing the basic sciences of physics, biology, and chemistry together with a wide range of engineering disciplines. This Enterprise asks questions that are basic to our future: How can human existence expand beyond the home planet to achieve maximum benefits from space? How do fundamental laws of nature shape the evolution of life?

http://SpaceResearch.nasa.gov

TOPIC B1 Cross-Disciplinary Physical Sciences

There are two strategic missions important to the Physical Sciences in the Biological and Physical Sciences Enterprise. The first mission is to understand and protect our home planet. The goal is to create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry and academia. The second mission is to explore the universe and search for life. The goal is to explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space. Research proposals are sought that are mission supportive and take advantage of this environment to conduct experiments in the biological and physical sciences that are impossible on Earth. BPR also seeks to engage the industrial sector in exploiting the economic benefits of the cross-disciplinary physical sciences. Cross-disciplinary research and enabling technology is sought to understand the effects of gravity on the physical sciences as well as in the area of vibration isolation/measurement technology.

B1.01 Exploiting Gravitational Effects for Combustion, Fluids, Synthesis, and Vibration Technology
Lead Center: GRC
Participating Center(s): MSFC

The objective of this subtopic is introduce new technology in the form of devices, models, and/or instruments of use in microgravity and/or for commercial applications on Earth. (For Biofluids, please see subtopic B1.03 Bioscience and Engineering.) Innovations are sought in the following areas:

- Understanding the effects of microgravity on fluid behaviors.
- Utilizing the mechanics of granular materials to determine how the reduced gravity environment affects transport and mixing of granular solids, with application to in situ resource utilization (ISRU) and more efficient terrestrial processes.
- Pool and flow boiling systems or subsystems that enable safe, efficient, and reliable heat transfer technologies for thermal control systems application in space.
- Multiphase flow and fluid management to provide designers key information on controlling the location and dynamics of liquid-vapor interfaces in microgravity. This is needed for safe and reliable fluid handling and transport in microgravity.
- Understanding the effects of microgravity on combustion behaviors.
- Measuring the residual accelerations on spacecraft or in ground-based low-gravity facilities. Emphasis is placed on MEMS or nanoscale devices.
- Improving in-space system performance that relies on fluid or combustion phenomena, principally spacecraft fire safety, especially fire prevention, smoke, precursor, and fire detection, fire suppression.
- Pollution reduction and improvement of the efficiency of liquid-fueled combustors.
- Characterization of ignitability, flame spread and spacecraft material selection.
- Micropumps and microvalves; individual as well as simultaneous diagnostics for determining fluid movement through microscale devices for the aforementioned applications; and identifying specific chemical or biological elements of interest.
- Micropower through microcombustion.
- Microfluidics for fuel cells and other power systems.

B1.02 Gravitational Effects on Biotechnology and Materials Sciences
Lead Center: MSFC

NASA has interest in experiments that utilize the influence of microgravity on biotechnology processes and materials science to understand physical, chemical, and biological processes. Areas of interest include protein crystal growth and structural analysis techniques, separation science and technology, biomaterials, polymeric materials, advanced electronic and photonic materials, as well as metals and alloys, and glass and ceramic materials technology. Other areas of interest relate to microgravity processing approaches such as containerless processing and advanced thermal processing techniques. NASA is interested in processes and methods that can utilize the Space Station Glove Box. Methods for conducting science and technology research required to enable humans to safely and effectively live and work in space are needed. Innovative studies are sought in the following research areas and in their enabling technologies including commercial applications on Earth:

Biotechnology

- Advancement of the analysis of biological crystals. This may include crystallization robotics, diffraction data collection, and the study of crystalline defects.
- Technology designed to improve our understanding of the effect of gravity on expression of biological macromolecules.
- Research and development of techniques in the field of separations of biological material designed to improve our understanding of the effect of gravity on separation efficiency.
- Technologies to determine the relationships between material substrates, tissue and cell culture conditions, and subsequent cell protein expression and differentiation.
- Development of high-throughput technologies for the determination of gene and protein expression.
- Biotechnology and instrumentation to help enable safe human exploration beyond Earth orbit for extended periods.

Materials Science

- Novel concepts and materials for efficient radiation shielding during human exploration of space. The materials must be capable of attenuating galactic cosmic rays, solar particles, and secondary particles to acceptable limits.
- Technology and instrumentation leading to high-leverage (useful product to Earth-bound weight) materials processes for the utilization in situ of space resources, both materials and energy for application to the establishment of safe self-sustaining, self-sufficient systems to enable science and a permanent human presence in space and on planetary surfaces.
- Development of techniques and processes that permit in-space fabrication of critical path components of future major projects.
- New development utilizing particles in the nanometer range size, having novel properties with applications to high-strength, low-mass materials, advanced electronics, or radiation shielding.
- Innovations in polymers, composites, and other materials that incorporate sensory and self-repair technologies.
- Development of materials for improved sensor technology, leading to the potential for miniaturization and high performance in hostile environments.
- Development of photonics materials of relevance to NASA's mission, including anticipated needs in future space travel that will rely increasingly on automation, minimize power consumption, and accommodate increases in complexity within the limited vehicle habitat volume and mass. Photonics devices of interest include those inherently less susceptible than electronics to electromagnetic pulse (EMP) exposure and those having unique capabilities with regard to parallel data processing. Nonlinear optics, in particular, can play a pivotal role in space communications, remote sensing, engine performance characterization, synthetic vision, rendezvous and docking, laser propulsion, biophotonics, solar cell development, autonomous robotic manipulation, and rover exploration.
- Advancement of the state of the art for the levitation and containerless processing of molten liquid materials including the development of techniques for uniform heating and maintenance of uniform temperature; precise position control of levitated samples, particularly in a gaseous environment; measurement and control, as well as reduction or elimination, of sample rotation in featureless samples; measurement of the emissivity of pure metals, alloys, oxides and ceramics; and measurement of the materials work function over a range of temperatures.
- Development of materials processing furnace technology that can operate with the limited resources of the Space Station Glovebox to support experiments of particular interest to NASA.
- Microgravity furnace and experiment instrumentation technologies to better monitor sample health (temperature, pressure, etc.) and experiment status, while minimizing the instrumentation's effect on the sample as well as reducing system impacts on experiment design; additionally, consideration should be given to extending the useful life of instrumentation in order to minimize the need for on-orbit recalibration and refurbishment/replacement.

- Microgravity furnace and experiment thermal technology such as improved insulation for minimizing power, volume, mass and complexity; improved high temperature thermal interface materials for transferring the heat into and out of the sample and furnace components (which move or be stationary relative to each other); heating and cooling approaches that enhance safety, science and resource utilization.
- Advanced sample containment technologies and forms for providing safe, efficient sample containment while enhancing scientific return and minimizing systems impacts on furnace and experiment system design.

B1.03 Bioscience and Engineering
Lead Center: GRC
Participating Center(s): ARC, MSFC

NASA recognizes the critical role that fluid mechanics and transport processes, along with their supporting technologies, play in many biological and physiological events. A wide variety of fundamental problems in the categories of physiological systems, cellular systems, and biotechnology may be addressed. The objective of this research is to deliver new technology in the form of devices, models, and/or instruments of use in microgravity and/or for commercial application on Earth in the following areas:

Micro-Optical Technology for Interdisciplinary & Biological Research
Micro- and nano-optical technologies are sought for the measurement and manipulation of Space Station and long-duration mission experiments, and for monitoring and managing astronaut health and the health of structures and systems affecting astronauts' environments. Areas of innovative technology development include:

- Diagnostic methods to assess the performance of labs-on-a-chip, including detecting the presence of bubbles and particles and removing or characterizing them.
- Measurements for fluids including spatially and temporally resolved chemical composition and physical state variables.
- Optically-based biomimetics for self-aware, self-reconfiguring measurement systems.
- Measurement and micro-control technologies for health monitoring and health management of experiments, astronauts, and astronauts' environments.
- Wireless communication for the transmission and detection of sensor data, Wireless power delivery for sensors and health systems.
- Optical quantum technologies for measurement systems including signal detection and transmission.
- Technologies enabling optically-based mobile sensor platforms for detection and maintenance, using optical sensing, control, power, and/or communication.

Biological Fluid Mechanics (Biofluids)
Biofluids, an intersection of fluid physics and biology, is a new area of emphasis within NASA's Office of Biological and Physical Research. Fluid mechanics and transport processes play a critical role in many biological and physiological systems and processes. An adequate understanding of the underlying fluid physics and transport phenomena can provide new insight and techniques for analyzing and designing systems that are critical to NASA's mission. The microgravity environment modifies vascular fluid distribution on a short time scale, due to the loss of hydrostatic pressure, and on a longer time scale, due to the shift of intercellular flows. This fluid shift could modify transport processes throughout the body. For example, modification of flow and resulting stresses within blood vessels could modify vascular endothelial cell structure and permeability, which may be detrimental in long-term space flight. Furthermore, reintroduction of gravity causes large-scale fluid shifts in the body, which can influence cardiac output and induce faintness. Studies of macro- and micro-scale biofluid mechanics of the vascular system in the microgravity environment may be important to understanding these physiological events. Innovations sought include but are not limited to:

- Studies of biological fluid mechanics that seek answers to questions related to effect of long-term exposure to microgravity on human physiology.
- Understanding the role of fluid physics and transport phenomena in the "fluid shift" observed in the human body when exposed to prolonged microgravity.
- Understanding the role fluid physics plays in human physiological processes such as cardiovascular flows and its effect on arteriosclerosis, and pulmonary flows and asthma.
- Use of the above knowledge to develop effective countermeasures.

BioMicroFluidics
Many biotechnology applications need manipulation of fluids moving through micro channels. As a result, microfluidic devices are becoming increasingly useful for biological/biotechnological applications. Since capillary forces can have a significant effect on the flow at this scale, a strong similarity with microgravity flows exists. Innovations sought include but are not limited to:

- Understanding of fluid mechanics underlying the operations of microfluidic devices crucial to their successful operation and continued miniaturization.
- Tools for prediction, measurement, and control of fluid flow in microchannels and microchannel network.

Models of Cellular Behavior
The simplest living cell is so complex that models may never be able to provide a perfect simulation of its behavior, however, even imperfect models could provide information that could shake the very foundations of biology. We are now at the point where we can consider models of molecular, cellular and developmental biological systems that, when coupled to experiments, result in an increased understanding of biology. Quantitative models of cellular processes require. Innovations sought include but are not limited to:

- New methods for better handling of large numbers of coupled reactions, increases in computing power, and the ability to transition among different levels of resolution associated with quantitative models of cellular processes.
- Development of models to form the basis of tools to aid in optimization of existing biological systems and design of new ones, enabling engineers to evolve biological systems by rounds of variation and selection for any function they choose.

Functional Imagery
Research on orbit has demonstrated that the microgravity environment affects the skeletal, cardiovascular and immune systems of the body. Few of the investigations to date examined functional changes due to microgravity at either the cellular or molecular scale. NASA therefore seeks innovations that would lead to an enhanced capability to image functioning biological systems at either length scale. All proposals should recognize the power, volume and mass constraints of orbital facilities. Examples of possible innovations include but are not limited to:

- Development of novel fluorophores that tag proteins mediating cellular function, particularly those that can be excited using solid-state lasers.
- Systems that can simultaneously image multiple fluorophores following different processes at standard video frame rates.
- Devices that enable three-dimensional imagery of the sample.
- Imaging hardware that can follow a metabolic process in a turbulent system.
- Compact tunneling or evanescent wave microscopes capable of scanning quickly enough to follow metabolic processes.

Understanding Living Systems Through Microgravity Fluid Physics
Developing strategies for long-duration space flight requires an understanding of the effects of the microgravity environment on biological processes. Interdisciplinary fundamental and applied research is required in biology, physiology, and microbiology to human, plant and microbial systems from the standpoint of physics. Of particular interest are studies that develop theoretical, numerical and/or experimental under-

standing of the effects of acceleration, radiation and other factors in microgravity environments on these systems. Exploring the effects of Martian and lunar gravity and the quasi-steady, oscillatory and transient accelerations that are typical of a space laboratory are of great interest, as well as fundamental studies of acceleration sensitivity. The knowledge obtained should contribute to related agency activities, such as the disinfection of water systems, development of self-sustaining ecosystems, treatment of bacterial infection in space, and optimal growth of plants as a food source. Moreover, we expect that the knowledge and technologies derived will also provide ground-based economic and societal benefits. Major research disciplines include the heat, mass and fluid transport in: microbiology, plant and human physiology, hematology, drug delivery systems. Innovations are sought in the following areas:

- Delineation of the effects of acceleration and radiation at the macro- and microscale levels on processes such as bacterial growth, growth rates, resistance to antibiotics and disinfectants, interactions among microbes, microbial locomotion and interaction with the surrounding fluid or solid medium, transport through cell membranes, electro-osmotic flows, and cytoplasmic streaming, as well as quantification of metabolic processes and other phenomena that permit the examination of these problems.
- Mass, momentum and energy transport in plant development, e.g., transport of nutrients through porous substrates to plant roots.
- Effects of bulk fluid flows on biofilms and liposome formation.
- Transendothelial transport.
- Improved techniques for mixing and separation in microgravity.
- Micro- or nanoscale modeling of fluid flows and mass transfer for drug delivery systems.
- Development of flexible numerical models to complement experimental and theoretical studies, which may require adaptive mesh refinement, micro/macroscale modeling, and/or treatment of moving boundaries.

TOPIC B2 Fundamental Space Biology

The NASA mission to explore the universe and search for life includes the goal of exploring the principles of biology through research in the unique natural laboratory of space. It includes understanding how life responds to the space environment and the role of gravity in the processes of life. It also includes the understanding of the fundamental organizing principles of nature and how they give rise to structure and complexity, using the low-gravity environment in space. Fundamental space biology is NASA's Agency-wide program for the study of fundamental biological processes through space flight as well as ground-based research that supports the NASA mission. Proposals are sought for research that: (1) Effectively make use of microgravity and other characteristics of the space environment to enhance our understanding of fundamental biological processes; (2) Develops the scientific and technological foundations for a safe, productive human presence in space for extended periods and in preparation for exploration; (3) Applies this knowledge and technology to improve our Nation's competitiveness, education, and quality of life on Earth. Ground-based and flight research is conducted on a broad spectrum of biological topics, including cell and molecular biology, developmental biology, and how the space environment affects whole organisms and their interactions.

B2.01 Understanding and Utilizing Gravitational Effects on Plants and Animals
Lead Center: ARC
Participating Center(s): KSC

This subtopic area focuses on technologies that support the NASA Fundamental Biology Program in understanding the effects of gravity on plants and animals. The program supports investigations into the ways in which fundamental biological processes function in space, compared to their function on the ground. To conduct these investigations, the program supports both ground and space flight research. The improved understanding of the role of gravity on plants requires innovative support equipment for observing, measuring, and manipulating the responses of plants to environmental variables. Areas of innovative technology development include:

- Measuring the atmospheric and radiation environment and optimizing the lighting and nutrient delivery systems for plants.
- Storage, transportation, maintenance, and in situ analyses of seeds and growing plants.
- Sensors with low power requirements and low mass to monitor the atmosphere and water (nutrient) environment, as well as automated control and data logging systems for the experiment containers to measure performance indicators, such as respiration (whole plant, shoot, root), evapotranspiration, photosynthesis, and other variables in plants.
- Data analysis and control.
- Modular seeding and/or planting units to minimize labor.
- Sensors for atmospheric, liquid and solid analyses, including atmospheric and liquid contaminants such as ethylene and other biogenic compounds as well as analyses of hydroponic and solid media for N, P, K, Cu, Mg and micronutrients.
- Remote sensors to identify biological stress.
- Expert control systems for environmental chambers.

The improved understanding of the role of gravity on animals requires innovative instrumentation which tracks and analyzes from organism development, including gametogenesis through fertilization, embryonic development and maturation, through ecological system stability. Technologies may incorporate a variety of processes such as metabolism and metabolic control, through genetic expression and the control of development. Of particular interest are technologies that require minimal power and can non-invasively measure physical, chemical, metabolical and development parameters. Such measurements will ultimately be made in environments at one or more of several gravity ranges, e.g., "microgravity" (.01 to .000001 g), "planetary" gravity (1 g (Earth); 0.38 g (Mars) or 0.12 g (Moon)) or hypergravity (up to 2 g). But, refined and stable measurements are as important as gravity independence. Of interest are sustained instrument sensitivity, accuracy and stability, and reductions in the need for frequent measurement standardization. Parameters requiring measurement include pH, temperature, pressure, ionic strength, gas concentration (O_2, CO_2, CO, etc.), and solute concentration (e.g., Na+, K+, etc.). In the case of new techniques and instruments, a clear path toward miniaturization, reduction in power demands and increased space worthiness should be identified. Technologies applicable to plant, microorganism, and animal study applications include:

- Expert data management systems
- Capabilities for specimen storage, manipulation and dissection
- Video-image analysis for specimen (cell, animal, plant) health and maintenance
- Sensors for primary environmental parameters and microbial organisms
- Electrophysiology sensors, biotelemetry systems and biological monitors carried on spacecraft

B2.02 Biological Instrumentation
Lead Center: ARC
Participating Center(s): JPL

The Fundamental Biology Program (FB) is the Agency lead for biological research and biological instrumentation/technology development, and focuses on research designed to develop our understanding of the role of gravity in the evolution, development, and function of biological processes. Increasingly, the research thrusts are directed at incorporating the most advanced technologies from the fields of cell and molecular biology, genomics, and biotechnology, to provide researchers with the most up-to-date methods to conduct their biological research. For these requirements, the capability to perform autonomous, in situ acquisition, preparation and analysis of samples to determine the presence and composition of biological components is a highly desired objective. As the size of flight payloads becomes increasingly smaller, and information technologies permit smarter and more independent payload and device control and management, the realization of completely autonomous in situ biological laboratories (ISBL) on spacecraft platforms and planetary surfaces will become more desirable.

Biological and biomolecular/microbiological/genomic research is enabling unprecedented insight into the structure and function of cells, organisms, and sub-cellular components and elements, and a window into the inner workings and machinations of living things. Techniques and technologies which have evolved from the microelectronics and biological revolutions have permitted the emergence of a new class of instruments and devices. Many devices, techniques, and products are now available or emerging, which allow measurement, imaging, analysis, and interpretation of the biological composition at the molecular level, and which permit determination of DNA/RNA and other analytes of interest. Advances in information systems and technologies, and bioinformatics, provide the capability to understand, simulate, and interpret the large amounts of complex data being made available from these biological-physical hybrid systems. These synergistic relationships are facilitating the development of revolutionary technologies in many areas.

Biological instrumentation technologies to support Fundamental Biology objectives are grouped into the following solicited categories:

- Biological Sample Management and Handling - Technologies for remote, automated biosample and biospecimen collection, handling, preservation/fixation, and processing. Modular, embeddable systems and subsystems capable of supporting a variety of tissue, liquid, and/or cellular specimens, from a wide range of biological subjects, including cells, nematodes, plants, fish, avians, mice, rats, and humans.
- In situ Measurement and Control - Technology development for sensors, signal processors, biotelemetry systems, sample management and handling systems, and other instruments and platforms for real-time monitoring and characterization of biological and physiological phenomena.
- Genomics Technologies - Technologies to enhance and augment research in genomics, proteomics, cell and molecular biology, including molecular and nanotechnologies, cDNA arrays, gene array technologies, and cell culture and related habitat systems.
- Bio-Imaging Systems- Advanced, real-time capabilities for visualization, imaging, and optical characterization of biological systems. Technologies include multidimensional fluorescent microscopy, spectroscopy systems, and multi- and hyperspectral imaging.
- Biological Information Processing - Capability for automated acquisition, processing, analysis, communication, and archival and retrieval of biological data, and interface/transfer to advanced bioinformatics and biocomputation systems.
- Integrated Biological Research Systems and Subsystems - Integrated, experiment/subject specific biolaboratory modules and systems, providing complete flight prototype capability to support the above five categories.

B2.03 Understanding and Utilizing Gravitational Effects on Molecular Biology and for Medical Applications
Lead Center: JSC
Participating Center(s): ARC

Microgravity allows unique studies of the effects of gravitational effects on cell and tissue development and behavior. These studies utilize novel and advanced technologies to culture and nurture cells and tissues. Additionally, the ability to manipulate and/or exploit the form and function of living cells and tissues has significant potential to enhance the quality of life on Earth and in space through novel products and services, as well as through new science knowledge generated and communicated. This capability may lead to new products and services for medicine and biology. Current space research includes new methods for purification of living cells; development of space bioreactors for culture of fragile cells that have applications in biomedical and cancer research; tissue engineering systems which take advantage of microgravity to grow 3-D tissue constructs; testing the effectiveness of drugs and biomodulators on growth and physiology of normal and transformed cells, and methods for measuring specific cellular and systemic immune functions of persons under physiological stress. Biotechnology research systems also are being developed for micro-g research on the International Space Station. Specific areas of interest are:

- New methods for culturing mammalian cells in bioreactors, including advanced bioreactor designs and support systems, miniature sensors for measurement of pH, oxygen, carbon-dioxide, glucose, metabolites, and microprocessor controllers.
- Methods for separation and purification of living cells, proteins and biomaterials, especially those using electrokinetic or magnetic fields that obviate thermal convection and sedimentation, enhance phase partitioning, or use laser light and other force fields to manipulate target cells or biomaterials.
- Techniques or apparatus for macromolecular assembly of biological membranes, biopolymers, and molecular bioprocessing systems; biocompatible materials, devices, and sensors for implantable medical applications, including molecular diagnostics, in vivo physiological monitoring and microprocessor control of prosthetic devices.
- Methods and apparatus which allow microscopic imaging and biophysical measurements of cell functions, effects of electric or magnetic fields, photoactivation, and testing of drugs or biocompatible polymers on live tissues.
- Quantitative applications of molecular biology, fluorescence image and flow cytometry, and new methods for measurement of cell metabolism, cytogenetics, immune cell functions, DNA, RNA, oglionucleotides, intracellular proteins, secretory products, and cytokine or other cell surface receptors.
- Microencapsulation of drugs, radiocontrast agents, crystals, and development of novel drug delivery systems wherein immiscible liquid interactions, electrostatic coating methods, and drug release kinetics from microcapsules or liposomes can be altered under microgravity to better understand and improve manufacturing processes on Earth. This includes methods for improving the controlled release from transdermal drug devices, iontophoresis, controlled hyperthermia and new drug delivery systems for inhalation and intranasal administration.
- Miniature bioprocessing systems which allow for precise control of multiple environmental parameters such as low-level fluid shear, thermal, pH, conductivity, external electromagnetic fields and narrow-band light for fluorescence or photoactivation of biological systems.
- Low-temperature sample storage (-80^{o}C) and biological sample preservation methods.

TOPIC B3 Biomedical and Human Support Research

NASA has the enabling goal to extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery. There are several objectives, namely: (1) Understand and control the human health risks of space flight, (2) Develop knowledge and technologies to make life-support systems self-sufficient and to improve human performance in space; (3) Resolve fundamental low-gravity issues affecting technologies for human space travel beyond low-Earth orbit; (4) Demonstrate the ability to support a permanent human presence in low-Earth orbit (LEO) as a stepping stone to a human presence beyond LEO; (5) Develop innovative approaches and concepts to inform future decisions concerning systems, infrastructures, and missions for the human and robotic exploration of space. Proposals are sought that support the objective of the enabling goal, including supporting the biomedical and human support research to ensure the health, safety, and performance of humans living and working in space. Included, as well, are life support functions such as a healthy air and water supply, food for the crew in future ultra-long duration missions, health maintenance and in-space medical care, radiation shielding for protecting humans in deep space missions, and unique human factors issues of the space environment.

B3.01 Advanced Spacecraft Life Support
Lead Center: JSC
Participating Center(s): ARC, JPL, KSC, MSFC

Advanced life-support systems are essential to enable human planetary exploration. These future life-support 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, high reliability, minimal use of expendables, ease of maintenance, and low-system volume, mass, and power. Innovative, efficient, practical concepts are needed in all areas of regenerative processes, providing the basic life-support functions of air revitalization, water reclamation, and waste management, as well as related sensors and controls. Also innovative, cost-effective flight experiment concepts are desired to understand the effect of microgravity and partial gravity on the operation and performance of advanced life-support technologies. In addition to these long-duration space applications, innovative regenerative life-support approaches that could have terrestrial application are encouraged. Phase-I proof of concept should lead to Phase-II hardware development that could be integrated into a life-support system test bed. Efforts are currently focused on the near-term missions ranging from International Space Station through an initial Mars mission. Proposals should include estimates for power, volume, mass, logistics, and crew time requirements as they relate to the technology concepts. Areas in which innovations are solicited include the following:

Air Revitalization
Oxygen, carbon dioxide, water vapor, and trace gas contaminant concentration, separation, and control techniques for space vehicle applications (space shuttle, ISS, transit vehicle) and long-duration planetary mission applications.

- Separation of carbon dioxide from a mixture primarily of nitrogen, oxygen, and water vapor to maintain carbon dioxide concentrations below 0.3 percent by volume.
- The recovery of oxygen from carbon dioxide with some focus on an approach to deal with the by-products, if any, of the process, keeping in mind the above mass, power, and expendables goals.
- Removal of trace contaminant gases from cabin air and/or other system (e.g., water reclamation, waste management, etc.) using advanced regenerable sorbent materials, improved oxidation techniques, or other methods.
- Alternate methods of storage and delivery of atmospheric gases to reduce mass and volume and improve safety. [Compare to 4300 psia tank storage with a weight penalty of 0.56 lbm of tank weight per lbm of nitrogen gas stored].
- Novel approaches to integrating atmosphere revitalization processes to achieve energy and logistics mass reductions.
- Alternate methods of atmospheric humidity control that do not use liquid-to-air heat exchanger technology (dependent upon the spacecraft active thermal control system) or mechanical refrigeration technology. [Design metabolic latent load is 2.277 kg of water vapor per person per day].

Water Reclamation
Efficient, direct treatment of wastewater--consisting of urine, wash water, and condensates--to produce potable and hygiene waters.

- Methods for the phase separation of solids, gases, and liquids in a microgravity environment that are insensitive to fouling mechanisms.
- Methods to eliminate or manage solids precipitation in wastewater lines.
- Disinfection technologies, both for potable water storage and point-of-use. Techniques for the elimination of biofilm or microbial contamination from potable water systems. Development of residual disinfectants that can be consumed by crewpersons.
- Methods for the treatment of brine solutions.
- 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.
- Physicochemical methods for primary treatment to reduce the total organic carbon concentration of the wastewater from 1000 mg/l to less than 50 mg/l and/or the total dissolved solids from 1000 mg/l to less than 100 mg/l.
- Methods to minimize biofilm formation on fluid handling components, including flowmeters, check valves, regulators, etc.

Waste Management
Concepts and methods to safely and effectively manage wastes for all future human space missions are required to perform the following functions: acceptance/collection, transport, storage, processing, disposal, and associated monitoring and control. Actual types and quantities of wastes generated during missions are

highly mission dependent. However, for sizing purposes, the "maximum" waste streams have been estimated as follows, based on a 6-person crew): trash (0.56 kg/day), food packaging (7.91 kg/day), human fecal wastes (0.72 kg/day dry, 3.0 kg/day wet), inedible plant biomass (2.25 kg/day), paper (1.16 kg/day), tape (0.25 kg/day), filters (0.33 kg/day), water recovery brine concentrates (3.54 kg/day), clothing (3.6 kg/day), and hygiene wipes (1.0 kg/day). [These estimates are derived from the Solid Waste Processing and Resource Recovery Workshop Report JSC-40193, and the Baseline Values and Assumptions Document, JSC-47804 with the exception of the water recovery brines]. Wastes can also be assumed to be source-separated, since this requirement has been identified for a majority of waste processing equipment.

- Small and compact fecal treatment and/or collection system.
- Volume reduction of wet and dry solid wastes.
- 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.
- Microgravity- and hypogravity-compatible solid waste management technologies.
- Microgravity-compatible technologies for the jettison of solid wastes in space.
- Storage devices needed for the containment of solid waste that incorporates odor abatement technology.
- Other novel waste management technologies for storage, transport, processing, resource recovery, and disposal that satisfy a critical need for the referenced missions (e.g., recovery of critical resources).

Sensors

Significant improvements 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 control of the life-support processes are sought.

- Sensitive, fast response, on-line analytical sensors to monitor suspended liquid droplets, dispersed gas bubbles, and water quality, particularly total organic carbon.
- Other species of interest include dissolved gases and ions in water reclamation processes major constituents (such as oxygen, carbon dioxide and water vapor) and trace gas contaminants (such as ammonia, formaldehyde, and polar organic compounds such as methanol, ethanol, isopropanol, butanol and acetone) in air revitalization processes. Both invasive and noninvasive techniques will be considered.
- Significant mass savings and ease of use may be enabled by approaches that detect more than one species at a time. Proposals that seek to develop new technologies or combine existing technologies to simultaneously monitor several major constituents and/or trace constituents are of interest.

B3.02 Space Human Factors and Human Performance
Lead Center: JSC
Participating Center(s): ARC

The long-term goal for this subtopic is to enable human space missions of up to 5 years with crew independence, without resupply. Specifically, this subtopic's focus is the development of innovations in crew accommodations and equipment; and the development of technologies for assessment, modeling, and enhancement of human performance.

Proposals are solicited that seek to develop technologies that address specific needs:

Habitability factors and working conditions essential for crew well-being

- Human accommodations: Develop design concepts and prototype systems for laundry or dishwashing tasks. The systems should be suitable for operation in microgravity environments with low water consumption and minimal trace gas emissions.

- Tools to design habitats that include opportunities to vary spatial, visual, acoustic, and thermal environments.

Monitoring and maintaining human performance nonintrusively

- Biomechanics and anthropometry data collection and analysis: Develop size or motion measurement systems using wireless or remote sensors. Donning, calibration, and maintenance steps should ensure efficiency and accuracy.
- Minimally invasive and unobtrusive 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.

Predictive modeling of effects on the crew due to potential spacecraft environments and operational procedures

- Develop computational models of the crew environment and of human performance and behavior to simulate the effects of factors that contribute to (or degrade) long-term performance capabilities. Such models of the environment, individual and group behaviors and performance can be used to simulate and explore the conditions that influence human performance (e.g., fatigue, noise, CO_2, microgravity, group dynamics, etc). Such capabilities would include digital models of human operators and routine and emergency tasks that interact in the context of the long-duration human exploration environment.
- New technology for illumination modeling with particular attention to real-time displays of shadowing, glare and bloom combined with predicted energy distribution values to quantify surface illumination and reflection. New technology for illumination measurements and evaluations such as "smart" sensor technology for measurement of illumination, color and surface reflectivity.

Design and evaluation of human-system interfaces for speed, accuracy, and acceptability in a cost-effective and reliable manner

- Automated analysis of computer-user interfaces for complex display systems to conduct objective review of displays and controls, and to determine compliance with guidelines and standards.
- Quantitative measures of the effectiveness of user interfaces to be used for task-sensitive evaluations.
- Tools to build just-in-time system and operational information software to aid human users conducting routine and emergency operations and activities. Such tools might include effective and efficient job aids (e.g., "intelligent" manuals, checklists, warnings) and support for designing flexible interfaces between users and large information systems.

B3.03 Human Adaptation and Countermeasures
Lead Center: JSC
Participating Center(s): ARC, JPL

In order for humans to live and function safely and efficiently in space, a good understanding of the effects of microgravity and other factors associated with the space environment on human physiology and human responses to microgravity and space flight exposure is required. A variety of countermeasures must be developed to oppose the deleterious changes that occur in space or upon return to Earth. The ability to monitor the effectiveness of countermeasures and alterations in human physiology during space flight, particularly when several countermeasures are used concurrently, is equally important. This subtopic seeks innovative technologies in several, specific, key areas as outlined below.

As launch costs relate directly to mass and volume, instruments and sensors must be small and lightweight with an emphasis on multifunctional 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. As the efficient utilization 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 is also a key necessity.

1) Measurement of Emboli in the Brain
A small Doppler ultrasound device [need not be oxygen compatible], emboli recognition system/software, and solid-state recorder of detected events. This would be worn in a fashion similar to a Holter monitor and help to monitor blood clots in the brain for those at risk for embolic stroke.

2) 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.

3) MEMS-Based Human Blood Cell Analyzer
Development of a small, automated, microgravity capable, lightweight, low-power instrument that will analyze a small sample (microliter quantity) of human whole blood and provide a complete blood cell count (RBC, WBC, platelet, hemoglobin concentration, hematocrit, WBC differential and calculated RBC indices) that correlates with traditional ground-based impedance or light-scattering technologies is needed. Likely devices based on MEMS will employ a biocompatible combination of microfluidics, micromechanics, micro-optics, microelectronics, and data telemetry capabilities in an integrated handheld package with a simple, user-friendly operator interface.

4) Human-worn Whole Body Biomechanical and Movement Analysis Suit
A whole-body suit and analysis system worn by human subjects which records and measures biomechanical movements and biomechanical characteristics in order to provide an assessment of total body physical activity during human spaceflight is needed. Measurements to be made and recorded would include upper and lower limb segment displacements along with related joint angular velocities and accelerations. The system would allow entry of limb segment and trunk mass and center of mass data specific to the individual wearing the suit, and then would provide data analysis related to work and power across different body segments and for the whole body based on analytical algorithms. Other capabilities include storage of raw data and the ability to download the data to other computer-based storage and data analysis systems through either hardwire connections or via telemetry.

5) Human-Worn Cardiophysiologic Monitoring Device for Space Flight
A portable, noninvasive device to be worn under the re-entry suit that will measure and record blood pressure (using Korotkoff sounds), heart rate and 7 lead electrocardiogram. It must not have any connections that can be pulled loose during donning of the suit. It must be battery operated, but using only batteries that will be allowed inside the oxygen-rich environment within the suit.

Functional Requirements:

<u>Primary Priority:</u>

- Displaying blood pressure (BP) on an integral screen
- Noninvasive measurement, recording, and display of blood pressure using the auscultation technique
- User-initiated recordings at any time once the hardware is donned
- Battery operation
- Providing automated analytical abilities that include blood pressure determination and verification
- Providing storage (digital or analog) of blood pressure and Korotkoff sounds
- Allowing the user to apply the blood pressure cuff single-handedly
- Interfacing with the Launch and Entry Suit Bioinstrumentation Port cable (as required)
- Recording data for at least 3 hours
- Noninvasive recording of Korotkoff sounds
- Must allow the user to clear the memory and/or to append reading to memory if the device has been shut off
- Power switch
- Display heart rate, and time, in addition to blood pressure, on an integral screen
- Noninvasive recording of continuous electrocardiogram (3 lead)

- Recording of voice annotations
- Heart rate calculation
- Providing digital storage of blood pressure, Korotkoff sounds, and electrocardiogram waveforms
- Minimum of 100 Hz diagnostic quality of signal
- Input impedance: 10 mega ohm (minimum)
- Size: Unit should be small and light - approx. 7” x 2” x 3” and approx. 12 oz
- Three accelerometers and the capability to store parameters
- A 5-7 lead ECG.

Secondary Priority
- Recording, in addition, display of heart rate
- Taking measurements automatically at variable intervals, ranging from every 2 minutes to every 2 hours
- Providing synchronized data output of blood pressure, electrocardiogram, Korotkoff sounds, time stamps, and voice annotation waveforms to a desktop computer: Note: If all measurements had time stamps, synchronizing of parameters could be done during analysis

Tertiary Priority
- Providing visual indicator(s) of subject preparation problems
- Allowing user to access previous blood pressure and heart rates while the unit is still being worn
- Allowing the user to don the equipment within 15 minutes, and commence recordings 5 minutes thereafter

6) Body Composition Hardware for Space Flight
Development of on-orbit instrumentation for determination of body composition. Specific parameters of interest include lean body mass, total fat mass, total body water. Validation data will be required using the current gold-standard techniques in this field. This information will be used in conjunction with nutritional status protocols to assess crew health.

B3.04 Food and Galley
Lead Center: JSC

As NASA begins to look beyond low Earth orbit and to plan for future exploration missions, such as to the Moon or Mars, new technologies in food science and food processing will be needed. The impossibility of regularly resupplying a Mars crew means that the prepackaged shelf-stable food, ingredients, and equipment to provide a complete diet for 6 crewmembers for more than 3 years will have to be carried with them. As the crew remains on the lunar or planetary surface, crops will be grown to supplement the crew's diet, especially within the context of experimental advanced life-support systems that use plants to revitalize the air and water supply. Hence, methods for processing potential food crops are needed. Areas in which innovations are solicited are:

Long-Duration, Shelf-Stable Food
An initial trip to Mars, for example, will require a stored food system that is nutritious, palatable, and provides a sufficient variety of foods to support significant crew activities on a mission of at least 3 years duration. Development of highly acceptable, shelf-stable food items that use high-quality ingredients is important to maintaining a healthy diet. Foods should maintain safety, acceptability, and nutrition, for the entire shelf life of 3-5 years. Shelf-life extension may be attained through new food preservation methods and/or packaging.

Advanced Packaging
The current food packaging used on the Shuttle and the International Space Station is not biodegradable or recyclable and thus represents a significant trash-management problem for exploration-class missions. Waste packaging in Shuttle missions is returned to Earth for disposal and waste packaging for International Space Station is incinerated upon reentry into Earth's atmosphere. New packaging technology is needed to minimize waste from packaged food. An example might be a biodegradable package that can withstand the

retort process or a plastic or other packaging material that can readily be recycled to make objects of value to the space flight mission.

Food Processing
Advanced life-support systems, which use chemical, physical and biological processes, are being developed to support future human planetary exploration. One such system might grow crops hydroponically and then process them into edible food ingredients or table-ready products. Variations in crop quality, crop yield, and nutrient content may occur over the course of long-duration missions, posing further requirements to the food processing and storage system. Such variations might affect the shelf stability and functional properties of the bulk ingredients and ultimately the quality of the final food products.

Equipment to process crops in space should be highly automated, highly reliable, safe, and should minimize crew time, power, water, mass, and volume. Equipment for processing raw materials must be suitable for use in hypogravity (e.g., 3/8th-g on Mars) and in hermetically sealed habitats. Some potential crops for advanced life-support systems include minimally processed crops such as lettuce, spinach, carrots, tomatoes, onions, cabbage, fresh herbs, and radishes. Other baseline crops that require processing would be wheat, soybeans, white potatoes, sweet potatoes, peanuts, dried beans, rice, and tomatoes.

Food Safety
Assurances of food quality and food safety are essential components in the maintenance of crew health and well-being. Food quality and safety efforts should be focused on monitoring the shelf stability of processed food ingredients, on identification and control of microbial agents of food spoilage, including the development of countermeasures to ameliorate their effects. For all food production and processing procedures, HACCP (Hazard Analysis Critical Control Points) must be established.

B3.05 Biomedical R&D of Noninvasive, Unobtrusive Medical Devices for Future Flight Crews
Lead Center: GRC

Human presence in space requires an understanding of the effects of the space environment on the physiological systems of the body. The objective of this subtopic is to sponsor fundamental and applied research leading to the development of noninvasive, unobtrusive medical devices that will mitigate crew health, safety, and performance risks during future flight missions. Medical diagnostic and monitoring devices are critical for providing health care and medical intervention during missions, particularly those of extended duration. Of particular interest are devices with minimized mass, volume, and power consumption, and capable of multiple functions. Design enhancements that improve the operation, design reliability, and maintainability of medical devices in the space environment are also sought. Of additional consideration are innovative instrumentation automation, ease of usage, improved astronaut (patient) comfort, and easy-to-read information displays.

Major research disciplines include endocrinology, immunology, hematology, microbiology, muscle physiology, pharmacology, drug delivery systems, and mechanistic changes in neurovestibular, cardiovascular, and pulmonary physiology.

Innovations in the following areas are sought:

- Biomedical monitoring, sensing, and analysis (including the acquisition, processing, communication, and display) of electrical, physical, or chemical aspects of a human's health or physiologic state.
- Instrumentation to be used for in-flight and ground-based studies for reliable and accurate noninvasive monitoring of human physiological functions such as the cardiovascular, musculoskeletal, neurological, gastrointestinal, pulmonary, immunological, and hematological systems.
- Noninvasive biosensors for real-time monitoring of blood and urine chemistry including, gases, calcium ions, electrolytes, cellular components, proteins, lipids, and hormones.
- In-flight specimen analysis to evaluate physiological, metabolic, and pharmacological responses of astronauts.
- Instrumentation to maintain and assess levels of aerobic and anaerobic physical capability.

- Instrumentation to monitor physical activity and loads placed on different segments of the human body.
- Instrumentation to provide quantitative data to establish the effectiveness of an exercise regimen in ground-based research, and to measure bone strain in the hip, heel, and lumbar spine during exercise.
- Assessment of gas bubble formation or growth in the body after in-flight or ground-based decompression, and to prevent or minimize associated decompression sickness
- In-flight assessment of the metabolism of proteins, carbohydrates, lipids, vitamins, and minerals.
- Smart sensors capable of sensor data processing and sensor reconfiguration.
- Small, portable, medical imaging diagnostic instrumentation.
- Virtual medical instrumentation.

B3.06 Radiation Shielding to Protect Humans
Lead Center: LaRC

Revolutionary advances in radiation shielding technology are needed to protect humans from the hazards of space-radiation during NASA missions. All space-radiation environments in which humans may travel in the foreseeable future are considered, including low-Earth orbit, geosynchronous orbit, Moon, Mars, etc. All radiations are considered, including particulate radiation (electrons, protons, neutrons, alpha, light to heavy ions with particular emphasis on ions up to iron, mesons, etc.) and including electromagnetic radiation (ultraviolet, x-rays, gamma rays, etc.).

Technologies of specific interest include, but are not limited to, the following:

- Advanced computer codes are needed to model and predict the transport of radiation through materials.
- Advanced computer codes are needed to model and predict the effects of radiation on the physiological performance, health, and well-being of humans in space radiation environments.
- Innovative lightweight radiation shielding materials are needed to shield humans in aerospace transportation vehicles, large space structures such as space stations, orbiters, landers, rovers, habitats, space suits, etc. The materials emphasis should be on non-parasitic radiation shielding materials, or multifunctional materials, where one of the functions is the radiation shielding function.
- Non-materials and "out-of-the-box" radiation shielding technologies are also of interest.
- Laboratory and space flight data are needed to validate the accuracy of radiation transport codes.
- Laboratory and space flight data are needed to validate the effectiveness of radiation-shielding materials and non-materials solutions.
- Comprehensive radiation-shielding databases and design tools are also sought to enable designers to incorporate and optimize radiation shielding into space systems during the initial design phases.
- Accurate and reliable theoretical and phenomenological models are needed for the collision of radiation ions to generate the input database for transport phenomena. The models that give comprehensive results in a fast manner for broader (preferably whole) ranges of colliding ions, for ion energies from a few MeV to a few GeV are desirable. The information needed is as follows:
- Total, elastic, absorption, and fragmentation cross sections
- Spectral and angular distributions of producing particles
- Multiparticle fragmentations
- Cluster effects
- Meson production

B3.07 Biomass Production for Planetary Missions
Lead Center: KSC
Participating Center(s): JSC

The production of biomass (in the form of edible food crops) in closed or nearly closed environments is essential for the future of long-term planetary exploration and human settlement. These technologies will lead not only to food production but also to the reclamation of water, purification of air, and recovery of inedible plant resources. Areas in which innovations are solicited include the following:

Crop Lighting
- Sources for plant lighting such as, but not limited to, high-efficiency lamps or solar collectors
- Transmission and distribution systems for plant lighting including, but not limited to, luminaires, light pipes and fiber optics
- Heat removal techniques for the plant growth lighting such as, but not limited to, water-jackets, water barriers, and wavelength-specific filters and reflectors.

Water and Nutrient Management Systems
- Technologies for production of crops using hydroponics or solid substrates
- Water and nutrient delivery systems
- Regenerable media for seed germination plant support
- Separation and recovery of usable minerals from wastewater and solid waste products for use as a source of mineral nutrients for plant growth.

Environmental Monitoring and Control
Innovations in monitoring and control approaches for plant-production environments, including temperature, humidity, gas composition, and pressure. Gases of interest could include carbon dioxide, oxygen, nitrogen, water vapor, and ethylene.

Mechanization and Automation
Innovations in propagation, seeding, and plant biomass processing. Plant biomass processing includes harvesting, separation of inedibles from edibles, cleaning and storage of edibles (seed, vegetable, and tubers) and removal of inedibles for resource-recovery processing.

Facility or System Sanitation
Methods or technologies to prevent excessive build-up of microorganisms within nutrient delivery systems.

Health Measurement
Remote, direct and indirect methods of measuring plant health and development using canopy (leaf) spectral signatures or fluorescence to quantify parameters such as rate of photosynthesis, transpiration, respiration, and nutrient uptake. Data acquisition should be noninvasive or remotely sensed using spectral, spatial, and image analysis. System modeling and decision making algorithms may be included.

Sensor Technologies
Innovations are required for development of sensors using miniature, subminiature and microtechnologies for evaluation of all phases of biomass production. Such sensor arrays include wide-ranging applications of gas and liquid sensors as well as photo sensors and microbiological community indicators. Innovations are required in all phases of sensor development, including biomass fouling, miniaturization, wireless transmission, multiple-phase and multiple-tasking sensors and interface with AI data collection systems.

Flight Equipment Support
Innovative hardware and components developed to support research in the Space Shuttle and on board the International Space Station. Biomass production investigations using flight-support equipment will be required to meet the demanding requirements for space flight operations, meet the rigorous scientific data collection standards, and produce plants in a controlled environment for research purposes and food. Innovations in whole package design and in component designs will be required.

B3.08 Software Architectures and Integrated Control Strategies for Advanced Life-Support Systems
Lead Center: JSC
Participating Center(s): JPL

Advanced Environmental Control in an enclosed crew environment presents a series of challenges as life-support goals move to minimize expendables, to minimize crew and ground involvement, and to incorporate biological systems for recycling air, water and solids. The interdependence of environmental processing systems, and the need for reducing operations support costs are included.

There is a need for the development and evaluation of control architectures and strategies which meet these challenges, both by building on current advances in distributed, modular, object-based protocols, and by new advances in integration of agent technology, planning and resource management across heterogeneous systems. This includes:

- Distributed network protocols, including support for fieldbus and intelligent controllers
- Development of ontologies for communication among autonomous systems or control agents
- Software development methodologies for autonomous systems, including requirements management, testing, performance metrics and long-term maintenance support, including development for growth and support for model-based simulations
- Approaches for integration of new controls technology (both hardware and software) with existing, legacy systems
- Fault detection, isolation and recovery across multiple systems; sharing of parameters and data between heterogeneous systems
- Control system failure tolerance
- Planning and scheduling, including reactions to system faults, supporting adjustments to operations, inventory, and logistics due to planned and unplanned maintenance
- Development and integration of autonomous system and inter-system control with crew and ground operations
- Development of architectures that support a range of autonomy, from fully autonomous to fully manual, with the corresponding range of support for human interaction
- Distributed Human-Computer Interface, with support for multiple platforms (handheld, head-mounted, voice, etc.)

TOPIC B4 Partnerships and Market Driven Research

NASA has the mission to understand and protect our home planet. It has the goal to create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies industry, and academia. It seeks to leverage resources in support of National priorities through partnerships across industry, academia, and the Government for market-driven research in space. It seeks to resolve scientific issues impacting Earth-based technological and industrial applications by using the unique low-gravity environment of space. Proposals are sought for innovative market-driven pivotal technologies and processes related to space and microgravity. Innovative proposals are also sought for the development of infrastructure equipment for market-driven experimentation and operations in space, or the use of these technologies by industry on Earth. Automated processes and hardware (robotics), which will reduce crew time, are a priority. Proposals that utilize partnering and collaboration to promote the market-driven research are encouraged. Dual use that supports market needs as well as NASA goals and National priorities, such as security, are desired.

B4.01 Space Commercialization
Lead Center: MSFC

In accordance with the Space Act, as amended, to "seek and encourage to the maximum extent possible the fullest commercial use of space," NASA facilitates the use of space and microgravity for commercial products and services. The products may utilize information from in-space activities to enhance an Earth-based effort, or may require in-space manufacturing. This subtopic has two goals. First, the commercial demonstration of pivotal technologies or processes; second, the development of associated infrastructure equipment for commercial experimentation and operations in space, or the transfer of these technologies to industry in space or on Earth. Automated processes and hardware (robotics), which will reduce crew time, are a priority. All Agency activity in microgravity, including those in life science and microgravity sciences, which lead to commercial products and services, are of interest. Some specific areas for which proposals are sought include:

Biotechnology and Agribusiness
This category comprises biotechnology, biomedical and agricultural instrumentation or techniques that exploit space-derived capabilities or data to support the commercial development of space by the agricultural, medical or pharmaceutical industry, including specifically:

- Portable biological sensors - The need for sensing devices that can detect and identify biological pathogens (airborne or in-vivo) is desired to support NASA's mission for a permanent presence of man in space.
- Development of noninvasive health monitoring systems/models - Application to NASA's crew health program for extended duration missions. For example, (1) novel in vitro cell-matrix models for studying the effects of microgravity on human tissue repair and wound healing, (2) novel organotypic skin models which simulate physiological changes found in humans under a microgravity environment, (3) functional models for delineating the MG-inducible or MG-responsive pathways of human tissue angiogenesis (new blood vessel formation).
- Physiological measurement in microgravity of bone growth and the immune system in microgravity.
- Innovative research in plant-derived pharmaceuticals using microgravity.
- Agricultural research, i.e., genetic manipulation of plants using microgravity.
- Instrumentation or technology to explore the use of microgravity in genetic assay, analysis, and manipulation.
- Instrumentation to analyze cell reactor systems and characterize cell structure in microgravity in order to develop enhanced drug therapies that can also be applied to pharmaceutical development and commercialization.
- Innovative techniques for dynamic control and cryogenic preservation of protein crystals.
- Innovations in preparation of protein crystals for x-ray diffraction experiments without the use of frangible materials.
- Innovation of low-technology temperature control chambers requiring little or no power for bringing temperature sensitive experiments up to or back from the International Space Station.

Materials Science
Areas in which Materials Science innovations are sought include the following:

- Applications using space-grown semiconductor crystals, including epitaxially grown materials for commercial electronic devices. The applications will also attempt to use the knowledge of the space-grown material behavior to enhance ground processing of the materials to achieve equivalent performance of space-grown materials in electronic circuitry.
- Applications using space-grown optical electronic materials such as fluoride glasses and nonlinear optical compounds for commercial optical electronic devices and to achieve equivalent performance of space-grown materials in ground processing.
- Innovations using nonlinear optical material to be processed in space.
- Innovations for new space-processed glasses for optical electronic applications.

Microgravity Payloads
The following applications/technologies are associated with Microgravity Payloads:

- Design/develop microgravity payloads for space station applications that lead to commercial products or services.
- Enabling commercial technologies that promote the human exploration and development of space.
- Enabling commercial technologies through the use of ISS as a commercial test bed for hardware, products, or processes.

- Enabling technology designed to reduce crew work loads and/or facilitate commercial investigations or processing through automation, robotics, or nanotechnology.

Combustion Science
Innovative applications in combustion research that will lead to developing commercial products or improved processes through the unique properties of space or through enhanced or innovative techniques on the ground.

Food Technology
Innovative applications of space research in food technology that will lead to developing commercial food products or improved food processes through the unique properties of space or through enhanced or innovative techniques on the ground.

Biomedical Materials
Innovative unique structure materials where microgravity promotes structures such as biodegradable polymers for use in wound healing and orthopedic applications.

Entertainment Value Missions
Innovative approaches for commercial economic benefit from space research involving broadcasting, e-business or other activities that have entertainment value.

B4.02 Space Commercialization Infrastructure
Lead Center: MSFC

In accordance with the Space Act, as amended, to "seek and encourage to the maximum extent possible the fullest commercial use of space," NASA facilitates the use of space for commercial products and services. The products may utilize information from in-space activities to enhance an Earth-based effort or may require in-space manufacturing. This subtopic's goal is the development of infrastructure technology that will enable or enhance commercial space operations. Processes and hardware which have a clear utilization plan are a priority. All space activities that lead to commercial use in space are of interest. Some specific areas for which proposals are sought include:

Power and Thermal Management
Power and thermal management technologies that enable or enhance commercial satellites or space systems are sought.

Communications
Broadband, data compression, and imaging which can enable or enhance commercial operations in space or commercial satellites. This includes use of hyperspectral imagery and remote sensing.

Space Vehicles and Platforms
Improved technologies are sought for autonomous commercial vehicles and platforms. These technologies include autonomous rendezvous and docking, structures, and avionics.

Space Resources Utilization
Advanced commercial space activities will benefit from utilizing nonterrestrial resources. These resources include propellants, power, and structural materials.

Security and Safety
NASA also has the goal to protect our home planet and better understand the use of technologies that improve the quality of life on Earth. By investing in Space research and by collaborating with other agencies, industry, and academia, NASA has the opportunity to contribute to the creation of a more secure world. By leveraging resources in support of research in the unique environment of Space, market needs, as well as NASA goals and National priorities, such as security, may be achieved. This dual use with good potential for commercial product development is strongly encouraged. Some example areas for which proposals are sought include:

Sensors and detection systems to improve processes and operations in support of NASA Space research and exploration goals, National security, and industrial processes. Areas of technology development include, but are not limited to, the following:

- Biotechnology
- Materials science
- Combustion science
- Radiation
- Optical systems
- Medical diagnostics
- Agriculture
- Microbiology
- Health and safety

Improved communication systems to effectively and efficiently gather information, and to disseminate warnings and other critical information, in the event of a National disaster, and/or to provide better communication capabilities in support of NASA Space research and exploration goals, and for use by the general public.

Innovative devices and procedures for use of technologies to protect citizens from various threats to their personal security and/or property, and to provide protection to personnel carrying out NASA Space research and exploration operations, both in space and on Earth.

Countermeasure systems and/or devices to better effect rescue, recovery, treatment, and environmental safety during and after the occurrence of a disaster or an accident.

TOPIC B5 Biomolecular Systems, Devices and Technologies

NASA has the mission to understand and protect our home planet. The goal is to create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry and academia. NASA recognizes that interdisciplinary research that systematically combines expertise in disciplines of physics, chemistry, biology, and engineering may provide new technologies for future space missions that are applicable to medical needs in space and on Earth. State-of-the-art knowledge and expertise in the areas of optical technologies and spectroscopy, fluid physics, sensor technology, and biomolecular approaches promise to enable lightweight, convenient, and highly focused biomedical applications to mitigate the health risks of space flight and long-duration missions. Innovations leading to prototype micro- and nano-systems for the detection, imaging, recognition and monitoring of biological signatures and processes at the molecular and cellular level are sought. Innovative research with application to this topic may include ultrahigh resolution imaging, biochip design tools, advanced microscopy, microscale diagnostics, and microfluidics. Research that provides for development of integrated systems and platforms based on these technologies should be focused on health issues associated with space flight. This research topic supports NASA's medical, diagnostic, clinical, life support, environmental monitoring, and space exploration objectives for long-duration space flight. Innovations in this topic area will provide leading-edge advances in health care.

B5.01 Biomolecular Sensors, Effectors and Imaging
Lead Center: ARC
Participating Center(s): JPL

Emerging technology for micrometer and nanometer scale fabrication, manipulation, and materials characterization enables a new range of technological possibilities. Of particular interest are techniques for miniaturizing biochemical analysis instruments that can interact with life and its constituents at the molecular scale. One of the NASA goals is to seek out and identify biochemicals in minute concentrations in the human body and in extraterrestrial settings. Initially, these microscopic devices, engineered on the molecular scale, will function primarily to gather data about their environment, with the ultimate goal of actively responding to threats to astronaut health (e.g., by killing tumor cells or by targeted delivery of medication).

Microelectromechanical Systems (MEMS) technology has enabled numerous innovative methods to miniaturize biomedical instruments. Microfluidic platforms are essential to the goals of detecting molecular signatures of real-time biological activities in the human body. Finally, investigations of nanoscale materials, such as carbon nanotubes, and fabrication techniques are needed to develop biochemical devices with new capabilities with implications beyond miniaturization.

Research Topics:

- In vivo sample acquisition and processing
- In vivo device propulsion
- Wireless communications for micro/nano biochemical instruments
- Power sources (biochemical, electrochemical)
- Self-assembled fabrication techniques for biochemical sensor arrays
- Other technologies which would contribute toward integrated prototype nanoexplorers (combining sample acquisition, processing, and sensing).
- Integrated in vivo biochemical sensor and targeted drug delivery device.

Cellular structures and functions are a marvel in architecture, engineering, and programming. Currently there are various imaging techniques which allow us to obtain concentration variations, map compositions and monitor transport and transduction mechanisms. Cellular biologists now use molecular imaging to localize and image which biological molecules are where inside a cell and its structures. In addition to where, we can also image when molecules are produced to track temporal changes in cell metabolism. Current technologies for molecular imaging in cellular biology would include the following: FISH, GFP, MRI, and spectral techniques that allow spectrally multiplexed probes. Atomic, chemical force micro-scopies, carbon nanotube, and proximal probes are all examples of new approaches to resolving molecular structure at a small enough scale to image individual atoms. Photon-based imaging from infrared to x-ray, PET, MRI, NSOM, STM/AFM, photo-acoustic imaging, IR spectral imaging are just some examples of imaging techniques. Proposals sought include:

- New technologies for imaging protein expression in cells at or below the diffraction limited spatial resolution of optical microscopies.
- Nanoscale imaging at a resolution sufficient to provide protein or DNA sequence.
- Image cellular activities such as gene expression at a molecular scale.
- Nanoscale imaging at a resolution sufficient to provide protein or DNA spatial configuration.

B5.02 Biosignatures, Signal Amplification, and Bioinformatics
Lead Center: JPL
Participating Center(s): ARC

Fundamental to the success of achieving NASA goals is the ability to identify biosignatures to distinguish life from nonlife on a planetary scale. Life is a thermodynamic enigma – seemingly violating thermody-namic laws by decreasing entropy. This ability comes from its ability to extract energy from the environment and use this energy to build structures and establish chemistries that are decidedly out of equilibrium. The combination of structural and chemical disequilibria, along with the resulting changes in the environment due to consumption and production of materials, make the technologies basis for the search for life rather straightforward: utilize thermodynamics and kinetics. Search over a variety of scales for structures, measure the chemistry of these structures, and search for metabolites that are disappearing or accumulating on a variety of time scales. Using such an approach, we imagine that life can be sought in a wide variety of environments simply by making simple measurements and asking the right questions of the data. NASA requires technology for in situ life detection that will provide a springboard for the use of similar approaches for detection of "unhealthy" subjects, be they unhealthy due to bacterial or viral infections, or malignancies. From this perspective, one can readily identify specific methods and approaches that will be used in astrobiology (things to be measured, statistical approaches, data handling and analyses, etc.), and how they might be adapted to laboratory, environmental, and in situ studies of life detection, and eventually to laboratory and clinical methods of diagnosis. Technology innovation areas include:

- Tools to assist in the identification of signatures of life via thermodynamic and kinetics of metabolism
- Detection of molecular level structures and anomalies
- Detection of chemical disequilibria and microscale chemical analyses

The ability to detect weak signals emitted from molecular interactions has always been a challenge for molecular biologists. Such signals highlight numerous important interactions such as antigen-antibody associations and nucleic acid hybridization reactions. These interactions are often used as assays to detect molecular indicators of disease pathology. As such, increasing sensitivity of these assays without compromising accuracy is of utmost importance. Traditionally, signal amplification in molecular biology has been achieved by one of two approaches - either amplification of the molecule to be detected or intensifying the signal from the detector molecule. Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) is an example of the former. In RT-PCR, one makes a DNA copy of a low copy number transcript to be detected, then amplifies the number of molecules by PCR before detecting the products. To illustrate increasing the signal from a detection molecule, consider the use of labeled secondary antibodies to enhance signal from primary antibody binding. While these techniques have improved detection, methods are still limiting when it comes to detecting molecules in very small quantity or in single copy. More recent examples include catalyzed reporter deposition (CARD), branched DNA signal amplification assays and Fluorescent Resonance Energy Transfer (FRET). Technology innovation areas include:

- Single, specific molecule detection among high background noise.
- Contrast and sensitivity enhancers for noninvasive real time imaging.
- Utilization of biological amplification or self-amplification of target molecules.
- Amplification methods to enhance the probability of finding target molecules.
- Amplification of the precursors of ailments (fever, infections, bone loss, muscle atrophy, etc.)
- Utilization of biological amplification or self-amplification for ailments.

The systematic handling and analysis of biological data to solve scientific problems will involve the development of new computational technologies. Bioinformatics will be important in assessing and modeling physiological conditions. Both pattern recognition and modeling of biological behavior and processes (both at global and local levels) will be crucial to scientific and medical research in space and on Earth. NASA's bioinformatics technology development is divided along the following lines: (1) data acquisition, (2) data handling and curation, (3) hypothesis generation, and (4) hypothesis testing.

Technology innovation development areas to enhance and enable:

- Coarse modeling of smaller scale cell functions
- Data mining/pattern recognition
- Model genomics and kinetics of infections, bone loss, muscle atrophy, etc.
- Complex modeling of large-scale cell functions
- Space information systems - systems for real-time data handling and analysis (types of data include gene chip blood panels, data of spacecraft environment, human body, etc.)
- Pattern recognition for ailments (fever, infections, bone loss, muscle atrophy) combined with model development for predictive use.

B5.03 Nano/Quantum Devices for Space Medicine and Biology Applications
Lead Center: ARC
Participating Center(s): JPL

NASA has been in great demand for rapid, high sensitive, in situ characterization and quantification of chemical and biological species and in-vivo health monitoring and therapy on the Earth and in space. Biological systems show remarkable sensitivity, specificity and efficiency due to the selective evolution of molecular mechanisms. Nanoscale materials and structures offer unique interface between biological systems and electronics. Stand-alone nanosensors as well as other biomedical devices that automatically perform multiple steps such as sampling, sample transport, separation and detection have the potential for NASA's mission. The development of advanced chemical and biological sensors, drug delivery systems, and space genetics requires an integration of analytical chemistry, physics of sensors, microfluidics, and biochemical molecular recognition methods on nanoscale devices and platform. It is anticipated that hybrid molecular assemblies involving biomolecules would enable the exploitation of these unique aspects of biological systems while affording the control that is possible through nanotechnology. This would lead to biomolecular assemblies with new functionalities and significant advantages in terms of size, power consumption, efficiency and ease of fabrication. The development of this technology will revolutionize sensing & detection, in-vivo diagnosis and drug delivery, repair of tissue/cell damage, integrated mechanical/electronic/chemical devices at the nanoscale.

This topic seeks innovative ideas for designing, fabricating and demonstrating different kinds of novel bio-nano-molecular assemblies specific for NASA's need. It includes, but is not limited to the following:

- Novel and improved nanoscale sensor technologies and materials (conductometric, potentiometric, capacitive, amperometric, calorimetric, gravimetric, optical, resonant sensors)
- Nanosensor arrays
- Drug delivery systems
- Noninvasive testing and monitoring nanodevices and systems (e.g., blood, urine)
- In-vivo molecular diagnostics devices and technology
- Environmental chemical sensors and biosensors
- Advanced photonics for environmental monitoring (fluorescence, phosphorescence, Raman, IR, UV absorption, microwave, RF, LIBS, x-ray)
- Nanochemical analysis systems, lab-on-the-chip (electrophoresis, flow injection analysis, chromatography, etc.)
- Nanofluidics for sensors (sample handling, fluidic mechanics, bioreactors, etc.)
- High throughput detection methods and systems
- Innovative growth and formation techniques of semiconductor quantum dots with greater uniformity of size, controllable achievement of higher quantum dot density, and closer dot-to-dot interaction range.
- Modeling, simulation and demonstration of innovative sensor concepts based on development of novel applications of nanotechnology and quantum mechanics.
- Innovative nanoscale functional device building blocks based on single-electron charging.

B5.04 Nanoscale Self-Assembly using Biological Molecules
Lead Center: GRC

Biomolecular self-assembly is an exciting new discipline lying at the intersection of molecular biology, the physical sciences, and materials engineering. A key feature of biological systems is their ability to undergo self-assembly, a process in which a complex hierarchical structure is established without external intervention. Bridging the gap between organic chemistry and materials synthesis, biomolecular self-assembly combines the powerful specificity of protein and DNA interactions with the more traditional synthetic material synthesis to produce novel materials and sensors. The resulting materials are structured in a way that is characteristic of biological materials, but they are not necessarily of biological origin.

Use of colloids is one route to nanoscale self-assembly. Colloidal particles can serve as substrates for molecularly thin films of biopolymers or other surface-active agents. Extensive use has been made of gold, silica, and latex particles as substrates to which antibodies and antigens could be attached for assaying and in drug delivery applications. Lock-and-key protein systems such as the biotin-avidin couple may be used as controllable strong adhesives. Colloidal dispersions have also been used as a solvent for self-assembling lamellar phases of surfactants.

The focus of this subtopic is the applications of biomolecular self-assembly to produce novel sensors or bio-engineered materials that enable technologies relevant to the nation's space program.

TOPIC B6 Mission Integration and Flight Support

NASA has an enabling goal, for supporting its strategic missions, to extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery. It is important that the space missions and experiments for biological and physical research be managed using new tools, models, and procedures that improve flight payload integration and operations. Proposals are sought for innovative ideas and efficiencies for International Space Station payloads integration, as well as manned exploration missions involving experiment logistics, processing and operations.

B6.01 Telescience and Flight Payload Operations
Lead Center: MSFC

It is important that the space missions and experiments for biological and physical research be managed using new tools, models, and procedures that improve telescience and flight payload operations. In addition, NASA wants to make available data/information associated with microgravity research investigations and results.

There are many potential users for NASA services and data located throughout the U.S. There are three general types of users of these services and data. The first type is the principal investigator (PI)/payload developer (PD) who is responsible for the payload, experiment, and attendant science, and who commands the payload or experiment. The second type is the secondary investigator(s) who participates in analysis of the science and its control, but does not send commands. The third type is the educational user, from graduate students to secondary school students. These users will receive either data processed by the PI or unprocessed data. Commercial investigations require the ability to receive, process, and display telemetry, view video from science sources, including the ISS, and interact with NASA concerning the science and operations. To conduct or be involved in general science activities, including the ISS science operations, a user will require various services from the Payload Operations Integration Center (POIC) located at the Marshall Space Flight Center near Huntsville, Alabama, or from other control centers located at various NASA facilities. These services are required to enable the experiment to be controlled using the inputs from various video sources, telemetry, and the crew. Inputs allow the experimenter to send to his/her payload or experiment commands to change various experiment operations. Before an experiment can get underway, an experimenter must participate in the payload planning process to schedule onboard services like power, crew time and cryogenics. This planning process is integral to the entire payload/carrier operation and requires the PI/PD or his representatives to participate via voice or video teleconferencing. To enable a user to operate from his/her home base, whether located in a laboratory, office, or home; these services (commensurate to the level of operation) must be provided at the user's location at a reasonable cost. Costs include both the platform upon which these services will run and the communications required to provide these services to the experimenter's location.

Proposals are sought for innovative ideas and efficiencies for systems to better effect communication and handling of data/information for scientific and commercial research on the International Space Station payloads and on manned exploration missions, and, at the same time, for general use as applicable.

B6.02 Flight Payload Logistics, Integration, Processing, and Crew Activities
Lead Center: MSFC

It is important that the space missions and experiments for biological and physical research be managed using new tools, models, and procedures that improve flight payload integration and associated activities. Proposals are sought for more effective and efficient flight payload logistics, integration, processing, and crew activities. As experiment hardware is developed, concurrent planning for logistics, processing, and for both analytical and physical payload integration, must take place. One objective is to minimize crew time required for experiment handling, transfer, installation, and operation through automation, procedural efficiencies, and other means. Some potential areas for payload improvements include, but are not limited to, the following:

- Acoustics – noise level reduction
- Power requirement reduction
- EMI/EMC reduction
- Thermal control
- Materials usage
- Data control/handling
- Safety
- Test and checkout
- Systems integration
- Logistics
- Automation, robotics, nanotechnology
- Training

TOPIC B7 Outreach

NASA has the mission to inspire the next generation of explorers with the goal of engaging the public in shaping and sharing the experience of exploration and discovery. The objective is to improve science literacy by engaging the public in NASA missions and discoveries, and their benefits, through such avenues as public programs, community outreach, mass media, and the Internet. The Biological and Physical Research (BPR) Enterprise conducts basic and applied research in the biological and physical sciences, and through partnerships with industry in market-driven research. It is imperative that all sectors of the public, including professional, technical, science, and the general public, understand what biological and physical research is taking place, why it is taking place, and how such research improves quality of life. Proposals are sought for innovative methods for analysis, metrics development, audience assessment, and outreach product development to improve public outreach planning and implementation.

B7.01 Development of Improved Outreach Planning and Implementation Products
Lead Center: MSFC

This subtopic places emphasis on the effective implementation of outreach activities.

BPR seeks to use its research activities to encourage educational excellence and to improve scientific literacy from elementary school through the university level and beyond. The Enterprise delivers value to the American people by facilitating access to the experience and excitement of space research. NASA wants to provide access to information/data about microgravity research experiments and commercial investigations to schools, industry, and the general public.

Proposals are sought which provide a system or systems based on commercial solutions to develop outreach products for the improvement of education and public outreach planning and implementation. These systems should allow outreach participation in NASA programs, including the science and operational levels. Systems could provide for the general public and the educational community access to NASA and commercial science activities and operations through low-cost technologies, and outreach and education activities. The systems should be capable of facilitating secondary and college-level students' access to, and the ability to participate in, science activities. Similarly, the systems should be able to accommodate institutions and organizations that promote the use of science and technologies, e.g., museums and space camps. Examples of potential outreach activities (also listed under subtopic B7.02) include, but are not limited to the following:

- Exhibits and educational/informational material for conferences, workshops, and schools.
- Development and distribution of outreach brochures, newsletters to the general public.
- Student flight experiment programs.
- Adult Ambassador Program, e.g., advocacy speakers for community education and outreach events
- Alliance with Collegiate Alumni Learning Weekend Programs.
- Development of Partnership with retirement organizations for a planning and implementation of a program with appropriate learning experiences.
- Development and implementation of "learning laboratories" for science centers/museums.
- Publication of articles in general interest periodicals
- Publication of articles and reports in scientific journals
- Multimedia outreach products
- Outreach web sites
- Education briefs, fact sheets, press releases

B7.02 Innovative Methods of Outreach Analysis, Assessment, and Metrics Development
Lead Center: MSFC

This subtopic places emphasis on evaluation of the effectiveness of outreach activities.

Systems are sought to assess and analyze the implementation and effectiveness of education and outreach activities associated with BPR research. BRP goals are to encourage educational excellence and to improve scientific literacy from elementary school through the university level and beyond. Systems are needed to measure and evaluate the achievement of these goals through outreach activities (alternate learning assessments that match selected BPR products). In addition, assessment of available learning venues for varied age groups and priority order of attendance would be valuable in helping formulate which venues and audiences to target. Examples of potential outreach activities (also listed under subtopic B7.01) include, but are not limited to, the following:

- Exhibits and educational/informational material for conferences, workshops, and schools.
- Development and distribution of outreach brochures, newsletters to the general public.
- Student Flight Experiment Programs.
- Adult Ambassador Program, e.g., advocacy speakers for community education and outreach events
- Alliance with Collegiate Alumni Learning Weekend Programs.
- Development of Partnership with retirement organizations for a planning and implementation of a program with appropriate learning experiences.
- Development and implementation of "learning laboratories" for science centers/museums.
- Publication of articles in general interest periodicals
- Publication of articles and reports in scientific journals
- Multimedia outreach products
- Outreach web sites
- Education briefs, fact sheets, press releases

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9.1.3 EARTH SCIENCE

NASA's Earth Science Enterprise uses satellites and other tools to intensively study the Earth in an effort to expand our understanding of how natural processes affect us, and how we might be affecting them. Such studies will yield improved weather forecasts, tools for managing agriculture and forests, information for fishermen and local planners, and, eventually, the ability to predict how the climate will change in the future. Earth Science has three main components: a series of Earth-observing satellites, and advanced data system, and teams of scientists who will study the data. Key areas of study include clouds; water and energy cycles; oceans; the chemistry of the atmosphere; land surface; water and ecosystem processes; glaciers and polar ice sheets; and the solid Earth. Working together with the nations of the world, Earth Science seeks to improve our knowledge of the Earth and to use that knowledge to the benefit of all humanity.

http://earth.nasa.gov

TOPIC E1 Instruments for Earth Science Measurements

NASA's Earth Science Enterprise is studying how our global environment is changing. Using the unique perspective available from space and airborne platforms, NASA is observing, documenting, and assessing large-scale environmental processes, with emphasis on biology and biogeochemistry of ecosystems and the global carbon cycle, global water and energy cycle, climate variability and prediction, atmospheric chemistry, and solid Earth and natural hazards. A major objective of the ESE instrument development programs is to implement science measurement capabilities with small or more affordable spacecraft so that the 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 the Instruments for Earth Science Measurements SBIR topic is to develop and demonstrate instrument component and subsystem technologies which reduce the risk, cost, size, and development time of Earth observing instruments, and enable new Earth observation measurements. The following subtopics are concomitant with this objective and are organized by measurement technique.

E1.01 Passive Optics
Lead Center: LaRC
Participating Center(s): ARC, GSFC, JPL

The following technologies are of interest to NASA for development through the 2003 SBIR program in the remote sensing Subtopic "Passive Optics." Passive optical remote sensing generally requires large apertures, and certainly large throughput devices. NASA is interested primarily in instrument technologies suitable for aircraft or space flight platforms, and these inherently 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 UV through the far infrared. Technical and scientific leads at NASA have given careful consideration to the technology areas described below, and responses are solicited for these topics. Development of techniques, components and instrument concepts that are likely to be available for use in actual deployed devices/systems within the next few years is encouraged. Technologies suitable only for micro-optics are not applicable to this subtopic.

- Stiff actuator technology designed to produce precisely controlled uniform motion of large optical elements intended for use in tunable Fabry-Perot and FTS instruments. Motion ranges of particular interest include 20-30 microns, 1-2 mm, and 5 -100 cm. Techniques applicable to very cold temperature (<150 K) and vacuum operation of optical components equipped with these actuators are especially desired.
- Technology leading to significant improvements in capability of large format (> 1 inch diameter), very narrow band (<5 cm-1 FWHM), high throughput infrared (3-15 micron) optical filters.
- Technology and methods for specification and very accurate characterization of optics fabricated via deterministic (non-random) processes.
- Tunable high performance UV detectors in the 300-350 nm spectral range with high quantum efficiency (80%), high responsivity, low noise, and ambient temperature operation.
- High performance four-bands two-dimensional (2-D) arrays (128x128 elements) in the 0.3 – 2.5-micron wavelength range with high quantum efficiencies (60% - 80%) in all spectral bands, low noise, and ambient temperature operation.
- Components and instruments, suitable for use on small aircraft platforms, that advance capabilities in spectral polarimetry of aerosols and clouds in Earth's atmosphere. Complete polarimeters, with polarizer and detector integrated as a matched system, are of special interest. The wavelength range of primary interest includes 0.5-1.5 microns. Use and measurements of both linear and circular polarizations are desired.
- Technology which advances capabilities in airborne sunphotometry, especially combining sky-pointing or sky-imaging with sun-tracking measurements, improving aerosol-gas separation (e.g., via improved spectral resolution), improving or simplifying detector and/or filter technology that is specifically geared towards airborne measurements.

- High signal to noise IR detectors for terrestrial fire assessment, thermal infrared detectors (3-13 microns) with improvement of signal to noise ratio to better than 10,000 to 1 and small size. For atmosphere sensing, array detectors sensitive to a smaller bandwidth (~ 3-5 microns,) but still providing better than 10,000:1 signal-to-noise ratio via a single acquisition frame, are also sought.
- Uncooled detector technology such as microbolometer arrays in the thermal IR range with array size 2 or 3 times larger than the present size of 240x320 elements.
- Optical technologies and instruments leading to highly accurate measurements of ammonia distributions in the Earth's atmosphere from aircraft or space-based platforms. Accuracy at the 1-2 parts per billion range is sought.

E1.02 Lidar Remote Sensing
Lead Center: LaRC
Participating Center(s): GSFC, JPL

High 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, and high performance. Innovative technologies that can expand current measurement capabilities to airborne, spaceborne, or Unmanned Aerial Vehicle (UAV) platforms are particularly desirable. Components, subsystems, and complete instrument packages addressing the following measurement and technology needs will be considered:

- Lidar instruments and components for measurement of molecular species (ozone, water vapor, carbon dioxide, and methane). Emphasis is on measurements from airborne (including UAVs) and spaceborne platforms.
- Lidar instrument and components for cloud and aerosol measurements, with emphasis on aerosol optical properties. Emphasis is on next-generation systems such as multiple wavelengths, high spectral resolution (HSRL), or other advanced measurement concepts.
- Lidar instruments and components for direct-detection and coherent (heterodyne) measurement of wind profiles. Advances are sought for components such as Fabry-Perot interferometers and scanning technologies for direct detection, optics and telescope/scanner technologies for coherent detection, and components that may be used for both direct detection and coherent detection. Emphasis is on airborne and spaceborne applications. (Note: fiber optic interferometers are not considered responsive to this area.)
- Lidar instruments and components for measurement of vegetation. Scanning and/or imaging approaches are preferred. Emphasis is on measurements from airborne and spaceborne platforms.
- Innovative component technologies that directly address measurement needs above, including:
    - High efficiency lasers, laser components, and optics
    - Solid-state laser materials for diode pumping
    - Non-linear optical materials for frequency conversion
    - Thermal designs, components, and materials for conductively cooled diode pumped solid state lasers
    - Large aperture, lightweight telescopes and scanning optics
    - Efficient, low noise, high quantum efficiency single element detectors and detector arrays
    - Data acquisition systems (may also include data acquisition algorithms)

E1.03 In Situ Sensors
Lead Center: GSFC
Participating Center(s): ARC, MSFC

Proposals are sought for the development of in situ measurement systems that will enhance the scientific and commercial utility of data products from the Earth Science Enterprise program and that will enable the development of new products of interest to commercial and governmental entities around the world. Technology innovation areas of interest include:

- Autonomous, reusable, GPS-located ocean platforms to measure and transmit to remote terminals upper ocean and lower atmosphere properties including temperature, salinity, momentum, light, precipitation, and biology. Similar sensor packages for use onboard ships while under way.
- Small, lightweight instruments for measuring cloud liquid water or ice content (mass) designed for use on radiosondes, dropsondes, aerosondes, tethered balloons, or kites.
- Instruments for measuring radiation flux (broadband shortwave and longwave), ozone and the bromine and chlorine compounds important to ozone chemistry, and the geomagnetic field. Sensors should be capable of use on Ultra Long Duration Balloons flying at 35 km altitude for periods over 100 days.
- Wide-band microwave radiometers capable of high-speed characterization of cloud parameters, including liquid and ice phase precipitation, that can operate in harsh environmental conditions (e.g., on-board ships and aircraft).
- Compact, lightweight instrumentation for in situ discrimination of biological and inert airborne particles, including genetic identification capability.
- Autonomous GPS-located airborne sensors that remotely sense atmospheric wind profiles in the troposphere and lower stratosphere with high spatial resolution and accuracy.
- Systems and devices for measurement of atmospheric aerosol chemical, microphysical, and radiative properties. Autonomy is desired for ground-station network applications and deployment aboard aircraft.
- Systems for in situ measurement of atmospheric electrical parameters including electric and magnetic fields, conductivity, and optical emissions.
- Systems to measure line- and area-averaged rain rate at the surface over lines of at least 100 meters and areas of at least 100x100 meters.
- Lightweight, low-power systems that integrate the functions of inertial navigation systems and GPS receivers for characterizing and/or controlling the flight path of remotely piloted vehicles.
- Low-cost, stable (<1% over several months), portable radiometric calibration devices in the shortwave spectral region (0.3 to 3 microns) for field characterization of radiance instruments like sunphotometers and spectrometers.
- Systems for autonomous in situ measurement of atmospheric trace gases relevant to global tropospheric and stratospheric chemistry aboard aircraft.
- Miniaturized, low (12V DC) power instruments especially suited for small boat operations that are capable of adequately resolving, at the appropriate accuracy, the complex vertical structure (optical, hydrographic, and biogeochemical) of the coastal ocean (turbid) water column. Sensors that can be easily integrated within a digital (serial) network to measure the apparent and inherent optical properties of sea water are preferred.
- Instruments to support oceanic carbon investigations (e.g., primary production, bicarbonate concentration, dissolved and particulate organic matter, and fluorescence line height) that either improve upon existing capabilities (calibration sources working in the UV) or bring emerging technologies to maturity (liquid core optical fiber and holographic filter methodologies).
- Portable field instruments for measuring ecosystem-atmosphere carbon exchange and ecosystem parameters affecting carbon exchange, such as, a) soil and vegetation carbon stocks and change; b) isotopic abundances and ratios of biogenic chemicals using small (on the order of milligrams) samples; c) nondestructive mass measurements of large trees using direct mechanical or biophysical methods (rather than allometric correlations); and d) compact, light-weight sensors providing well-calibrated hyperspectral images of complex scenes at short ranges.
- Instrumentation for measuring the structure and biomass change, particularly in dense vegetation with canopies shorter than 5 m, at accuracies of 0.5 to 1 kg m-2 and 10 to 25 km spatial scales (recommended approaches include imaging lidar, hyperspatial-multiangular-hyperspectral optical imagery, interferometric SAR, and SAR-profiling lidar systems).

E1.04 Passive Microwave
Lead Center: GSFC
Participating Center(s): JPL

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 microwave frequency band from, principally, about 1 to 300 GHz, but also with applications outside that band. 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, 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 an important element of competitive proposals under this solicitation.

Specific technology innovation areas include:

- Imaging radiometers, receivers or receiver arrays on a chip, and flux radiometers for microwave wavelengths (1 - 500 GHz).
- Large aperture, deployable antenna systems suitable for highly reliable space deployment with RMS surface accuracy approaching 1/50th wavelength. Such large apertures can be real or synthetic apertures. Of key importance is the ability for a highly compact launch configuration, followed by a highly reliable erection and resultant surface configuration. Novel approaches to beam steering for these very large aperture antenna systems are also desired.
- Enhanced onboard data processing capabilities that enable real-time, reconfigurable computational approaches that enhance research flexibility. Such approaches should improve image reconstruction, enable high compression ratios; improve atmospheric corrections and the geolocation and geometric correction of digital image data.
- Techniques for the detection and removal of Radio Frequency Interference (RFI) in microwave radiometers are desired. Microwave radiometer measurements can be contaminated by RFI that is within or near the reception band of the radiometer. Electronic design approaches and subsystems are desired that can be incorporated into microwave radiometers to detect and suppress RFI, thus insuring higher data quality.
- New technology calibration reference sources for microwave radiometers that provide greatly improved reference measurement accuracy. High emissivity (near black body) surfaces are often used as on-board calibration targets for many microwave radiometers. NASA seeks ways to significantly reduce the weight of aluminum core target designs, while reliably improving the uniformity and knowledge of the calibration target temperature. NASA seeks innovative new designs for highly stable noise-diode or other electronic devices as additional reference sources for on-board calibration. Of particular interest are variable correlated noise sources for calibrating correlation-type receivers used in interferometric and polarimetric radiometers.
- New approaches, concepts and techniques are sought for microwave radiometer system calibration over or within the 1-300 GHz frequency band, that provide end to end calibration to better than 0.1Ø°, including corrections for temperature changes and other potential sources of instrumental measurement drift and error.
- Focal plane array modules for large-aperture passive microwave imaging applications.
- Microwave and millimeter wave frequency sources are sought as an alternative to Gunn diode oscillators. Compact (<10cm^3) self contained oscillators with output frequency between 40 GHz

and 120 GHz, low phase noise <125 dBc/Hz @ 1kHz, and high output power (>100 mW) are needed.

- Low noise (<1000K) with low conversion loss (< 6 dB), compactly designed (< 8 cm^3) heterodyne mixers requiring low local oscillator drive power (<2mW), are needed over the frequency range between 100 GHz and 1 THz. Multi-GHz. Low power, 4-bit undersampling analog-to-digital converters and associated digital signal processing logic circuits.
- Low power lightweight microwave radiometers are desired that are able to operate stably over long periods, with DC power consumption of less than 2 W and preferably less than 1 W, not including any mechanisms.
- MMIC LNA for spaceborne microwave radiometers, covering the frequency range of 165 to 193 GHz, having a noise figure of 6.0 dB or better (and with low 1/f noise).
- NASA is developing satellite systems that will use passive and active microwave sensing at L-band and other frequencies to measure sea surface salinity, and soil moisture to a depth of ~ 10 cm. In support of these global research efforts, the following ancillary measurement systems are required:
    - Inexpensive approaches to ground sensors are desired that are capable of measuring areas at least 100,000 km2, with spatial resolution of 20 km. These ground sensors will be needed to validate those space-borne measurements. Measurement of ground-wave propagation characteristics of radio signals from commercial sources may satisfy that need. Although absolute values of soil moisture are desirable, they are not required if the technique can be calibrated frequently at suitable sites. Cost per covered area, autonomous operation, anticipated accuracy and depth resolution of the soil moisture measurement will be considerations for selection.
    - Autonomous GPS-located ocean platforms are needed that can measure upper ocean and lower atmosphere properties including temperature, salinity, momentum, light, precipitation, and biology, and can communicate the resultant data and computational or configuration instructions to and from remote terminals. Similar sensor packages are desired for use onboard ships while under way. This includes the development of intelligent platforms that can change measurement strategy upon receipt of a message from a command center.
    - Autonomous low-cost systems are desired that can measure earth and ocean surface and lower atmospheric parameters including soil moisture, precipitation, temperature, wind speed, sea surface salinity, surface irradiance and humidity.
    - Novel approaches to beam steering for these very large aperture antenna systems are also desired. This includes:
        - lightweight, electronically steerable, dual-polarized, phased-array antennas,
        - shared aperture, multi-frequency antennas
        - high-efficiency, high power, low-cost, lightweight, phase-stable transmit/receive modules.
        - Advanced antenna array architectures including scalable, reconfigurable and autonomous antennas
        - Sparse arrays, digital beamforming techniques, time domain techniques, phase correction techniques
        - Distributed digital beamforming and on-board processing technologies
        - Brightness temperature/scatter co-registration data processing algorithms, data reduction and merging techniques.
- Ground-based microwave radiometer instrumentation, subsystems, and techniques for validating space borne precipitation measurements.
    - Passive microwave instrumentation, or subsystems, capable of ground-based retrievals of precipitation. The instrumentation, or subsystems, shall operate in inclement weather conditions without the interfering affects of liquid water accumulation on the aperture or field-of-view obstructions. Capabilities for volumetric scanning of the atmosphere and autonomous operation are of great interest.

E1.05 Active Microwave
Lead Center: JPL
Participating Center(s): GSFC

Active microwave sensors have proven to be ideal instruments for many Earth science applications. Examples include global freeze/thaw monitoring and soil moisture mapping, accurate global wind retrieval and snow inundation mapping, global 3-D mapping of rainfall and cloud systems, precise topographic mapping and natural hazard monitoring, global ocean topographic mapping and glacial ice mapping for climate change studies. 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. High performance yet affordable radars will provide data products of better quality and deliver them to the users more timely and frequently, with benefits for science, as well as civil and defense communities. Technologies which 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.

The frequency and bandwidth of operation are mission driven and defined by the science objectives. For SAR applications, the frequencies of interest include UHF (100 MHz), P-band (400 MHz), L-band (1.25 GHz), X-band (10 GHz) and Ku-band (12 GHz). The required bandwidth varies from a few MHz to 20 MHz to 300 MHz to achieve the desired resolution; the larger the bandwidth, the higher the resolution. Ocean altimeters and scatterometers typically operate at L-band (1.2 GHz), C-band (5.3 GHz) and Ku-band (12 GHz). Ka-band (35 GHz) interferometers have application to river discharge. The atmospheric radars operate at very high frequencies (35 GHz and 94 GHz) with only modest bandwidth requirements on the order of a few MHz.

The emphasis of this subtopic is on core technologies that will significantly reduce mission cost and increase performance and utility of future radar systems. Specific areas in which advances are needed include:

SAR for surface deformation, topography, soil moisture measurements:

- Lightweight, electronically steerable, dual-polarized, L-band phased-array antennas.
- Very large aperture L-band antennas (50 m x 50 m) for MEO SAR applications.
- Shared aperture, multi-frequency antennas (P/L-band, L/X-band).
- Lightweight deployable antenna structures and deployment mechanisms.
- Rad-hard, high-efficiency, high power, low-cost, lightweight L-band & P-band T/R modules.
- High-power transmitters (L-band, 50-100KW)
- L-band and P-band MMIC single-chip T/R module.
- Rad-hard, high-power, low-loss RF switches, filters and phase shifters.
- Digital true-time delay (TTD) components.
- Thin-film membrane compatible (flex) electronics.
- Advanced transmit/receive module architectures such as optically fed T/R modules, signal up/down conversion within the module and novel RF and DC signal distribution techniques.
- Advanced radar system architectures including flexible, broadband signal generation and direct digital conversion radar systems.
- Advanced antenna array architectures including scalable, reconfigurable and autonomous antennas; sparse arrays; phase correction techniques.
- Distributed digital beamforming and on-board processing technologies.

- SAR data processing algorithms and data reduction techniques.
- SAR data applications and post-processing techniques.

Low-Frequency SAR for Subcanopy and Subsurface Applications:

- Lightweight, large aperture (30m diameter) reflector/reflectarray antennas
- Large electronically scanning P-band arrays
- Shared aperture, dual-polarized, multiple low-frequency (VHF through P-band, 50-500 MHz) antennas with highly shaped beams.
- Lightweight, low frequency, low loss antenna feeds (VHF through P-band, 50-500 MHz)
- High-efficiency T/R modules and transmitters (50-500 MHz, 10KW)
- Lightweight deployable antenna structures and deployment mechanisms.
- Data applications and post-processing techniques.

Polarimetric Ocean/Land Scatterometer:

- Multi-frequency (L/Ku-band) lightweight, deployable reflectors.
- Large, lightweight, electronically steerable Ku-band reflectarrays.
- Lightweight L-band and Ku-band antenna feeds.
- Dual-polarized antennas with high polarization isolation.
- Lightweight deployable antenna structures and deployment mechanisms.
- High efficiency, high power, phase stable L-band and Ku-band transmitters
- Low-power, highly integrated radar components.
- Calibration techniques, data processing algorithms and data reduction techniques.
- Data applications and post-processing techniques.

Wide Swath Ocean & Surface Water Monitoring Altimeters:

- Shared aperture, multi-frequency (C/Ku-band) antennas.
- Large, lightweight antenna reflectors and reflectarrays.
- Lightweight C-band and Ku-band antenna feeds.
- Lightweight deployable antenna structures and deployment mechanisms.
- High efficiency, high power (1-10KW) C-band and Ku-band transmitters.
- Real-time on-board radar data processing
- Calibration techniques, data processing algorithms and data reduction techniques.

Ku-band & 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).
- Ka-band along/across track interferometers with few centimeters height accuracy.
- Ku-band interferometric polarimetric SAR.
- Phase-stable Ku-band and Ka-band electronically steered arrays and multi-beam antennas.
- Lightweight deployable reflectors (Ku-band and Ka-band).
- Shared aperture technologies (L/Ku-band)
- Phase stable Ku-band and Ka-band receive electronics
- High-efficiency, rad-hard Ku-band and Ka-band T/R modules or >10KW transmitters
- Ku-band and Ka-band antenna feeds
- Calibration/metrology for accurate baseline knowledge
- Real-time on-board radar data processing
- Data applications and post-processing techniques.

Atmospheric Radar:

- Low sidelobe, electronically steerable millimeter wave phased-array antennas and feed networks.
- Low sidelobe, multi-frequency, multi-beam, shared aperture millimeter wave antennas (Ka-band and W-band).

- Large (~300 wavelength), lightweight, low sidelobe, millimeter wave (Ka-band and W-band) antenna reflectors and reflectarrays.
- Lightweight deployable antenna structures and deployment mechanisms.
- High power (10 Kwatt) Ka-band and W-band transmitters.
- High-power (>1kW,duty cycle >0.05), wide bandwidth (>10%) Ka-band amplifiers.
- High-efficiency, low-cost, lightweight Ka-band and W-band transmit/receive modules.
- Advanced transmit/receive module concepts such as optically fed T/R modules.
- On-board (real-time) pulse compression and image processing hardware and/or software.
- Advanced data processing techniques for real-time rain cell tracking, and rapid 3-D rain mapping.
- Lightweight, low-cost, Ku/Ka band radar system for ground based rain measurements.

E1.06 Passive Infrared - Sub Millimeter
Lead Center: JPL

Many NASA future Earth science remote sensing programs and missions require microwave to submillimeter wavelength antennas, transmitters, and receivers operating in the 3-cm to 100-micron wavelength range (or a frequency range of 10 GHz to 3 THz). General requirements for these instruments include large-aperture (possibly deployable) antenna systems with rms surface accuracy of <1/50th wavelength (or better); the ability to scan or image many beamwidths on the sky(array receivers); small low-power MMIC radiometers, and high-throughput, low power, backend correlators and spectrometers. The focus is on technology for passive radiometer systems that are more spectrally flexible, lighter, smaller, and use less power. These systems must be of durable design for use on aircraft platforms and at remote/autonomous observatory sites; they must also be suitable for space applications with lifetimes of 5 years or more. Earth remote sensing receivers typically operate at LN2 (or higher) temperatures and require moderate noise performance. Advances in cooler technology will enable use of technology presently used in astrophysics receivers, which are cooled to a few Kelvin for better sensitivity, requiring near quantum- noise-limited performance.

For these systems, advancement is needed in primarily three areas: (1) the development of frequency-stabilized, broadband, tunable, fundamental local oscillator sources covering frequencies between 160 GHz and 3 THz; (2) the development of submillimeter-wave mixers in the 300-3000 GHz spectral region with improved sensitivity, stability, and IF bandwidth capability; (3) the development of higher-frequency and higher-output-power MMIC circuits.

Specific innovations or demonstrations are required in the following areas:

- Heterodyne receiver system integration at the circuit and/or chip level is needed to extend monolithic microwave integrated circuit (MMIC) capability into the submillimeter regime. MMIC amplifier development for both power amplifiers and low noise amplifiers at frequencies up to several hundred GHz is solicited. Integration of a local oscillator multiplier chain, mixer, and intermediate frequency amplifier is one example. There is also a specific need to demonstrate radiometer systems using phased-arrays and MMIC radiometers from 60 GHz, to approximately 400 GHz.
- Solid-state, phase-lockable local-oscillator sources with flight-qualifiable design approaches are needed with >10 mW output power at 200 GHz and >100 micro-watts at 1 THz; line widths should be <100 kHz. Since heterodyne mixers are relatively broadband, a major limitation of existing local oscillator sources is narrow tuning range, which requires many devices for the broad spectral coverage. For example, a single local-oscillator source that could tune from 1-2 THz with flat output power in excess of 10 micro-watts would find immediate use. These local oscillator sources should be compact and have direct current power requirements <20 W.
- Stable local-oscillator sources are needed for heterodyne receiver system laboratory testing and development.
- Multi-channel spectrometers that analyze intermediate frequency signal bandwidths as large as 10 GHz with a frequency resolution of <1 MHz, that are small and lightweight, and that use low direct current power (<5 mW per channel) with high stability.

- Compact and reliable millimeter and submillimeter imaging instrumentation that produces high sensitivity images simultaneously in multiple spectral bands.
- Schottky mixers with high sensitivity at T = 100K and above.
- Superconducting HEB mixers and SIS mixers.
- Receivers utilizing planar diodes or alternative reliable technologies in the 300-3000 GHz spectrum.
- Lightweight and compact radiometer calibration references covering 100-800 GHz frequency range.
- Lightweight, field portable, compact radiometer calibration references covering frequencies up to 200 GHz. The reference must be temperature stable to within 1 Kelvin with a minimum of 3 temperature settings between 250 and 350 Kelvin.
- Low cost special purpose ground based receivers to detect signals radiated from active satellites that are in orbit, for estimating rain rate, water vapor, and cloud liquid water.
- Large diameter (up to 25-m) deployable antennas suitable for Earth remote sensing at frequencies up to 30 GHz.
- Calibrated radiometer systems that can achieve accuracy and stability of 0.1 K.

Astrophysics receiver-detector technology proposals are also solicited, specifically under topic S2.01, Sensors and Detectors for Astrophysics.

E1.07 Thermal Control for Instruments
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC, MSFC

Future instruments and platforms for NASA's Earth Science Enterprises will require increasingly sophisticated thermal control technology. For example, optical alignment needs and sensors require ever tighter temperature control, heat flux levels from lasers and other similar devices are increasing (up to >100 W/cm2), and cryogenic applications are becoming more common. Large, distributed structures such as mirrors will require creative techniques to integrate structural, mechanical alignment, and thermal control functions in very light weight structures. The advent of very small instruments may also drive the need for new technologies, particularly since such small instruments will have low thermal capacitance. In general, high performance, versatility, low cost, smaller mass and volume (down to the MEMS level), and high reliability are the prime technology drivers. Furthermore, the drive towards 'off-the-shelf' commercial spacecraft buses presents engineering and technological challenges for instruments as such buses may be somewhat limited in resources. Innovative proposals for instrument thermal control systems are sought in the following areas:

- Miniaturized heat transport devices, especially those suitable for cooling sensors and very small electronics, at both ambient and cryogenic temperatures.
- Highly reliable, miniaturized Loop Heat Pipes and Capillary Pumped Loops which allow multiple heat load sources and multiple sinks.
- Advanced thermoelectric coolers capable of providing cooling at 150 K and below.
- Inexpensive radiative coolers for low earth orbit.
- Technologies for cooling very high flux (>100W/cm2) heat sources.
- Advanced thermal control coatings such as variable emittance surfaces and coatings with a high emissivity at cryogenic temperatures.
- High conductivity materials
- Advanced analytical techniques for thermal modeling, focusing on techniques that can be easily integrated
- Integrated structural, alignment, and thermal control concepts for very large structures, at both ambient and cryogenic temperatures.

TOPIC E2 Platform Technologies for Earth Science

NASA is fostering innovations that support implementation of the Earth Science (ES) Enterprise program, an integrated international undertaking to study the Earth system. ES uses the unique perspective available from orbit to study land cover and land use changes, short and long term climate variability, natural hazards, and environmental changes. Additionally, ES uses terrestrial and airborne measurements to complement those acquired from Earth orbit. ES has a parallel development effort to these platforms which include the largest ground and data system ever undertaken which will provide the facility for command and control of flight segments and for data processing, distribution, storage, and archival of vast amounts of Earth science research data. The ES Program defines platforms as the host systems for ES instruments. That is, they provide the infrastructure for an instrument or suite of instruments. Traditionally, the term 'platform' would be synonymous with 'spacecraft,' and it certainly does include spacecraft. However, 'platform' is intended to be much broader in application than spacecraft and is intended to include non-traditional hosts for sensors and instruments such as airborne platforms (piloted and unpiloted aircraft, balloons, drop sondes), terrestrial platforms, sea surface and subsurface platforms, and even surface penetrators. These application examples are given to illustrate the wide diversity of possibilities for acquiring Earth Science data consistent with the future vision of the ES Program and indicate types of platforms for which technology development is required.

E2.01 Structures and Materials
Lead Center: LaRC
Participating Center(s): ARC, JPL, JSC, MSFC

Advanced materials and structures technologies are needed for future ES platforms. These include materials and multifunctional structures that enable significant weight reduction and that possess extended life in the space environment, novel structural concepts for deployment to allow packaging of large apertures in small volumes, and innovative materials and technologies to enable dynamically and thermally stable platforms. Specific topics of interest include:

Multifunctional materials for structural applications
- Carbon nanotube-based composites
- Bio/nano inspired materials and composites
- Materials for morphing and adapting structures
- Self healing and self repair materials and concepts

Ultra-lightweight materials and large structural concepts
- Large deployable and/or inflatable/rigidizable aperture systems
- In-space assembly from modular multifunctional components
- Sensing and actuating materials and systems for quasi-static and dynamic control of large aperture wavefront errors
- Space rigidizable polymers

Low temperature materials for cryogenic applications
- Materials for cryogenic containment
- Insulation materials capable of retaining structural integrity while accommodating large operating temperatures ranging from cryogenic to elevated temperature conditions.

E2.02 Guidance, Navigation and Control
Lead Center: GSFC
Participating Center(s): JPL

Future ES architectures will include platforms of varying size and complexity in a number of mission trajectories/orbits. These platforms will include spacecraft, sounding rockets, balloons, and aircraft (both piloted and unpiloted). Advanced Guidance Navigation and Control (GN&C) technology is required for these platforms to address high performance/reliability requirements while simultaneously satisfying low power/mass/volume resource constraints. A vigorous effort is needed to develop guidance, navigation and control methodologies, algorithms, and sensor/actuator technologies to enable revolutionary Earth science missions. Of particular interest are highly innovative GN&C technology proposals directed towards enabling Earth Science 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. Novel approaches for the autonomous control of distributed Earth Science spacecraft and/or the management of large fleets of heterogeneous and/or homogeneous Earth Science assets are desired. Proposals that are either directed towards routine engineering enhancements of existing GN&C products, techniques and concepts or not directly related to the mission of NASA's Earth Science Enterprise will be judged to be non-responsive as they do not address the future NASA Earth Science technological challenges that will clearly require a significant leap beyond the current state of the art. Specific areas of research include:

Attitude/Orbit/Trajectory Determination and Control Technologies

- Control techniques/strategies/theories, signal filtering/processing advances, and improved environmental models for platform attitude/orbit/trajectory determination and control.
- Methods for rigid and flexible body control that are robust to parametric uncertainty and modeling error.

GN&C System Technologies

- Innovative GN&C testbed development capabilities and computer aided engineering, simulation and design tools with parallel algorithms for analysis and development of advanced GN&C systems. Open architecture object-oriented simulation tools and testbed systems for modeling and evaluating dynamically complex space systems.
- Advanced GN&C solutions for the Microsat attitude determination and control problem. Of special interest are low cost (at high production volumes) and highly integrated Microsat GN&C subsystems suitable for enabling both spin stabilized and three-axis stabilized Microsats. GN&C proposals that exploit and combine recent advances in miniature spacecraft subsystem architectures, spacecraft attitude determination and control theory, advanced electro-mechanical packaging, MEMS technology, ultra low power microelectronics are encouraged. Proposals that address the technologies needed to design and develop closed-loop spacecraft control system architectures that provide the "Drag-Free" precision orbit determination/maintenance capabilities needed for future ES LEO (Low Earth Orbit) formation-flying applications are of special interest. Technology solutions are encouraged which employ Drag-Free sensors (similar to accelerometers), high specific impulse (Isp) thrusters, and low-cost processors with appropriate closed-loop filtering/control algorithms to implement a complete Drag-Free spacecraft control system module.
- Vision-based GN&C system concepts, subsystems, hardware components and supporting algorithms/flight software. Applications of high performance video image processing technology to provide alternative solutions to challenging GN&C problems such as spacecraft relative range/attitude determination while in close formation and/or during proximity operations are of interest.
- Advanced GN&C solutions for balloon-borne stratospheric science payloads, including sub-arc second pointing control, sub-arcsecond attitude knowledge determination and trajectory guidance for individual balloon-borne payloads. Innovative techniques for modeling, simulating, and analyzing the inherent dynamics and control of balloon borne-payloads are of interest. Also of interest are innovative concepts, strategies, techniques, and methods for modeling, simulating, and analyzing formations, constellations and/or networks of multiple balloon-borne stratospheric science payloads.

GN&C Sensors and Actuators

- Advanced sensors and actuators with enhanced capabilities and performance, as well as reduced cost, mass, power, volume, and reduced complexity for all spacecraft GN&C system elements. Emphasis is placed on improved stability, accuracy, and noise performance. Non-traditional multi-functional sensor/actuator technology proposals are of particular interest. Proposals that address the GN&C needs for miniature reaction and momentum wheels, miniature star cameras/trackers, precision accelerometer-like sensors for "Drag-Free" spacecraft control and miniature Fine Guidance Sensors (FGS's) are encouraged.

- Low power, low mass, and low cost propulsive actuators, and related subsystem components, for generating attitude/orbit control torques/forces. Propulsive actuators that consume less than one watt of power at 3 volts, providing impulse bits on the order of one micro-N-sec for 3-axis control or 40 milli-N-sec for spin-stabilized control.
- Innovations in Global Positioning System (GPS) receiver hardware and algorithms that use GPS code and carrier signals to provide spacecraft navigation, attitude, and time:
  - Combined navigation/attitude space receivers, including advanced antenna designs/configurations,
  - Navigation techniques that may employ Wide Area Augmentation System (WAAS) corrections,
  - Navigation, attitude, and control for spacecraft proximity operations, and
  - Innovative uses of GPS which enable new Earth science measurements; for example, the use of differential GPS in repeating aircraft flight patterns and the use of ocean-reflected GPS signals.

Spacecraft Formation Flying Technologies

- Novel approaches to autonomous control of distributed spacecraft and the management of large fleets of heterogeneous and/or homogeneous assets. Submissions should focus on one or several of the following technologies and system-level concepts:
  - Formation self-organization
  - Reconfigurable control laws
  - Robust and fault-tolerant control laws
  - Algorithms for autonomous formation reconfiguration
  - Nonlinear, robust estimation algorithms for relative navigation
  - Integrated, multi-spacecraft formation guidance and control
  - On-board, multi-spacecraft, closed-loop responsiveness to sensed events
  - Low-cost approaches for formation navigation and control exploiting low-cost and existing technologies such as GPS Optimal (e.g., minimum fuel, minimum time) approaches for formation maintenance and maneuvering
  - Unique concepts for dealing with relevant perturbations and disturbances such as J2, solar radiation pressure, etc.
  - New modeling techniques to support the technologies and concepts listed above

E2.03 Command and Data Handling
Lead Center: GSFC

Advancing science with reduced levels of mission funding, shorter mission development schedules and reduced availability of flight electronic components creates new requirements for spacecraft Command and Data Handling (C&DH) systems. Specific areas for which proposals are being sought include:

Onboard Processing

- General purpose data processing - higher levels of spacecraft autonomy require higher levels of general purpose CISC and RISC processing with fault tolerance & error correction (system and application). Development of spacecraft computers that match or exceed the commercially available desktop computers is essential to meeting the "lights out" spacecraft control requirements.
- Special purpose data processing - higher levels of automated onboard science data processing such as histogramming, feature recognition and image registration are necessary to match the data gathering capabilities of future instruments with the limits of spacecraft to earth communications. Development of technologies such as Digital Signal Processors (DSP) and related hardware is necessary to address these future needs.
- Reconfigurable computing hardware - achieving pure hardware processing capabilities with the flexibility of reprogammability would allow different science objectives to be met with the same hardware platform. Development of technologies such as radiation hardened Field Programmable

Gate Arrays (FPGAs) and similar components for data communications and processing is necessary to achieve this goal.
- Low-power electronics - in order to provide higher capabilities on smaller less expensive spacecraft, lower power consumption components is essential to reducing solar array and battery sizes, affecting the overall spacecraft design. Development of low voltage, such as 3.3V or 2.5V or lower technologies is essential to achieving the power constraints of smaller spacecraft.

Command and Data Transfer
- Subsystem data transfer - communications between various spacecraft subsystems become increasingly important in order to realize higher autonomy. Development of technologies and architectures that increase the rate of data transfer above 20 Mbits/s are necessary to achieve the self-diagnosis, autonomous control, and science data transfer requirements.
- Intra-system data transfer - communications within the spacecraft subsystem (between cards within a box) is currently a limiting factor in achieving higher overall data throughputs. Development of technologies for communications within a box that would replace the conventional passive backplane are necessary to achieve higher science data throughput.

E2.04 Advanced Communication Technologies for Near-Earth Missions
Lead Center: GRC

To realize the Earth Science Enterprise vision of Sensor-Web, a host of in-space and terrestrial communication link technologies and protocols are required. These technologies are likely to perform in an internet-based multi-point to multi-point communication architecture. Furthermore, in this architecture, the spacecraft, as well as the ground systems will be fully capable of interfacing to commercial communication networks to transport data directly to the users. Innovations are sought in space communications technologies and satellite-terrestrial network protocols for data delivery from NASA's future Earth science enterprise near-earth spacecraft, constellations and platforms directly to users. Advanced techniques and products are solicited that support communication among NASA spacecraft and commercial GEO networks for data delivery to users in a cost-effective manner. In addition, ever increasing demands are being placed on missions conserving bandwidth and power resources, while driving up the demands for data transmission and access. Innovative communications technologies are sought at the device, subsystem and system level in such areas as microwave, millimeter wave and optical communications; onboard processing, reconfigurable communication systems, software radio technologies, modulation and coding, communications architectures and network technologies. Revolutionary or "breakthrough" improvements in communications technology are required to increase the success potential for planned NASA missions and enable missions for which adequate communications and information technologies do not presently exist. Advances in communications are sought that address provocative, unsolved or unexplored techniques that revolutionize existing methods and paradigms for packaging and communicating data or knowledge through space-time. Specifically, the required products are described below, but are not limited to the following:

Data Communications Technology
- High rate data communication microwave or optical system technologies for supporting multi-Gigabit/sec data rates between and from spacecraft LEO (Low Earth Orbit), MEO (Mid Earth Orbit) or GEO (Geo-synchronous Earth Orbit) orbits to ground networks. Communications include routing, encoding, encrypting of data to allow services on demand to address the need for autonomous spacecraft operations.
- Direct data distribution communication architectures (including multicasting) from LEO spacecraft directly to several users at various data rates and associated communication subsystems. Small, highly efficient, integrated communication receivers and transmitters for inter-spacecraft and constellation communications are needed.
- Communication link technologies to transfer data from an Earth observing balloon or airplane, where the collection and transmission of data is by Internet protocols.

Component Technology

- Innovative approaches to enable higher frequency, miniature, power efficient Traveling Wave Tube Amplifiers (TWTAs) operating at millimeter wave frequencies. Of particular interest is the development of TWTA's that can operate at communication bit rates of 10 Gbps or higher.
- Wide band-gap semiconductor (WBGS) based III-nitride devices for high power, high efficiency microwave/millimeter-wave solid state power amplifiers (SSPAs) and also devices for low noise microwave/millimeter-wave amplifiers. In addition, integration of III-nitride devices with III-nitride light emitting/detecting devices.
- Low loss MEMS based RF switches are needed that would enable the development of microwave components such as reconfigurable antennas, phase shifters, amplifiers, oscillators, filters for in flight control of the radio frequency bandwidth and power. Photonic band-gap and left-hand meta materials for microwave devices, circuits and components.
- RF component and sub system technologies that enable integration for system on chip packaging type, such as mixed signal (analog/digital/optical) communication systems. Low cost, Ka band flat plate array antennas and low noise block down-converters are desired for small earth terminal applications. Low cost, precision tracking Ka-band earth terminals for OC-3 (155 Mbts/sec.) to OC-12 (622 Mbts/sec.) data rates direct-to-earth downlinks from LEO/MEO spacecraft are also of interest. Wide scan angle (+/-60 degrees), low profile, transmit/receive Ka-band antennas, Ku-Ka band transceivers and closed loop acquisition/tracking algorithms for low-orbit space platforms and communication satellites are desired. Fractal-Element antennas are required for size reduction, broad or multi-band, increased gain and beam agility.
- V-Band (60 GHz) receiver components, in particular, low phase noise local oscillators, voltage controlled oscillators, and low loss down-converters.
- Digital components enabling space-based networking. Routers, switches and network interface cards, network processors.
- Reconfigurable, multi-mode transceivers, software radio technologies, etc., which can lead to integration in FPGA, DSP, GPP. Onboard signal processing; bandwidth- and power-efficient modulation and coding; low power transceivers; integrated wireless devices.
- Integrated communications and relative navigation subsystems to perform high data rate, continuous communication with precise onboard relative navigation.
- Internet-based protocol modules and architectures that will provide seamless network continuity between terrestrial and aerospace-based platforms and environments.

Optical Communications

- High (greater than or equal to 15%) over-all efficiency 1550 nm amplifiers; large (greater than or equal to 250 micron) diameter, high- speed (greater than 2.5 Gbps), In GaAs APD and PIN detectors; simplified acquisition, tracking and pointing architectures for LEO to GEO links; end-to-end optical communications which allow for higher bandwidth availability and greater than 10 Gbps data rates; simulation program with emphasis on acquisition, tracking and pointing.
- Highly sensitive photoconductors (e.g., SiGe) which could dramatically improve the link budget for intersatellite links.
- Integrated optoelectronic and microwave components into a system-on-a-chip architecture.
- Novel integrated optical sensors and RF circuitry to improve the acquisition, tracking and beam pointing capability of single-aperture RF communication links.
- Novel techniques for signal coupling into optical fibers and/or waveguides and switching networks to route the signals within transceiver circuits.
- Revolutionary low voltage electro-optic modulation technologies; e.g., improvements with respect to Mach-Zehnder electro-optic modulators; electro-optic modulators based on thin film ferroelectrics such as lead-lanthanum-zirconium titanate (PLZT).
- Signal encoding using electro-optic modulation, as opposed of using tunable lasers (where a microwave signal is generated by mixing optical signals at two slightly different frequencies).
- Transmit/receive modules for optical phased array antennas.
- Characterization techniques and methodologies for optical phased array antennas.
- Coding methods to maximize the data rate and improve the bit error rate from space probes.
- Optical beam forming for optical phased array antennas.

- Radiation hard optical components and devices; trade-off studies between optical as well as optical/RF circuit performance and radiation hardness.
- Optical wave guide devices.

Protocols and Architectures

- Internet-based protocol modules and extensions that will support seamless connectivity between terrestrial and aerospace platforms by mitigating variable latencies and bit error rates among distributed air and spacecraft to terrestrial gateways.
- Novel methodologies for performing medium to large-scale simulations of space internet architectures, protocols and applications.
- Advanced network security technologies to assure integrity and authentication of data from the public Internet to protected space-based networks.
- Adhoc and innovative lightweight networking protocols to support spacecraft constellation, formation flying, satellite clusters, proximity and sensor based networks.

Breakthrough Communications Technology

- Methods or techniques which demonstrate breakthrough means of effectively "packaging," "storing" and/or "transferring" information or knowledge directly between separate, independent entities using new techniques including, but not limited, "qubit" type devices. Transferring knowledge directly must be suggested or accomplished without first breaking down the information into fundamental "data" transmission elements such as bits, bytes, symbols or other "raw data" types.
- 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.
- Breakthrough power-efficiency in communications brought about through the use of natural phenomenon, e.g., soliton pulse/wave/energy propagation.
- Verifiable holographic or other multi-dimensional breakthrough communications technologies, which enable credible, repeatable communications techniques. Demonstrating functionality is more crucial than theoretical explanations for the effects.
- Enhancements in modulation, coding, protocol development and information or knowledge routing brought about through the inspection or imitation of effective biological, biochemical and other natural and living systems. Examples include cellular "messenger molecules", adapters, aquatic bio-systems and any other communications systems occurring in nature which may demonstrate breakthrough enhancements to existing space communications paradigms.
- Demonstrations of using biological or living systems to successfully, effectively and/or efficiently transfer data, information or knowledge directly, intentionally and controllably between other nonliving (electronic, etc.) mediums for use in bio or living networks or systems.
- Provocative, nonstandard uses of radiofrequency spectrum for demonstrating practical yet breakthrough means of communications.
- Innovative uses of planetary atmospheres or planetary electromagnetic properties for the breakthrough communication of data, information or knowledge directly between independent entities.
- Enhancements in automated communications carriers through any type of media (including living) where a breakthrough improvement due to the technique can be explained or demonstrated.
- Development of nano-scale communication devices and systems (e.g., FET arrays, nano-antennas, etc.) for nano-satellite applications.

E2.05 On-Board Propulsion
Lead Center: GRC
Participating Center(s): GSFC, JSC, MSFC

This subtopic seeks technologies that will significantly increase capabilities and reduce costs for Earth science spacecraft. Propulsion functions include orbit insertion, orbit maintenance, constellation maintenance, precision positioning, in-space maneuvering, and de-orbit. Propulsion technologies are sought that will provide platforms with larger scientific payloads, longer-life missions, and increased operational flexibility during missions. To accomplish these goals, innovations are needed in low thrust chemical and electric propulsion technology, including thruster components, advanced propellants, power processing units, and feed system components. Of particular interest are innovations in propulsion technology that lead to smaller-sized, integrated, autonomous spacecraft. The following specific areas are of interest:

Miniature/Precision Propulsion

- Propulsion technologies for spacecraft less than 10 kg that emphasize system simplicity, low power requirements, and minimal mass. This includes concepts with fundamentally different approaches to propulsion than for larger scale spacecraft, accounting for the unique physics occurring in physically small propulsion devices. These technologies could leverage micro- electromechanical system (MEMS) fabrication techniques, though more robust substrate materials are also sought.
- Propulsion technologies to provide high-precision (impulse bit < 100 milliNewton-second) stationkeeping and attitude control.

Thruster Technology

- High-performance, high-efficiency electrostatic and electromagnetic propulsion technologies, including thruster components and advanced power processing, for small, power-limited spacecraft.
- High-performance (specific impulse > 250 s), high-density monopropellant technologies, including propellant formulations, catalytic and noncatalytic decomposition methods, and chamber wall materials.
- High-performance (specific impulse > 360 s) bipropellant technologies for either non-toxic or hypergolic propellant systems
- Suitability of propellant gelation to enhance operability and performance of in-space propulsion operations.

Propulsion System Components

- Materials compatible with high-temperature, oxidizing, and reactive environments
- Components for fluid isolation, pressure/mass flow regulation, relief quick disconnect, and flow control
- Technologies for metering, injection, and ignition of fluids in combustion devices
- Gaseous storage and pressurization system
- Components for xenon storage and flow control

E2.06 Energy Storage Technologies
Lead Center: GRC
Participating Center(s): GSFC, JPL

Advanced power storage technologies are required for Earth science observation missions employing spacecraft, balloons, sounding rockets, surface assets, and piloted and robotic aircraft and marine craft. Improvements are sought in size, mass, capacity, reliability, and operational costs. A vigorous effort is needed to develop energy storage technologies that will enable the revolutionary Earth science missions.

The energy storage technologies solicited include batteries, regenerative fuel cells, alternative high-power-density storage technologies such as dual-use energy storage such as flywheels and structural batteries. Specific areas of interest are:

- Battery technologies are needed for spacecraft requiring greater than a 100 watt-hour per kilogram specific energy density and a 10-year lifetime in LEO (Low Earth Orbit). Flywheel technologies are needed for spacecraft requiring greater than a 100 watt-hour per kilogram specific energy density and a 10-year lifetime in LEO. Rechargeable lithium ion batteries with advanced anode and cathode materials and liquid/polymer electrolytes and other advanced battery systems capable of meeting the above performance criteria are of interest. For some terrestrial missions, energy storage is needed which is capable of delivering 30-50% of their ambient specific energy at temperatures as low as -100° C. Energy storage integrated into spacecraft structures is also of interest for future spacecraft. Micro flywheels with high Wh/kg and highly integrated components are needed for small spacecraft.

- Fuel cell and regenerative fuel cell technologies are of interest to NASA because they represent enabling technology for some robotic terrestrial and Earth observation missions. Improvements in specific energy, efficiency, life, cost, and operational overhead will benefit balloon and other terrestrial observation missions.
- Micro flywheels for small and mid-size spacecraft (200 to 2000W). Spacecrafts in LEO will require high wh/kg and highly integrated subsystem-to-subsystem components to achieve future Earth Science requirements.
- Future micro-spacecraft require distributed power sources with rechargeable batteries/fuel cells that can provide power in the micro to milliwatt range. Due to the low thermal mass of the micro-spacecraft in LEO, these spacecraft must operate over a wide temperature range (-100 to 100° C). Long cycle life performance capability is also needed for micro-rechargeable batteries.
- Power systems based on micromachining fabrication techniques and in energy storage components based upon carbon nano-tube, micro, and nano technologies.

E2.07 Energy Conversion for Space Applications
Lead Center: GRC
Participating Center(s): GSFC

Earth science observation missions will employ spacecraft, balloons, sounding rockets, surface assets, and piloted and robotic aircraft and marine craft. Advanced power technologies are required for each of these platforms that address issues of size, mass, capacity, reliability, and operational costs. A vigorous effort is needed to develop energy conversion technologies that will enable the revolutionary Earth science missions. Exploiting innovative technological opportunities, developing power systems for adverse environments, and implementing system-wide techniques which promote scalability, adaptability, flexibility, and affordability are characteristic of the technological challenges to be faced and are representative of the type of developments required beyond the current state of the art.

The energy conversion technologies solicited include photovoltaics, Brayton, Rankine, Stirling, and thermophotovoltaic, as well as related technologies such as concentrators and thermal technologies. Specific areas of interest are:

- Photovoltaic cell and array technologies with significant improvements in efficiencies, cost, radiation resistance, and wide operating conditions are solicited. Potential concepts include rigid arrays, concentrator configurations, and ultra lightweight array technologies that exploit the properties of lightweight, flexible thin film photovoltaic cells. Photovoltaic cell and array technologies for extreme environments such as high- or low-temperature operation are solicited. Technologies for electrostatically clean spacecraft solar arrays are also of interest.
- Future micro-spacecraft require distributed power sources that are integrated with microelectronics devices/instruments. These microelectronic devices/instruments integrate energy conversion and storage into a hybrid structure.
- Thermal power conversion technologies for earth orbiting spacecraft and/or orbit transfer vehicles are sought. Advances may be in solar concentrators (rigid or inflatable, primary or secondary) and receivers to improve specific power and reduce mass. Topics of interest in power conversion include heat cycles (Brayton, Rankine, and Stirling), compact heat exchangers, advanced materials and fabrication techniques, and control methods, as they relate to life, reliability and manufacturability. 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.

E2.08 Power Management and Distribution
Lead Center: GRC
Participating Center(s): GSFC, JPL

Earth science missions employ spacecraft, balloons, sounding rockets, surface assets, aircraft, and marine craft as observation platforms. Advanced technologies are required for the electrical components and systems on these platforms to address the issues of size, mass, capacity, durability, reliability, modularity, and operational costs. Using advanced materials and components, developing packages and coatings for adverse environments, and using intelligent, system-wide techniques that promote modularity, flexibility, and affordability are the technology challenges this subtopic will address. Advanced technologies for power management and distribution (PMAD) systems are sought in the following areas:

Environmentally Durable Technologies
Technologies that enable materials, surfaces, coatings, and components to be durable in a space environment, in atomic oxygen, soft x-ray, electron, proton, ultraviolet radiation, and thermal cycling environments are of interest to NASA. Environmentally durable coatings for radiators and lightweight electromagnetic shielding are sought.

Electrical Packaging
Packaging technologies capable of wide-temperature operation or radiation resistance for use in electrical power systems are also of interest. Thermal control technologies that are integral to electrical devices with high heat flux capability and advanced electronic packaging technologies that reduce volume and mass or combine electromagnetic shielding with thermal control are sought.

Electrical Materials and Components
Advanced magnetic, dielectric, semiconductor, and superconductor materials, devices, and circuits are of interest. Advancements in energy density, operating temperature, voltage capability, speed, or efficiency are required. Candidate applications include transformers, inductors, motors, semiconductor switches and diodes, integrated circuits, capacitors, micro batteries, electro-optical devices, micro-electro-mechanical systems (MEMS), carbon nanotube cables, current sensors, and low-loss soft-magnetic materials.

Power Conversion, Protection, and Distribution
Technologies that provide significant mass, size, low noise, high reliability, efficiency, or integration cost savings in electrical power conversion and protective switchgear components are of interest to NASA. Modular, building block technologies for power conversion/conditioning, battery charging, motor drives, distribution, and protection are sought that provide higher performance, simple system integration, and greater flexibility through the use of innovative topologies and intelligent controls. Advanced power distribution technologies such as combining power cables with the vehicle structure and advanced connector technologies are sought to reduce mass, increase reliability, and decrease integration costs.

Power Management
Management, control, and monitoring of electrical power systems with autonomous operation to improve the performance, safety, reliability, status reporting, and operations scheduling of terrestrial and aerospace power systems are of interest to NASA. Candidate technologies include: digital power management controllers, battery charge controllers, fault detection, fault isolation, autonomous fault recovery, active impedance control, active noise cancellation, built-in test, component and system health monitoring, and advanced circuit protection concepts.

TOPIC E3 Advanced Information Systems Technology

The Earth Science Enterprise (ESE) acquires, processes and delivers very large (gigabyte to terabyte) volumes of remote sensing and related data to public and government entities that apply this information to understand and solve problems in Earth Science. Information technology is currently employed throughout ESE's space and ground systems and the Advanced Information System Technology theme is soliciting technologies that apply to the end-to-end system functions. The information system functions found in ESE include data acquisition, data transmission, data processing, data management and storage, data distribution, data/metadata/document search, browse and access, data subsetting, knowledge discovery, spatio-temporal analysis, and visualization. The ESE is interested in advanced information technology that can improve any of these functions in isolation or in combination, or is able to support alternative architectures that better address the scientific requirements.

E3.01 Knowledge Discovery and Data Fusion
Lead Center: JPL

NASA's Earth Science Enterprise collects terabyte-scale datasets routinely during its missions, and charges the scientific community with extracting usable and scientifically relevant information from them. These data sets may be images, multispectral images, time series, or field and particle event lists. They may also be engineering time series about spacecraft health collected from on-board sensors. Emphasis has recently been placed on handling and analyzing in situ data from networks or sensorwebs. In addition to the ongoing challenges entailed by handling, analyzing and mining very large data sets, NASA now needs a new framework for performing science data evaluation onboard spacecraft and from in situ sensor networks. New onboard or in situ science capabilities will enable mission activities to be directed by scientists without the assistance of a ground sequencing team, and the constraints of communications links. The science capabilities will be adaptive in nature, and must be efficient in transmission of the usable key data.

This subtopic enlists help in developing a new generation of tools and algorithms for effective acquisition and analysis of data and image sets, appropriate for ground or onboard/in situ use. Of special interest are: 1) the ability to deal quantitatively with uncertainty present in data, perhaps in a statistical framework; 2) development of flexible models through which observables are linked to quantities of scientific or engineering interest; 3) harnessing database technology for organizing the observed data, models, and inferred knowledge, perhaps in onboard or in situ archives; 4) fusion of multiple datasets for enhanced scientific return; and 5) system concepts for handling interactions between onboard science analysis and event detection capabilities and other functions of an autonomous spacecraft or sensor web. One or more of these areas should be addressed by every proposal. Specific subtopics of interest include:

- Automated classification of data.
- Supervised and unsupervised learning methods.
- Knowledge discovery techniques.
- Image analysis and segmentation.
- Statistical pattern recognition.
- Time series feature extraction and analysis.
- Trainable object recognition.
- Automatic image registration and change detection.
- Visualization and rendering techniques.
- Spatiotemporal datamining.
- Intelligent, goal-directed data acquisition and/or compression.
- Science data analysis algorithms designed for scalable computing.
- System concepts for onboard science.
- Adaptive data acquisition techniques.

E3.02 Automation and Planning
Lead Center: ARC

The Automation and Planning Subtopic solicits proposals concerned with technologies that allow a spacecraft or ground system to react to uncertainties or unplanned events in a robust fashion, while still achieving a set of high-level goals or tasks. Technology innovations include, but are not limited to: 1) automation and autonomous systems that support high-level command abstraction; 2) efficient and effective techniques for processing large volumes of data into useful information; 3) intelligent search of large, distributed data archives; and 4) intelligent data discovery through search over heterogeneous datasets and architectures. Collaboration between Earth scientists and computer scientists is encouraged so that these proposals demonstrate useful results.

Specific areas of interest include the following, and offerors should identify their specific target categories:

- Autonomous agents: intelligent, autonomous search agents that support applications involving science data available on the internet.
- Autonomous data collection: automatic dynamic reconfiguration of space-based on-board data gathering instruments to make effective use of observing conditions, baseline image data priority scheme, history of observations, and limited on-board resources; note this work may arise form the UAV heritage.
- Autonomous data logging devices (software, or hardware and software) supporting a variety of weather/climate sensors, capable of ground-based operation in a wide variety of environmental conditions; such systems would probably be solar powered with accurate time stamping.
- Planning and scheduling methods related to Earth Science Mission objectives.
- System/subsystem health and maintenance, both space- and ground-based.
- Distributed decision making, using multiple agents, and/or mixed autonomous systems.
- Automated software testing.
- Verification and validation of automated systems.
- Legacy code maintenance and conversion.
- Automatic software generation and processing algorithms.
- Software tools for parallelization; tools for production planning.
- Control of Field Programmable Gate Arrays (FPGA) to provide real-time products, using hyper-spectral instrument data from airborne platforms.

E3.03 High Performance Computing and Networking
Lead Center: ARC

This subtopic focuses on innovations in efficient and effective information technology tools and techniques for enabling NASA's science discovery processes. The emphasis in these proposals must be on collaboration among domain experts, application developers, and computer scientists to develop and demonstrate such advanced IT technologies. Areas of interest include:

- Large-scale modeling and simulation
- Computer system performance modeling, prediction, and optimization
- Parallelization and performance analysis tools and techniques
- Runtime execution systems (e.g., smart operating systems, dynamic adaptive software environments to support cross-discipline interactions)

E3.04 Geospatial Data Analysis Processing and Visualization Technologies
Lead Center: SSC

Proposals are sought for the development of advanced technologies to enhance human and machine interaction in support of scientific, commercial and educational application of remote sensing data. An emphasis is on distributed and/or mobile teams in validation and verification exercises and for the commercialization of remote sensing data. Focus areas are to provide tools for interpretation, visualization or analysis of remotely sensed data and to provide qualitative and quantitative analysis tools and techniques for performance analysis of remotely sensed data. Applications can support the commercial remote sensing industry and enhance the commercial or educational application of Earth science data. Areas of specific interest include:

- Unique, innovative data reduction and rapid analysis methodologies and algorithms, particularly for hyperspectral data sets
- Innovative techniques for validation of imaging systems (i.e., thermal and Lidar imaging systems)
- Software tools for mobile computing and efficient data collection and/or presentation

- Innovative approaches for incorporation of GPS data into in situ data collection operations with dynamic links to spatial databases including environmental models
- Innovative techniques to automate quality assurance processes for science data products
- Distribution and sharing of fused science data sets to correlate similar data sets from diverse spacecraft and aerial vehicles and provide unique, commercially useful information products
- Data merge and fusion software for efficient production and real-time delivery of commercial digital products to teams and remote users
- Tools for enabling distributed scientific collaboration
- Software to automate the rapid processing and distribution of sub-setting and presenting RS data over a network
- Software to develop commercial products from digital topography and vegetation canopy data obtained from airborne and space-based active optical sensors
- Innovative approaches to technologies that contribute to the understanding of data through the display and visualization of some or all of the above data types including providing the linkages and user interface between the cartographic model and attribute databases
- Visualization of multivariate geospatial data including remotely sensed data from the following: airborne and satellite platforms, vector data from public and private archives; cartographic databases from public and private sources; continuous surface data held as a raster data model; and 3-D data held in a true 3-D raster model.

E3.05 Data Management and Visualization
Lead Center: GSFC
Participating Center(s): ARC

This subtopic focuses on innovative approaches to locating, summarizing and presenting large collections of Earth science data in a highly distributed and networked environment. Areas of technology innovation include:

- Design and implementation of a virtual reality CAVE for scientific data visualization Ideas can include: 3-D virtual reality environments that will let users 'fly' through the data space; precomputed data fly-throughs that let users search within the fly-through space (i.e., fast forward, reverse, slow motion) to locate specific areas of interest; incorporation of commodity data compression techniques (such as HDTV/MPEG) for reduced storage and transmission requirements; progressive compression and caching techniques that optimize resolution and performance when zooming in for additional detail; techniques for georectification, data overlays, data reduction, and data encoding that work across a distributed environment of widely differing data types and formats; development of integrated object oriented storage and compression techniques that are integrated into search algorithms; novel 3-D presentation techniques that minimize or eliminate the need for special user devices such as goggles or helmets; techniques for high bandwidth collaboration with other users in a distributed environment; development of techniques that invoke integrated visual and auditory presentation cues. Data viewing and real-time data browse, including fast, general purpose rendering tools for scientific applications. Viewing of multi-variate geospatial data including remotely sensed data.
- Tools for enabling distributed scientific collaboration
- Technologies supporting management, storage, search and retrieval of very large, distributed, geospatial earth science data volumes: Tools to facilitate automatic data product legacy, quality assurance and metadata updates. Object relational technologies specific for Earth sciences. Meta-data discovery to facilities the automated use of data from different sources. Automatic metric collection and analysis for data use and data ordering. Smart Objects Dumb Archives (SODA) and storage, archival and retrieval standards applicable to ESE mission requirements.

E3.06 On-Board Science for Decisions and Actions
Lead Center: ARC

Current sensors can collect more data than is possible to transmit to the ground for analysis. One solution is to incorporate intelligence in the sensor or platform to prioritize or summarize the data and send down high priority or synoptic data. In the future, a sensor-web capability will demand this remote on-board autonomy and intelligence about the kind and content of data being collected to support rapid decision-making and tasking. Most sensors operate remotely with limited resources; solutions are needed that efficiently operate in these environments to classify or understand the data to support decision and actions on-board or in conjunction with mission operations. This subtopic is interested in developing new methods to autonomously understand Earth Science data in support of making rapid decisions and taking actions.

- Software methods that can identify and select adaptive compression and/or prioritize data for transmission.
- Approaches that can reduce the complexity of data or identify redundant and low priority data in favor of novel or unique data.
- Methods to segment sensor data streams and for compression, analysis and/or summarization.

TOPIC E4 Applying Earth Science Measurements

The Earth Science Enterprise (ESE) continues to strive to better understand how the global environment is changing, predict change and understand how these changes affect the human and economic condition. In this Topic, the Enterprise wants innovative companies to propose technology and techniques to accomplish two goals: Goal 1, accelerate the deployment of NASA science data and understanding into existing decision support tools used by managers concerned with stewardship of the Earth's resources. This goal addresses the development of innovative technology solutions that allow the routine use of Earth science results in automated decision support tools already in use by a broad user community. Management decision support tools of interest are used daily in the management of land/biota, air, water, educational, and emergency issues; Goal 2, inspire and motivate students to pursue careers in science, technology, engineering and mathematics.

E4.01 Innovative Tools and Techniques Supporting the Practical Uses of Earth Science Observations
Lead Center: SSC
Participating Center(s): MSFC

Technical innovation and unique approaches are solicited for the development of new technologies and technical methods that make Earth Science observations both useful and easy to use by practitioners. This subtopic seeks proposals that support the development of operational end-to-end systems that produce information for decision makers. Proposed applications must use NASA Earth Observations (see http://gaia.hq.nasa.gov/ese_missions/). Other remote sensing data and geospatial technologies may also be employed in the solution.

This subtopic focuses on the systems engineering aspect of application development rather than fundamental research. Offerors are therefore expected to have documented proof-of-concept in hand. Topics of current interest to the Earth Science Applications Division may be found at http://www.esa.ssc.nasa.gov. Innovation in processing techniques, including, but not limited to, automated feature extraction, data fusion, parallel and distributed computing are desired for the purpose of facilitating the use of earth science data by the non-specialist. Ease of use, fault tolerance, and statistical rigor and robustness are required for confidence in the product by the non-specialist end user.

Promotion of interoperability is also a goal of the sub-topic, so Federal data standards, communication standards, Open GIS standards, and industry-standard tools and techniques will be strongly favored over proprietary 'black-box' solutions. Endorsement by the end user of both system requirements and the proposed solution concept is desirable. While the proposed application system may be specific to a particular end user or market, techniques and tools that have broad potential applicability will be favored. An objective assessment of market value or benefit/cost will help reviewers assess the relative potential of proposed projects.

E4.02 Advanced Educational Processes and Tools
Lead Center: GSFC
Participating Center(s): SSC

This subtopic focuses on innovation in effective applications related to classroom or museum ready software tools for display and/or analysis of Earth science information for learners in both formal and informal settings, and tools for organization and dissemination of NASA's Earth Science educational materials to a wide array of educational audiences. The Earth Science educational program covers a wide range of audiences from students to adults in both classroom settings such as public schools or continuing education venues to all matter of informal learning settings such as radio, television, museums, parks, scouts, and the internet. In these venues the learning focuses on the scientific discoveries by the ESE, the technology innovations and the applied use of these discoveries and technologies for improved decision making by all.

The areas of interest (described below) cross-cut the three programmatic areas within the ESE program (formal, informal and professional development) and hence are anticipated to have utility in at least two of these areas and most likely in all three areas.

The first area of interest focuses on innovation in the application of digital library technologies to educational materials and audiences. NASA's Earth Science Education Program currently collaborates with the Digital Library for Earth System Education (DLESE). The successful proposal must be able to integrate with or be integrated into existing educational digital library efforts within NASA and/or make contributions to DLESE. These proposals will advance the use and usability of globally distributed, networked information resources, and encourage existing and new communities to focus on innovative applications areas. Collaboration between Earth scientists, formal or informal education community professionals, and computer scientists is required for these proposals to demonstrate useful results. Areas of interest include:

- Extend the current Joined Digital Library (JOIN) effort by developing additional Jini applications. JOIN is a collection of tools based on Sun's Jini technology used to implement efficient, decentralized, and distributed computing systems and follows "the network is the computer" philosophy.
- Development of formal and informal education audience-specific interfaces (for example, specific interfaces for students, park interpreters, TV producers, curriculum developers, etc.)
- Development of interfaces to promote diversity within educational audiences (such as age, ethnicity, cultural, urban/rural, etc.)
- Development of accessibility tools for disabled users to interact and search digital libraries
- Development and access to educational materials including new resources for science, mathematics and engineering education at all levels
- Development of interoperability tools to integrate dissimilar library archives.
- Develop applications that enhance the general functionality of existing digital libraries by providing new general purpose tools for archive management, metadata ingestion, intelligent search and retrieval.
- Tools to support online community interaction which could include new means for gathering, interacting, and communicating with other library users

The second area of interest focuses on innovation in effective software and related development techniques, and in highly practical methods for maintaining and disseminating software for use by educational audiences engaged in teaching or learning about Earth science. The specific areas of greatest interest are highly-portable, classroom-ready software for analysis, visualization and processing of Earth science satellite data, and methods to provide long-term support and viability for educational software. Collaboration between Earth scientists, educators, computer scientists and "business" model experts is required for these proposals to demonstrate useful results. Areas of interest include:

- Extend the current Image 2000 effort by developing additional plug-in applications and modifying core software if necessary. Image 2000 is a Java/JAI-based image processing package being developed at GSFC.
- User-friendly, extensible, Earth science satellite image processing software for multiple operating systems, for educational use in K - 12, undergraduate and continuing education venues.
- Techniques and software for integrating vector and raster data for the visualization and analysis of geo-spatial Earth science data.
- Tutorials geared toward the use of image processing software for visualization and analysis of Earth science related satellite imagery.
- Infrastructure and startup of an Internet based user-supported support and development network, in the spirit of "Open-Source," to ensure continued maintenance and development of Earth science satellite image processing software and tutorials for educational audiences.

E4.03 Wireless Technologies for Spatial Data Input, Manipulation and Distribution
Lead Center: SSC

Technical innovation is solicited for the development of wireless technologies for field personnel that can send and receive digital and analog data from sensors such as photography cameras, spectrometers, infrared and thermal scanners and other systems. The intent of this new innovation is to rapidly, in real time, ingest data sequentially from a variety of input sensors, provide initial field verification of data, and distribute the data to various nodes and servers at collection, processing and decision hub sites. Data distribution should utilize existing wireless, satellite and land communication carriers. The technologies' operating system should be compatible with commonly available systems. The operating system should not be proprietary to the offeror. The innovation should include biometric capability for password protection and relational tracking of data with the field personnel inputting the data. The innovation should contain technologies that recognize multiple personnel so that several personnel can use the same unit in the field. Biometric identification can be fingerprint, retina scans, facial or other methods. The innovation should include geospatial technologies to use digital imagery and have GPS location capabilities. The innovation should be able to display with sufficient size and resolution the rendering of vector and raster data and other sensor data for easy understanding. The unit should have several serial, parallel and USB interfaces, memory sufficient to store and manipulate several gigabytes of information. The field capability of the innovation must be fully integrated end to end with computing capabilities that range from laptop computers to servers at distant locations. Field personnel providing information and support to science investigations, resource managers, and community planners will use the innovative wireless technology. First responders to natural and human-made disasters will also use the innovation.

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9.1.4 SPACE FLIGHT

The mission of the Space Flight Enterprise is to open the space frontier by exploring, using and enabling the development of space and to expand the human experience into the far reaches of space. It does this through three themes: The International Space Station theme supports activities for establishing a permanent human presence in Earth orbit. The ISS provides a long-duration, habitable laboratory for science and research activities investigating the limits of human performance, expanding human experience in living and working in space, and enabling the commercial development of space. The Space Shuttle theme builds on the Shuttle's primacy as the world's most reliable and versatile launch system. The Shuttle, first launched in 1981, provides the only capability in the United States for human access to space. The Space and Flight Support theme encompasses several programs: Space Communications, Launch Services, Rocket Propulsion Testing, and Advanced Systems.

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

TOPIC F1 Systems Integration, Analysis and Modeling

The goal of this topic is to enable the optimization of investments made in multi-disciplinary technologies for the development of on-orbit intelligent modular infrastructures and systems for manufacturing, assembly, deployment, servicing, repair, refueling to create and maintain an entirely new and revolutionary generation of space infrastructure. These systems of systems involve the development of integrated and interoperable components and sub-systems that are more capable than those currently achievable. The effort includes identification and refinement of advanced system and architecture concepts that may dramatically increase the self-sustainability, safety and reliability -- and reduce the cost while enhancing the multi-functionality, performance and capabilities of ambitious future human exploration missions and campaigns beyond Earth orbit. This topic also encompasses establishing a foundation of relationships with the space users community including the space, Earth and biological science community and potential commercial or international partners for in-space operations. Specific objectives of this topic involve the development and validation of innovative new analysis/modeling/design tools and techniques for 1) conducting advanced concepts studies to create/identify innovative new approaches to modular space infrastructures, energy-rich modular platforms, human-machine teams capabilities, intelligent self-sustained modular robotics capabilities, and affordable "Anywhere-Anytime" class access to space capabilities throughout the earth neighborhood 2) Conducting detailed, end-to-end architecture studies incorporating the most promising new systems and infrastructure concepts, 3) Develop and test in the laboratory concepts, technologies and validate performance and limitations, and 4) Continuous-thrust propulsion systems which offer an efficient and flexible compliment and/or alternative to traditional high thrust only chemical systems.

F1.01 Process and Human Factors Engineering Technologies
Lead Center: KSC
Participating Center(s): ARC

Process and Human Factors Engineering Technologies include research and development of innovative tools and technologies to improve process/task safety and efficiency. Spaceport launch and payload processing systems have many unique aspects that require development of advanced process, human factors, and industrial engineering technologies. Process and Human Factors Engineering Technologies emphasize the interfaces between people, processes, and hardware/software systems in specific work environments. Process and Human Factors Engineering focuses on the science of process improvement and optimization of operational phases complex systems, including current and future space transportation systems. The overall goal of the Process and Human Factors Engineering Technologies subtopic is to develop highly effective technologies for designing, implementing, improving, and managing safe and efficient processes, systems, and work environments that can be quickly adapted to the changing needs of current and future spaceports and ranges.

Process and Human Factors Engineering Technologies directly support NASA's goals of achieving safe, reliable, and low cost space access and exploration. Proposals may address the development of new concepts, methodologies, processes, and/or software support systems that advance the state-of-the-art in one or any combination of the following technology focus areas: modeling and simulation, human factors and ergonomics, task analysis technologies, process and operations analysis, life cycle systems engineering, and scheduling and risk assessment technologies.

Specific high priority Process and Human Factors Engineering Technology needs for the 2003 SBIR solicitation include:

- Developing technologies to improve or automate planning/scheduling/asset allocation functions for spaceports and ranges. Resource (people, hardware, etc.) management and allocation technologies. Schedule optimization technologies.
- Technologies supporting model development of vehicle/spacecraft flows and processes. Process simulation and streamlining technologies. Models of launch and landing scenarios.

- Operations management technologies for spacecraft testing, checkout, and verification, e.g., paperless work control systems. Paperless electronic work authorizing document and problem reporting and corrective action systems to be used during spaceport test procedure authoring, execution, and post-test data trend analysis.
- Character recognition inspection systems for vehicle and ground system inspections using technologies such as automation/robotics and expert systems/neural networks.
- Technologies to improve thermal protection system water proofing techniques and densification processes that reduce the hazard level to spaceport personnel. Develop new thermal protection systems and processes that do not require waterproofing or densification.
- Develop models to analyze the concept of universal pads for each class of launch vehicles; expendable launch vehicles (low, med, high) and reusable launch vehicles (vertical and horizontal launch). Establish connection points, fuel storage, logistics, processing requirements, automatically in the evaluation tool.
- Develop the capability to automatically record the entrance and exit of all components from an item such as a small drill bit to large ground support equipment within critical areas; i.e., automatic parts/tool identification and tracking systems. Electronic integration of identification for area access, equipment checkout/control, and personnel identification.
- Develop technologies to recognize/measure/record damage in thruster nozzles and thermal insulation incurred during manufacturing or processing. Develop technologies to enable automated vehicle inspection and repair of subsystems.

F1.02 Systems Architecture and Infrastructure Modeling
Lead Center: JPL
Participating Center(s): JSC, MSFC

This subtopic focuses on the development of innovative modular space systems incorporating high levels of intelligence and enabling at least a factor 2:1 reduction in cost and 5:1 improvement in reliability and self-sustainability compared to current systems and architectures. These systems of systems, which involve the development of integrated and interoperable systems and components, require breakthrough technologies in four main areas: long-term survivability, administration of consumable resources, evolvability and adaptability, and long-term operation of the space system. Long-term survivability is to handle failures due to random events, design errors, and wear-out mechanisms. Administration of consumable resources is to maximize the acquisition and minimize the consumption of consumable resources such as power and fuel. Evolvability is to build in mechanisms so that the capabilities and functions of the spacecraft can be updated after launch. Otherwise, the useful life of the spacecraft will be limited by the obsolescence of the on-board technology. Long-term operation is to reduce the operation costs and maintain a workforce knowledgeable of the spacecraft. The tools should be adaptable to various NASA missions as well as to the non-space community. This subtopic should act as a building block to ultimately achieving an end-to-end product-based campaign for institutionalizing an innovative paradigm of space operations that makes possible a new dynamic era of reconfigurable hardware and evolvable software to create multifunctional systems of systems. This will reduce cost and increase systems capabilities and functionalities while increasing the safety, life cycle and reliability of space missions. Specific areas of interest include:

- Modular systems concepts, which are composed of a collection of similar or dissimilar elements that grow in capability and functionality as more elements, are added. Each element is smart, adaptive and self-sustainable and can be configured to perform a variety of functions in the overall system. The elements can be either separate or attached and interact via the remote exchange of signals or hard connections.
- A general purpose concept analysis, modeling and design optimization tool based on intelligent modules, general purpose design interfaces, expandable and reconfigurable architecture that can either be integrated in space or be able to be self-reconfigurable to evaluate or optimize a hierarchical system design based on user defined goals, parameters and criteria.
- Modular Structures: Structure elements and concepts for assembly with emphasis on joints and actuation mechanisms. Self-healing structures. Electron beam free form fabrication. These ele-

ments can be made with advanced lightweight materials or hybrids with embedded sensors and actuation that give the structures maximum adaptability, and reconfigurability.

- Modular Electronics: Distributed computing, storage, sensing, and power management, programmable gate array processors, powered without wire.
- Distributed Intelligence: Reconfigurable networks and architectures, autonomous reasoning, advanced human-machine seamless interface and collaboration, biomorphic software and cellular programming. Biologically inspired optimization algorithms, design, and systems such as perception and automated reasoning.
- Modular Robotics: Orchestrated assembly, servicing, and repairs, brilliant manipulators, human-robot teams, intelligent mission-adaptable positioning systems and assembly aids.
- Modular Components: Components and subsystems for cryogenic systems, power generation, and management, heat management, scalable radiators, thermal and electric conductive composite layered materials.
- Modeling structure that can accommodate systems and subsystems with their technology options. The model structure should be mission generic, yet capable of capturing space infrastructures system elements for assessing specific mission concepts. For example, the model should be capable of assessing the impact of specifying that a particular technology option be used for all elements in a mission architecture, including vehicle, surface and orbital infrastructure subsystems. In addition, this subtopic focuses on developing innovative computer based hardware and software tools, components and subsystems that can evaluate and analyze competing technologies from a systems point-of-view and will allow the offerors to have a product suitable for marketing by the end of phase III. The tools should be applicable to a number of different applications.
- Continuous-thrust mission design consisting of a synthesis of trajectory, vehicle, and operations considerations. A comprehensive analysis is needed to provide direction for development of emerging continuous-thrust hardware technologies. Specific interest includes: Precision dynamic modeling of N-body gravity fields, solar shading, solar radiation pressure, specific vehicle mass configurations, and performance degradation. Improved convergence. Monitoring of radiation dosage, power characteristics, and engine characteristics (duty cycle, accumulated engine on-time, efficiency). Analysis run times that allow both precise and parametric evaluation in a reasonable timeframe. Seamless transitions among gravity fields including escape, capture, and transfer flight phases. Seamless transition between propulsion modes allowing for hybrid propulsion configurations. Optimization capability based on trajectory and vehicle parameters (including both equality and inequality constraint features). Station-keeping in an N-body gravitational system. Guidance laws for selected maneuvers. Navigation of low thrust spacecraft - with particular emphasis on gravitational field transitions during planetary departure or capture phases.

TOPIC F2 Self-Sufficient Space Systems

The goal of this topic is to drive down the cost of human/robotic exploration missions and campaigns. This includes supporting improved health/safety for human explorers beyond Earth orbit. It also includes working with the space science community to test concepts and technologies. Specific objectives of this topic include 1) developing and validating the technology to utilize local resources, such as Regolith / Minerals, Ices and Atmosphere -- in order to produce, process and deliver consumables, including propellants -- storable and cryogenic; Life Support and other gases; and Water, 2) fabricate key physical structural systems/elements from local materials, including radiation shielding; structural elements (e.g., trusses, panels, etc.); and mechanical spares for mission system elements, 3) Enable local fabrication of selected "finished products" and/or "end-items", including photo-voltaic cells and solar arrays, wires, tubes, connectors, etc., and pressurized volumes, 4) Testing key technologies and demonstrate innovative new systems concepts in space, and 5) establishing a foundation for profitable commercial development of space applications of these technologies in the mid- to far-term.

F2.01 In Situ Resources Utilization of Planetary Materials for Human Space Missions
Lead Center: JSC
Participating Center(s): ARC, KSC, MSFC

The great explorers of the Earth learned to live off the land for food, clothing, replacement of lost or broken items, transportation, and shelter as they ventured far and long from their own bases of support. Likewise, it is fundamental to any program of extended human presence in near-Earth space (Earth-Moon and Earth-Sun libration points and the lunar surface), and to Mars and other planetary bodies that we learn how to make the maximum use of local, indigenous materials as a source for products such as propellants, life support consumables, spare parts, radiation protection, and fabrication and construction materials and products. By pursuing the philosophy of "make what you need where you need it" instead of bringing it all the way from Earth, In Situ Resource Utilization (ISRU) can result in a reduction of mass requirements for exploration missions, a reduction in mission risk and cost, and expanded human presence in near-Earth space on extraterrestrial surfaces. It can also enable the long-term commercial development of space by enabling low cost transportation and providing the resources, technologies, and the capabilities required to allow infrastructure and commercial development activities to grow.

For any ISRU concept to be successfully implemented, the concept must be (i) easily transportable, (ii) minimize the mass which must be brought from the Earth (including the equipment required to move or process the resource), (iii) minimize the power and Earth supplied processing consumables needed to perform its function, (iv) require little or no maintenance, (v) operate in extreme environments if not used in habitable enclosures, (vi) require little or no human supervision, crew operation, and crew training, and (vii) must enable or enhance new mission concepts not possible without the use of space produced products and consumables.

All ISRU activities can be divided into one or more of the five focused task areas below. Proposals can be submitted for any single or combination of these task areas, but proposals should not ignore the complexity or challenges associated with linked areas not covered (ex. proposals on resource processing should not ignore the potential resource collection and conditioning challenges).

Resource Collection and Conditioning
ISRU requires efficient excavation and transport of resources in extremely cold (ex, permanent shadowed lunar crater, dusty/abrasive, and/or micro-g environments (e.g., asteroids, comets, Mars moons, etc.). Proposals of interest include methods and systems for digging, sorting, mineral separation, and transporting regolith or other surface materials to a processing reactor in reduced gravity.

Resource Processing & Refining
ISRU requires efficient and economical production of propellants, mission critical consumables, and feedstock (such as silicon, aluminum, iron, and plastic) for use in in situ manufacturing. Proposals of interest include methods for extracting, collecting, and processing in situ materials into usable products or feedstock from atmospheric, surface, and subsurface space resources and/or life support and power system byproducts and waste. Also of interest are methods for gas separation and purification with membranes or adsorption processes for atmospheric raw materials (planetary bodies with atmospheres, Mars, etc.), in process operations (metal oxide reductions, Moon, Mars, etc), product purification, and life-support. Emphasis should be placed on innovative designs and processes. Proposals for water/ice extraction or drilling should recognize the uncertainty and potential variability of both the location and abundance of such water.

In Situ Manufacturing
ISRU requires processing and manufacturing techniques capable of producing 100's to 1000's their own mass of product in their useful lifetimes, with reasonable quality. In situ manufacturing can use either in situ or Earth supplied feedstock. Proposals of interest include methods for processing Earth supplied, Moon, Mars, and asteroid surface materials or processed feedstock into useful equipment (e.g., solar panels, radio antennas, replacement parts, etc.) and construction materials, which require little or no further manufacturing or assembly that enable long-term settlement.

In Situ Construction
Proposals of interest include construction and erection techniques capable of producing complex structural elements (trusses, beams, shells, etc.) and complete structures from a variety of available or in situ manufactured materials and the minimum of Earth supplied consumables. Maintenance, repair, and replacement costs must be less than 20% (min) of the cost of Earth delivered equipment and products. Of particular interest are free form fabrication or forming technologies that can utilize direct or minimally processed local materials and are easily transportable.

End-to-End System Integration
To minimize mass, volume, and power ISRU processes must be structurally, thermally, and electrically integrated to a significant degree. Proposals of interest include methods of packaging ISRU collection, reactor, separation, distribution, and control equipment that significantly reduce total package mass, volume, and power requirements for use in robotic and human mission applications.

F2.02 Multi-agent and Human-centric Systems Technologies
Lead Center: ARC

NASA will expand future human space flight exploration with highly trained human and robotic agents, capable of working intelligently and collectively together. Multitudes of autonomous systems and small teams of humans must work seamlessly together for efficient operations and effective scientific discovery, and will need to provide effective support for one another, even in harsh and unpredictable environments.

To achieve these ambitious exploration goals, researchers must develop a broad spectrum of technologies for robust, self-learning and evolvable systems with varying degrees of system level autonomy. Large multi-agent systems will work fully autonomously, yet collaboratively across different capabilities (such as a “swarm” of scout probes on an alien surface to search and roadmap for future human exploration. Other partially self-sufficient systems might operate automated experiments on a remote planetary surface or on ISS, yet communicate as needed for human guidance as anomalous data or significant results are experienced. Still other systems might serve as single agent assistants for various astronauts to help monitor Shuttle, ISS or perhaps future planetary habitat systems that may require ongoing monitoring, control, diagnosis, and repair.

To complement this varying degree of multi-agent autonomy, a correspondingly complex level of human-centric interfaces will need to be developed to ensure a total system design approach that properly integrates multi-agent computational systems with human performance and constraints, such that the total system of systems amplifies, corrects, and leverages the capabilities of both people and machines. In order to achieve this, the architectural requirements of multi-agent systems are required, plus fundamental theories of human perceptual, cognitive, and social systems that anticipate the context and contribution of human behavior in which technologies are utilized and maintained. Beyond this, the harsh realities of working in space environments must be thoroughly understood, so tools such as electronic notebooks, alarm systems, and scheduling systems are adapted to the living and work environment of a space habitat or planetary explorers.

To achieve these space systems technology goals, proposals are sought in the following areas:

- Multi-agent command, control and communication methodologies for overall system autonomy including planning, scheduling, diagnostics and recovery methodologies.
- Diagnostic methods that integrate models of critical hardware and software functionality to detect absence of function and reconfigure to assure safe system operation.
- Methods for aggregating health-monitoring information within subsystems or across subsystems to enable integrated system health management and self-reliant systems.
- Collaborative system intelligence capabilities to enhance science and self-reliance capabilities.
- Evolvable and adaptive capabilities for component and aggregate system functionality.
- Advanced AI systems/architectures for mixed-initiative system planning, monitoring, and control, with provision for human oversight and decision-processes.

- Methods that enable the coordination of diagnostic activities between automated systems and humans for rapid detection of anomalies, troubleshooting, and recovery of critical system functions.
- "Cognitive prostheses" that qualitatively change the capabilities of human perception, pattern analysis, scientific domain modeling, reasoning, and collaborative activity in a multi-agent environment.
- Computing architectures that address the limitations of knowledge-based systems and neural networks, relative to human capabilities, advancing the state-of-the-art in coordination across multiple sensory modalities. Applications might include planetary probes and rovers with new kinds of instrumentation, signal processing, and sensing-through-movement that expand human space flight capabilities.
- Information technologies for enabling comprehensive sharing across multiple agents, with support for intelligent organization, access and presentation of information. Particularly, workflow tools that fit the human activities of scientific inquiry and engineering design, but are developed for interfacing with autonomous, multiple-agent systems.

F2.03 Modular Spacecraft Systems
Lead Center: GSFC
Participating Center(s): ARC, JSC, MSFC

There is a need for large and complex space systems in the missions of the future. The traditional monolithic approach to such large structures has always resulted in complex, custom designs with a rigid system architecture that had to be integrated on the ground before launch. Expensive heavy-lift launch vehicles were required to get them to orbit. This approach depended on a large initial investment and the resulting mission risk was substantial.

A new modular concept for engineering these large space systems is based on expandable and reconfigurable system architectures that will be integrated in space using intelligent modules of a general purpose design. These modules could be launched into orbit by medium expendable launch vehicles and once deployed would either assemble themselves or be assembled (human, robotic or a combination of both) into a pre-determined configuration. This lowers the overall risk to the mission because the loss of any one launch vehicle would only represent a small portion of the overall system. It also allows the cost to be spread out over many years and the cost of the individual modules will only be a low recurring cost because they are produced in mass quantities.

This subtopic will develop the technology building blocks to enable the assembly of these large space systems from a variety of modular components. There are deployable modules such as solar arrays, antennas and radiators. There are large integrated modules, such as habitation modules. And there are structural modules, such as truss elements, large aperture telescope elements and phased array microwave antenna elements. The assembly of these modules will require innovative construction approaches using either autonomous self-assembly, human (EVA) assembly, robotic assembly, or a combination of human and robotic assembly.

Questions that must be addressed as part of the infrastructure are the module interfaces and the module resources and services (power, data, thermal, communications and control). The functionality of each modular component must be considered in the context of the overall integrated system.

Reconfigurable Systems
One significant advantage of a modular approach to space systems is that it lends itself naturally to reconfigurable systems. Reconfigurability is a concept that allows the reassignment of functionality among modules in the event of a system failure or a change in mission objectives. Systems can be reconfigured before launch or on orbit. Before launch space vehicles can be assembled from a stable of modular components to provide a launch-on-demand capability. This permits late assignment of functionality to a particular mission. For example, today we may need a reconnaissance capability with adequate propellant for plane changes. Tomorrow we may need to call up a communications capability with multiple high-bandwidth transponders. Using existing “plug-and-play” modules we can quickly assemble the needed elements that will meet the particular mission objectives.

On orbit there are many advantages to being able to reconfigure a system. For example, a system may autonomously reassign functions among modules in the event of a failure so that other modules pick up the function that was performed by the failed modules. We may choose to alter the mission objective and transform the reflector for a large space telescope into a microwave synthetic aperture radar. Modularity is what enables this flexibility. The economic advantages of such a capability are enormous.

In this subtopic we invite proposals that support the overall goal of developing technologies for intelligent modular systems for the assembly of large space structures and for the reconfiguration of any space system. This includes ground and flight testbeds and demonstrations for these intelligent modular systems.

There are four specific key functional areas of research:

Intelligent Modular Architectures
This area addresses innovative system architectures in which larger space systems are autonomously assembled in orbit by the coordinated effort of many intelligent modules. The functionality of each module, the logic for self-assembly and the cooperative aspects of the modules in the fully assembled system are areas of interest.

Several new missions of exploration and space operations envision architectures that are based on what are called Gateway stations at the L1 and L2 Lagrange points. Exploration missions launched from these Lagrange points require relatively small changes in velocity to reach their destinations. With Lagrange points used as mission assembly points, many exploration missions may be assembled, launched and operated from these locations. Such architectures will require a complex infrastructure of reusable modular components for transportation from low Earth orbit as well as for intelligent self-assembly at the Lagrange point.

Modular systems offer the opportunity to build in system capabilities in a manner that is both highly efficient and capable of interacting with many other such modules to create “systems of systems” of great complexity. Such capabilities include science planning and execution, guidance and navigation, autonomous capabilities of various levels, and system health management.

Modular Electronics
The realization of modular architectures depends on the modularity of the electronics. This area will explore innovative approaches to modular electronics, everything from plug-in assemblies to smart chips embedded in the structure. The interconnectivity and the functional reconfigurability of the electronic elements are important considerations.

Distributed Intelligence
This area addresses the concept of modularity in the computational capabilities of space assets in which many intelligent modules form the nodes of a larger computing network thereby making the whole more intelligent than the sum of all the parts. Each module is autonomous in itself, yet contributes to the overall intelligence of the assembled space system.

Reconfigurable Modular Architectures
This area investigates new and innovative design concepts for modular space systems that makes reconfiguration possible, either prior to launch or on orbit. Capability for survivability, adaptability and interoperability are to be considered. Survivability should address longer life through system redundancy, graceful degradation, self repair and either human or autonomous servicing. Adaptability focuses on agile missions that evolve and adapt to changing mission needs both in terms of resource management and data-gathering functionality. Interoperability addresses plug-and-play subsystems and payloads for reduced time and cost for system development and integration.

TOPIC F3 Space Utilities and Power

A key goal of the space utilities and power topic includes working with appropriate NASA and external organizations to identify and establish robust sources for abundant power for in-space, surface and transportation systems for human exploration and the commercial development of space. In additional another key objective is to drive down the cost of human/robotic exploration missions and campaigns. Some selective specific objectives include 1) development and validation of technology for a range of power levels and/or requirements, such as - Large space platforms - Space transportation systems for human exploration and space development - Mobile, piloted or human-supporting lunar or planetary surface systems, and - Various other systems (e.g., habitats, extravehicular activity (EVA) systems, etc.) 2) Developing a foundation for the future testing and validation of key technologies and demonstrate innovative new human exploration and development of space systems concepts in space, and 3) establishing a foundation for profitable commercial development of space applications of these technologies in the mid- to far-term. Some of the technical objectives targeted by this topic include: - Space Solar Power Systems - Space Nuclear Power Systems -- for surface and in-space power applications - Wireless Power Transmission Systems - Cryogenic propellant depots - Energy Storage Systems

F3.01 Thermal Control Systems for Human Space Missions
Lead Center: JSC
Participating Center(s): MSFC

Thermal control is an essential part of any space vehicle, as it provides the necessary thermal environment for the crew and equipment to operate efficiently during the mission. The requirements for human-rating and the specified temperature range (275 K - 310 K) drive the development of enabling active thermal control technologies to support human space exploration. A primary goal is to provide advanced thermal system technologies, which are highly reliable and possess low mass, size and power requirements (i.e., reduced cost). Areas in which innovations are solicited include the following:

- Heat pumps capable of acquiring waste heat at near 273 K and rejecting the heat above 300 K.
- Alternative technologies to provide cabin dehumidification and temperature control on-orbit with a fluid heat sink of 288 to 298 K.
- Microgravity and/or partial gravity thermal energy storage systems for applications at 311 K, 299 K, 277 K, 193 K, and 88 K.
- Lightweight, controllable evaporative heat rejection devices for use with water and ammonia.
- Microgravity compatible food and science sample refrigerator/freezer and cryogenic preservation technologies and systems that provide increased efficiency over current ISS and STS systems, in the temperature range from 277 K to 93 K.
- Insulations or insulation systems for use in creating lightweight, efficiently packaged, rectangular, cold volume enclosures for spacecraft refrigeration/freezer/cryogenic preservation systems, for the temperature range from 277 K to 93 K, and which are comparable to or improvements upon current vacuum wall performance.
- Fluid storage concepts and designs that provide an acceptable alternative to traditional pressure vessels, with the primary benefits of reduced hazards. Concepts should provide function of tanks and/or accumulators and be targeted for fluids such as ammonia, nitrogen, oxygen and refrigerants. Possibilities include but are not limited to solid or liquid phase storage, chemically combining with other materials, and use of any materials with an affinity for these candidates.
- Low vibration or vibration isolating fluid components including fans, pumps, compressors, coolers, tubing, fittings, heat exchangers, and valves for use in microgravity processing applications.
- Highly accurate, remotely monitored, in situ, non-intrusive thermal instrumentation for meeting in-space science, manufacturing and safety needs.
- Materials and concepts for thermally efficient containment and processing of hazardous materials and samples in space.
- Advanced analytical tools for thermal/fluid systems design and analyses, which are amenable to concurrent engineering processes.

- Fluid quick disconnects that allow activation without exact alignment of the halves, that have low activation force (approx. 10 lbf) with internal pressures of 500psi, that are not sensitive to level 200 contamination, that leak less than 1x10-6 sccs He at 500psia over at temperature range of 100F to +100F and can be used with ammonia, water or R-134a.
- Radiator designs for orbital vehicles that will survive the high temperatures of re-entry (~200-600F). Innovations may include high temperature materials, high temperature or easily reapplied coatings, and thermal diodes to prevent fluid overpressure.

Offerors should indicate explicitly how their research is expected to improve the mass, power, volume, safety, reliability, and/or design and analyses techniques for future thermal control systems for human space missions as compared to state-of-the-art technologies.

F3.02 Spaceport Cryogenic Fluids Handling and Storage Technologies
Lead Center: KSC
Participating Center(s): GRC, JSC, MSFC

Cryogenic systems are essential for a variety of aerospace applications, including Earth based spaceports (EBS) and extraterrestrial bases(ETB). Each application has unique performance requirements that need to be met. Sizes of these systems range from the small (100 l for Mars consumables) to very large (>3400 m3 for Earth based launch systems). 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 goals the Space Flight Enterprise. Earth based systems should focus on enhancing technologies to minimize recurring costs. Extraterrestrial systems should focus on enabling technologies that maximize efficiency and minimize system mass and power. Technology focus areas are divided as follows; passive systems, storage and distribution components, refrigeration systems, advanced instrumentation, and advanced operational concepts. Intended applications are listed following each focus area solicitation.

Passive Systems
Passive systems are required to minimize heat leak into cryogenic storage and distribution systems for the purpose of extending propellant storage life and decreasing transfer line losses. Proposed systems can include insulation as well as advanced materials and mechanical supports. Space applications should feature extremely low levels of heat leak to allow for long term storage of cryogens and minimization of refrigeration power. Earth based systems should focus more on a balance between simplicity and robustness vs efficiency to achieve a minimum operational cost.

- Lightweight, low thermal conductivity cryogenic tank struts and support concepts (ETB)
- Low thermal conductivity cryogenic tank penetrations, i.e., instrumentation feed throughs, feedlines, vent lines (ETB)
- Lightweight, insulating thermal protection schemes for use on Mars or the Moon (ETB)
- Energy efficient, cost effective distribution systems for cryogenic transfer over distances up to several miles (EBS)
- Lightweight, cost effective, tough insulations for expendable launch vehicles. Should be capable of multiple thermal cycles but only one launch cycle. Should be operationally efficient, easy to apply and repair (EBS)
- Lightweight, robust insulation concepts for reusable launch vehicles. Should be capable of multiple launch/landing, thermal and ambient/pressure cycles (EBS)
- High efficiency insulation for in place replacement of perlite in large ground storage tanks that eliminate the issues associated with performance degradation and settling over time (EBS)

Storage and Distribution Components
Innovative designs for systems components such as shut-off and flow control valves, pumps, compressors, relief devices, couplings, etc.. that minimize thermal and fluid loss and maximize operational effectiveness. Earth based systems are generally larger and should be optimized for robust operations with many cycles.

Extraterrestrial systems should be optimized for low mass, high efficiency, and long life with less cycles and minimum/no maintenance.

- New technology valves for cryogenic applications including LOX, LH2 and LCH4 that minimize thermal losses and pressure drops. Components include shut off and flow control valves. Valves should be adaptable to electromechanical actuation and range in size from ½ to 6 inches (EBS,ETB)
- New LOX pumping system capable of 75-115 liters per second to support current vehicle loading operations. Highly reliable, variable controlled, parallel pumping system is desired that minimizes the potential for leakage (EBS)
- Small, low power, lightweight liquid oxygen pumps for flowrates up to 2 liters per minute (ETB)
- Leak proof, easy to use cryogenic couplings utilizing robust sealing technology. Must be compatible with LOX and LH2 (EBS,ETB)
- Automated umbilical systems and components designed for high reliability and safety. Smart umbilicals for ground to flight and flight to flight interfaces (EBS, ETB)
- System control components designed specifically for unique handling issues associated with using densified propellants (EBS)

Refrigeration Systems
Active thermal control systems to cool gasses and liquids for the purpose of liquefaction, zero boil-off, and densification of cryogens. Space systems should enable the development of small scale flight quality cryocooolers optimized for long life, low mass and high efficiency. Earth based systems should focus on integrating active thermal control systems with storage and distribution systems for increased reliability and operability while maximizing economic efficiency.

- Cryocooler systems with cooling capacity greater than 10 W in the 10-40K range (ETB)
- Small scale tank pressure control and/or integrated tank boil off control and liquefaction technologies for liquid oxygen, liquid hydrogen, supercritical air, and/or liquid methane (ETB)
- Integrated heat exchangers in large scale storage systems designed to provide for zero boil off and densification of liquid hydrogen and liquid oxygen (EBS)
- Advances in medium to large scale hydrogen or oxygen liquefaction systems to increase economic efficiency, reliability, or operability. Systems that are capable of providing refrigeration over a range production rates, such as turn down ratios of 10 to 1 with little to no loss in COP. (EBS)

Advanced Instrumentation
Instrumentation designed to provide pressure, temperature flow rate, composition, and liquid level data as well as to monitor the health of system components.

- Real time, in line gas composition meters that eliminate the need to take external samples to monitor contaminants in hydrogen systems during purge operations. Contaminants include all condensable components at hydrogen temperatures, specifically moisture, air, nitrogen, oxygen, and carbon dioxide (EBS)
- Flowmeters and/or densitometers for measurement of densified, normal boiling point, or two phase cryogens at flowrates from 3 to 115 liters per second (EBS)
- Non-intrusive gas and liquid flowrate/quantity measurements (EBS, ETB)
- Advanced instrumentation for monitoring the health of systems components such as pumps and compressors, valves (timing and position), connections and umbilicals (EBS)

Advanced Operational Concepts
Advanced cryogenic systems concepts, including all phases of cryogenic use from production, liquefaction, delivery, storage, control and transfer.

- Separation and recovery of gaseous hydrogen and/or helium from waste gas streams. Waste streams could contain small quantities of moisture, air, GN2, GH2, and GHe (EBS)

- Development of purge gas processes that reduce the need for large quantities of gaseous helium (EBS)
- Innovative technologies to recover product losses arising from heat leak or chill down processes (EBS)
- Advanced cryogenic loading technologies that include system health monitoring, autonomous operation, energy efficiency, and economic optimization (EBS)

F3.03 Spaceport/Range Instrumentation and Control Technologies
Lead Center: KSC
Participating Center(s): GSFC, JSC

The goal of this subtopic is to develop instrumentation, systems and associated sensors required by Spaceports/Ranges to operate future generation space vehicles safely and efficiently. Technologies developed under this subtopic shall support the reduction of vehicle and payload cost per pound to orbit while increasing the safety of ground and flight operations by orders of magnitude.

The vision of the future is that multiple vehicles will be operating simultaneously in various phases of processing, launch, and landing from multiple terrestrial and planetary Spaceports/Ranges. In order to realize this, it will be necessary to have systems that integrate a suite of ground and space based sensors and instrumentation that provide the total Spaceports/Ranges solution. These systems need to be distributed and capable of supporting multiple sites and operational phases without reconfiguration. This will require autonomous knowledge based expert systems that can be implemented at multiple sites and require minimal infrastructure and personnel to operate.

This subtopic focuses on the development of sensors, instrumentation systems, meteorological and communications technologies that are uniquely suited to Earth and planetary spaceports for the launch, tracking, controlling, and landing of space vehicles. The specific focuses are on sensors, transducers, instrumentation and systems that will be applied to the following areas:

Space Based Range
Development of technologies for instrumentation systems that perform, or support the following functions on satellite platforms or launch vehicles: metric tracking, area surveillance, navigation aids, communications and atmospheric sensing. Each of these functions will require development of one or more of the following technologies; Integrated multi-, hyper-, and ultra-spectral instrumentation and sensors; Multichannel, low power, spectrum efficient transceivers high gain antennas. These technologies will provide directors, controllers and vehicles vital real-time data that is necessary to safely interface with the National Airspace System for all phases of ascent and decent.

Search and Rescue (SAR) Technologies
As a participating agency of the National Search and Rescue Plan and a member of the National Search and Rescue Committee (NSARC), NASA supports SAR technologies and application of aerospace technology for the search, rescue, survival, and recovery of victims of distress as a result of land, sea and air incidents. These incidents are predominantly accidental in nature. However, with the occurrence of 9/11, it is recognized that NASA may be called upon to provide technology for SAR in response to Homeland Defense.

Distress Alerting: SAR communications, distress alerting will soon undergo a major improvement with the addition of the Distress Alerting Satellite System (DASS). The DASS system leverages on the use of the GPS satellite constellation by utilizing the system's slightly modified on-board repeaters. A Proof-of-Concept system is currently being developed for DASS. Once proven, DASS will evolve to greatly compliment the existing Cospas-Sarsat satellite system and will be compatible with existing 406 MHz beacons. Areas in which innovative research is particularly sought in communications for SAR distress alerting are:

- Cost effective implementation of communications technology for DASS and Cospas-Sarsat
- Application of Smart Antenna Technology in the design of a DASS receive-only phased array antenna for the DASS ground station. A Smart Antenna system combines multiple antenna elements with a signal-processing capability to optimize the reception pattern automatically in response to the signal environment.
- Improving survivability of Emergency Locator Transmitter (ELT) beacons by developing a rugged integrated unit/antenna
- Improving Personal Locator Beacon (PLB) antenna patterns. PLBs use a monopole with a very small ground plane (PLB case) and its pattern is dependent on height above the ground and nearby surfaces. Reflections may destructively interfere leaving nulls in some directions. A more robust or uniform antenna pattern could reduce the susceptibility of the pattern to reflections from nearby surfaces.
- Develop ELT functionality compatible with planned Automatic Dependent Surveillance Broadcast (ADS-B). ADS-B airborne systems will transmit an aircraft's identity, position, velocity, and intent to other aircraft and to air traffic control systems on the ground.

Low cost enhancement of 406 MHz distress beacons: It is desired to improve basic 406 MHz beacon protocols while remaining compatible with the existing Cospas-Sarsat satellite system and utilizing the DASS under development. Proposals should include but not be limited to:

- Improving link margins
- Providing improved error correction (for example, by implementing new cyclic error correction such as Viterbi)
- Providing more message content as needed by SAR authorities

Remote Sensing for SAR: Where beacons have either failed in the incident or were not properly utilized, innovative research in portable low cost remote sensing instruments are sought. These must be capable of locating downed aircraft, vessels in distress or incapacitated individuals based on the spectral, spatial or polarization characteristics presented by the target to be discriminated from its surroundings. Current remote sensing systems under study include active sensors, Synthetic Aperture Radar for Search and Rescue (SAR2) and Laser-Search and Rescue (L-SAR).

Techniques capable of supporting interactive analysis and target recognition in airborne polarimetric SAR at foliage penetrating wavelengths: Polarimetric SAR employs simultaneous horizontal and vertical polarization transmit and receive modes. This provides four independent channels that provide significantly more information than a traditional detected (amplitude) SAR image. SAR operation at P-Band or UHF frequencies provides significant foliage penetration and the ability to detect plane parts otherwise obscured by foliage. One significant problem in crash site detection is that traditional automatic target recognition approaches using modeling and templates may not work since the crash geometry is unknown. It is thus necessary to fully exploit the polarimetric information and to additionally infer from the structure and/or neighboring returns whether it is a candidate crash site. Proposals should develop the needed methodologies and plans for a prototype inferential system capable of exploiting polarimetric, foliage penetrating SAR data for crash site detection, along with a Concept of Operations for its employment.

Techniques to support interactive analysis of spectral/polarization signatures of targets using Hyperspectral instruments: As a member of NSARC, the Civil Air Patrol has expressed a need to apply Hyperspectral imaging for Search and Rescue. Proposals should describe innovative methods to address the following Hyperspectral instrument requirements for Search and Rescue:

- Identify different plant species by spectral signature to categorize the search environment.
- Detect man-made materials in various backgrounds of the search environment.
- Discriminate between the materials of SAR targets and other objects based on their physical properties.
- Detect or identify material smaller than a pixel size for establishing efficient search patterns.

- Use hundreds of narrow spectral bands for identification of the SAR target.
- Detect, geo-locate and report possible detections to the SAR forces in real-time.

Automated Multiple Object Optical Tracking and Recognition System
Develop an automated optical multiple-object tracking and object recognition system to be used during the early stages (first 2 minutes) of a vehicle's ascent. Applying image processing techniques to a wide area view should reduce operational costs compared with radar-based tracking systems and provide more information during a catastrophic event. This system would provide critical position data in near real-time for recovery and analysis of objects of interest. Solutions provided from this capability would be utilized for analysis of nominal or catastrophic events that may occur during a launch operation.

- Minimum object size: ~ 1 m^2
- Minimum number of objects: 50
- Position accuracy: 10 m
- Field of view: 10 km^2 at 70 km

Decision Support Instrumentation and Models
New and innovative methods are needed to ensure safe and cost effective real-time decision models that safely reduce conservatism and provide the necessary fidelity. Improvements in real-time computational capability and software development can significantly improve assessments. Specific technologies needed.

Range Dispersion Monitoring Instrumentation: Develop ground-based and airborne time-resolved, real-time instruments to measure atmospheric chemical species associated with spaceport propellants and combustion products. Deployable instruments, both physical sampling and remote sensing, shall be capable of being networked to provide real-time data to a central processor for formatting and ingestion into a spaceport decision model. Sensors will be capable of identifying specific chemical species including hydrogen chloride, nitrogen dioxide, hydrazine (anhydrous, monomethyl, and unsymmetrical dimethyl), hydrocarbons, sulfur hexafluoride, and particulate matter.

Decision Model On-Screen Editor: Develop methodology to enable on-screen editing of graphical outputs, such as meteorological parameters utilized in spaceport decision models. Shapes, slopes, and uncertainty bandwidths of curves should be automatically digitized based on operator on-screen inputs. This editing capability must allow the user to make changes to the forecasted toxic corridor in near real time. Methodology must execute with sufficient speed to accommodate user inputs, decision model reevaluations, and input refinements to assess decisions, consequences, and uncertainties.

Measurement of Chemical Species in Hypergolic Propellant Systems
Propulsion systems for manned spacecraft use highly reactive propellants in space whose performance can be significantly effected by the presence of impurities, often at the part-per-million level. These result from the reactivity of the propellant with materials of construction of the propellant manufacturing facility, the spacecraft propellant supply system, the ground storage system, and exposure to air or other accidentally introduced impurities. Examples of problems from impurities include the flow decay of nitrogen tetroxide caused by iron nitrate adduct formed from attack on stainless steel by nitrogen tetroxide and the degradation of silver solder on the Shuttle tank screens caused by contamination of the monomethylhydrazine ground supply system.

To detect these contaminants or impurities, sensors are sought that can survive the highly reactive environment of the propellant hydrazines and/or nitrogen tetroxide while providing accurate, real-time information on the presence and concentration of specific contaminants. These sensors could be employed on ground-based propellant storage facilities, in the spacecraft propellant supply systems, or in propulsion test systems to monitor the changes in the propellants when subjected to known sources of contamination.

Specific contaminates of interest include, but are not limited to, those listed below:

- Halides, dissolved metals, carbon dioxide or carbazic acid, decomposition products, and oxidation products for the propellant hydrazines (hydrazine, monomethylhydrazine, unsymmetrical-dimethylhydrazine, and Aerozine-50).
- Halides, dissolved metals, and water for nitrogen tetroxide.

F3.04 Electromagnetic Physics Measurements, Control, and Simulation Technologies
Lead Center: KSC
Participating Center(s): JSC

Spacecraft launch operations involving toxic and explosive vapors, liquid and solid propellants, as well as the operation of electronic components on the ground, in space, and in extra-terrestrial environments have created special concerns for understanding the dynamics of surfaces in contact with each other as well as the production and dissipation of electrostatic charge due to this interaction. These concerns are of crucial importance to NASA in the fabrication, processing, launch, and safe operation of unique and expensive spacecraft launching from Earth as well as from other planetary surfaces.

Specific interests for the 2003 solicitation include, but are not limited to, those listed below:

- Instrumentation should be developed that can identify the constituent by-products resulting from gas and corona discharges. High electrostatic fields such as those produced by lightning are known to dissociate gases, create ions, free radicals, ozone, and other oxidizing species that break down the surface properties of materials. The instrument should be lightweight, portable, and available for use in the field. The instrument should not only identify the constituents but also quantify them. Small portable devices for use in soils and liquids are highly desired.
- Develop instrumentation or techniques to monitor electrostatic fields remotely. Instruments should operate in closed environments at distances ranging from a few centimeters to several meters and work at relative humidities ranging from 5% to 70%. Similar instruments that operate in the field, at larger distances, in the meter to kilometer range, to detect electrostatic build-up in the atmosphere that could lead to lightning are also desired. Instruments could, for example, use spectroscopic techniques to detect ionic concentration as a signature for the existence of electric fields.
- Develop improved triboelectric charge measurement and decay test devices that will become part of new testing standards for protective clothing and other materials to be used in space, hazardous ground processing, and extra-terrestrial environments. Performance of the devices should be compared to similar data already collected by the Kennedy Space Center using existing technology. Instruments and devices proposed for demonstration should be lightweight, small in size, and suitable for operation in a vacuum with temperature ranges from –160^{o} C (– 250^{o} F) to 200^{o} C (400^{o} F), in various gaseous environments with pressures from 100 millitorr to 5000 torr and temperatures from –160^{o} C (– 250^{o} F) to 200^{o} C (400^{o} F) as well as terrestrial environments with temperatures from – 75^{o} C (–100^{o} F) to 65^{o} C (150^{o} F) and humidity from 0.5% to 100%.
- Develop miniature sensors for detecting and measuring the electrostatic potential and charge distribution generated on payloads, spacecraft, and landers. Develop software for modeling the electric potentials of payloads, spacecraft, and landers based on previous flight experiment data and models.

F3.05 Wireless Power Transmission
Lead Center: MSFC

This activity has two related goals. The first goal of this activity is to conduct research for Space Solar Power (SSP) Wireless Power Transmission (WPT) technology development to reduce the cost of electrical power and to provide a stepping stone to NASA for delivery of power between objects in space, between space and surface sites, between ground and space and between ground and air platform vehicles. WPT can involve lasers or microwave along with the associated power interfaces. Microwave and laser transmission techniques have been studied with several promising approaches to safe and efficient WPT identified. These investigations have included microwave phased array transmitters, as well as visible light laser transmission and associated optics. Within the roadmap of SSP WPT there is a need to produce "proof-of-concept" validation of critical WPT technologies for both the near-term as well as far-term applications. These investments will be harvested in near-term beam safe demonstrations of commercial WPT applications. Proposals are sought that include such activities as the technology elements, architecture, and demonstration program for wireless transmission of power. Receiving sites (users) include ground-based stations for terrestrial electrical power, orbital sites to provide power for satellites and other platforms; and space-based sites for spacecraft and space vehicle propulsion.

The second goal of this activity is conduct research on any and/or all aspects of using lasers to remove orbital debris in the 1-10 cm size regime to reduce associated costs while increasing capability. Traveling at hypervelocity's, there exist approximately 150,000 objects this size distributed nonuniformly over a range of altitudes from 400 km to 1500 km. These objects represent a significant environmental hazard for spaceflight. A laser pulse of sufficient intensity striking an object ablates a thin layer of material from its surface resulting in a small, but finite orbit change. Many pulses per second for several minutes at the appropriate point in the object's orbit lowers perigee sufficiently for atmospheric capture and object termination. The key technologies for this approach are the laser beam director and associated technologies; the sensors subsystem and associated technologies for detecting and tracking the object while on orbit; and the system integration process employed. The laser and/or sensors may be located either on the ground or in space. The Project Orion study and other related literature references have found that there are a number of feasible laser and associated sensor, technical and cost options for completely removing 1-10 cm debris up to 1500 km. Crucial to success is a robust systems integration process for synergistically using diverse technologies. Emerging new technologies both in lasers and associated sensors are expected to enhance these initial findings. Research proposals are sought across the board in this area and may take any combination of the following approaches: theoretical analysis, simulation, experimentation, systems and subsystem's design, and/or demonstrations.

Technology Elements

- Transmitting elements, both microwave and laser
- Transmission power systems
- Relay stations, if any
- Receiving stations
- Distribution systems
- Thermal management
- Interference
- Legal issues
- Land use
- Public perception
- Economics
- Power management and distribution
- Safety
- Robotic assembly of on-orbit elements
- Laser design
- Laser beam director
- Laser pointing and tracking
- Laser adaptive optics
- Radar design
- Radar tracking small objects in LEO
- Coupling coefficient of orbital debris materials
- Laser radar design
- Laser radar tracking small objects in LEO
- Systems integration

Objectives
- Develop advanced laser and/or microwave power transmission concepts
- Identify small-scale technology demonstrations, both land and space based
- Identify research and technology activities, concentrating on "tall poles" and promising concepts
- Develop a methodology for discriminating and choosing the most promising systems and methodologies

Tasks
- Develop advanced candidate wireless power transmission and laser orbital debris removal concepts and systems designs
- Perform trades on the concepts and designs, and identify the most promising by means of a quantitative selection process
- Identify required and beneficial technology demonstrations, and recommend solutions
- Conduct research and advanced development work

F3.06 Propellant Depots and In-Space Cryogenic Fluids, Handling and Storage
Lead Center: MSFC
Participating Center(s): GRC, JSC

The focus of this subtopic is to develop and advance enabling technologies required to build and operate a propellant depot near Earth or in deep space. In-Space cryogenic or gel propellant storage depot technology is quite unique, in that it has been studied in detail but little research has been accomplished in space, where the effects of low gravity come into play. The in-space propellant depot will provide affordable propellants and similar consumables as needed in the development of space. An in-space propellant depot not only requires technology development in key areas such as cryogenic or gel storage and fluid transfer but in other areas such as lightweight structures, highly reliable connectors and autonomous operations. These technologies can be applicable to a broad range of propellant depot concepts or specific to a certain design. Also, these technologies are required for spacecraft and orbit transfer vehicle propulsion and power systems, and space station life support. Generally, applications of this technology require long term storage (>30 days), on-orbit fluid transfer and supply and unique instrumentation. Components or concept proposals are being solicited to improve the performance, operating efficiency, safety and reliability of cryogenic fluid storage and handling in a low gravity (10-6 g to 10-2 g) environment. Specific areas of interest include:

- Electrolysis system that manufactures cryogenic propellants from water or ice in a low gravity environment. This system should incorporate innovative techniques and components to provide an automated, safe and highly reliable process.
- Water storage and transfer interface such as a bladder positive-expulsion system or other innovative techniques.
- Reliable and safe cryogenic storage for extended periods of time. This includes zero boil-off systems, advanced insulations and thermal control techniques such as vapor cooled shielding, systems utilizing the boil-off for drag make-up and innovative tank designs.
- Automated assembly, operations and maintenance. This includes cryogenic connects, disconnects and couplings; robotic assembly and repair; docking of large components; health monitoring and smart systems.
- Lightweight structures including inflatables, deployables and advanced composites.
- Suitability of propellant gelation to enhance propellant depot operations.
- Micrometeoroid and space debris protection schemes and associated technologies including advanced lightweight materials, self healing, integration with other structures and tankage and possible avoidance techniques.
- Associated propellant tank-set technologies including fluid slosh and orientation in low gravity environments, tank support structure dynamic interaction in orbit, support struts thermal performance, integrated insulation, instrumentation and plumbing penetrations and coating degradation.
- Schemes for warm tank chilldown including spray nozzle configurations, liquid flow rate and duration, number of gas venting steps and performance in a low gravity environment.

- Stratification/hot spot management including mixing needs, mixing strategies and performance determination in low gravity environments.
- Low gravity performance and operating life determination of key components such as the liquid pumps, condensers, pressurization, liquid acquisition device, refrigerator and mass gauging instrumentation.
- Low heat leak valves and lines that are highly reliable with long life.
- Connects/disconnects with small or no fluid and heat leakage. The connects/disconnects should also have small pressure drops, small force and alignment requirements and long life with high reliability.
- Procedure for the capability for a no-vent fill with consideration given to micro-g condensation and fluid mixing.
- Devices for vapor free acquisition of cryogenic liquids or liquid free venting in a microgravity environment.
- Cryocooler systems with cooling capacity greater than 10 W in the 10-40K range.
- Small and medium scale tank pressure control and/or tank boil off control technologies for long term storage of liquid hydrogen in space.
- Instrumentation for monitoring cryogens in low gravity including mass gauging, liquid-vapor sensing, and free surface imaging.

Several options are available to test the technology needed for propellant depots. Technologies can be tested in the laboratory, on Expendable Launch Vehicles, the Space Shuttle, the ISS, a Small Scale Depot, or a Full Scale Depot. Laboratory testing can use sub- or full-scale tank sets for tests carried out on components, subsystems, and integrated systems on the ground. Identified improvements can be incorporated into subsequent tank sets, which may be used on the ground or in orbital tests. In some cases, a "proto-flight" approach may be used, where the original ground-test tank set can potentially be modified for subsequent testing on-orbit. For example, test requirements may be addressed by building a subscale experiment, which simulates the hydrogen fluid systems of the storage facility, evaluating their performance in a vacuum chamber, and then demonstrating micro-g fluid transfer by performing an orbital experiment.

F3.07 Spaceport Command, Control and Monitor Technologies
Lead Center: KSC
Participating Center(s): MSFC

Spaceport Command, Control and Monitor Systems need to be able to support both the evolving role of spaceports and ranges, as well as the eventual requirements of next generation spacecraft. Some of the technology areas are required to support the concept that spaceport processing systems may not be located on the surface of the Earth, but may reside on an orbiting space station or on the surface of the Moon or Mars. To that end, traditional Command and Control Systems that are developed for a specific vehicle will have to evolve into systems that are adaptable and can communicate with multiple potential vehicles and at multiple spaceports. The following topics require work:

Sensors / Connection / Data Acquisition / Communication
Computing Hardware / Architecture
Advanced Software / Interfaces
End Item Control / Health Monitoring / State Determination / Simulation

Sensor / Connection / Data Acquisition / Communication
Traditionally, sensor systems have been less reliable than the systems that they monitor. In addition, intrusive sensing adds additional failure modes. NASA is seeking improvements in sensor technology, specifically aimed at non-intrusive sensing techniques. In addition, new technology that replaces mechanical sensors is desired. Technology that supports smart sensors, including sensors that perform qualification, integrity checking, self identification and may know their history such that they know when they are operating in a degraded mode, is needed to support health management.

Wiring and interconnects continue to be a maintenance problem as spacecraft and spaceports age. In addition, wiring weight, and cost continue to be a hindrance to Integrated Health Management. Development on Wireless, or self-healing wired technology that supports health monitoring is desired.

Another area of interest is in Automated inspection. Technology areas from new or multiple sensing capabilities to the automated and autonomous control system that would allow non-intrusive inspections are of interest.

Computing Hardware / Architecture
In the spaceport operational concept, integrated spacecraft checkout would occur both at a ground-based spaceport as well as a space-based or other non-terrestrial spaceport. To achieve desired efficiencies, the same software should be used at any spaceport. This leads to the need to evaluate concepts and architectures for software that may be mobile between the spacecraft and the spaceport and operate at an appropriate level of abstraction that the differences between terrestrial and non-terrestrial spaceports can be hidden.

Explore the architecture for mobile software that would support service discovery and remote execution in support of future spacecraft / spaceport interaction.

Explore the best network technology for spaceport / spacecraft communications that meets all the criteria for active operations during all mission phases. This network connection must support umbilical separation and re-mating, in addition to existing lightning and space radiation effects.

Advanced Software / Interfaces
In the spaceport concept of mobile software between spacecraft and spaceport, software concepts and techniques must be developed and refined to support mobile heterogeneous systems in a critical role.

Evaluate the use of Java or other languages that support mobile software between heterogeneous systems that could be used for both a terrestrial and space based spaceport processing system. On a real-time spaceport processing system, consider that the system must be stable, responsive and support remote operation.

Development of a set of standards that allow mobile software in a heterogeneous system to execute on a platform independent basis, move between systems and query the host system or set of systems for the services and capabilities available is desired to support future spaceport processing systems.

Investigate Loss-Less Telemetry compression and improved security algorithms for spacecraft to spaceport communication that maximizes measurement throughput over existing bandwidth capabilities.

End Item Control / Health Monitoring / State Determination
End Item Control has always been by its nature specific to each system. The types of process control that is performed to service a spacecraft at a spaceport can be reduced in scope and made generic such that one set of End Item Control software could be developed for any number of spacecraft and spaceports.

Evaluate the best abstraction technique to develop a common set of software to support spaceport and spacecraft servicing operations.

Evaluate a structured software specification language that provides a readable reference by non-computer software professionals and adequately describes programming constructs such that process control (both procedural and reactive) can be automatically generated.

Evaluate techniques for automated software test and validation of the automatically generated software, including test coverage of logic paths. Tests that can be developed from the same specification that generated the software is desired.

Advanced simulation techniques that could be utilized to support development testing of spaceports and spaceport processing systems is needed. The capability should be evolvable to be utilized in real-time to support decision analysis and improved situational awareness.

F3.08 Solar Power Generation and Power Management
Lead Center: GRC

NASA is interested in the development of highly advanced solar power generation and power management systems, sub-systems and components for use in spacecraft of power levels ranging from 10kW -1MW. This opportunity has the intent to explore options for, and the viability of, highly innovative new concepts and technologies that might dramatically increase performance, improve environmental robustness and lower the cost of critical technologies/systems. Proposals should focus on incorporation of modular and scalable techniques which allow the use of technologies across a wide range of power levels.

Solar Power Generation
Proposal efforts for photovoltaic cells and arrays could include technology development, validation, studies and demonstrations in the areas of innovative solar cells, solar array blanket technology and associated array structure and deployment methods.

Cell and blanket technology shall have the potential for significant cost reduction compared to state-of-the-art space qualified arrays at these sizes. Technology advances needed to achieve MWe output levels at costs consistent with the economic viability of large space power systems should be identified. For example, innovative processes for thin film solar array manufacture. Other areas of interest include demonstration of high efficiency, lightweight concentrator cell and array designs, multi-bandgap cells, advanced concentrator concepts (with up to 100x concentration), multi-quantum well and multi-quantum dot concepts and advanced multi-band gap schemes.

Concepts are sought at the 10 - 100kW levels which, within 10 years, could enable total array specific power to exceed 300W/kg for the missions of LEO, GEO and beyond. Array designs at the multi-hundred kilowatt to MWe output level should have the potential to achieve total array specific powers of 500 W/kg or more.

Lightweight, high power, high efficiency solar arrays are absolutely necessary for large space platforms. Most concepts also require high voltages however; high power, high voltage arrays in specific Earth orbits are subject to continuous arcing, which can destroy lightweight substrates. Therefore, enabling research and technology development and/or demonstrations are needed that leads to operational array voltage level of 1000 v which are resistant to radiation damage and arcing voltages up to 10 kV. Proposals should have provisions for verification in ground-based plasma chambers and/or space flight experiments

Power Management
NASA is interested in scalable, modular components and systems for distributing up to megawatt levels of electric power in satellite systems. Preliminary studies have identified the following key technology areas for studies and demonstrations:

NASA is interested in high-voltage DC-to-DC converters, initially investigating designs for accommodating at least 1000 volt distribution with a clear evolution path for growing to 10k-volt systems. Proposed designs should consider a modular switch and transformer combination that allows for multiple increments of input voltage and current as well as multiple increments of output voltage and current.

To reduce the weight of heat rejection systems, studies have indicated that 300°C converter chassis temperatures are required. NASA is seeking proposals in high-temperature, power semiconductors for use in high-voltage DC-DC converters. Proposal topics include, but are not limited to defect-free epitaxy, dynamic characterization, space radiation hardness, device packaging to sustain simultaneous high voltages and temperatures, life prediction and thermal management.

Intelligent power controls, fault and health management through autonomous control will be necessary for future large space power systems. Concepts and demonstrations of such components and systems are requested to enable development of intelligent controls which will sense/detect faults, shut down affected regions and re-route power to maintain operations. Self-healing concepts are sought which allow the system and components to maintain high reliability. Detection and reporting of failures due to the environment (micrometeoroids) or component breakdown will have to be a part of the system. Materials that can recognize failures and initiate self-correction are of interest.

Concepts for cabling, switches, distribution units and current-limiting switches housed in distribution units with the capability of handling systems of up to 100k volts are required for achieving efficient power management in large spacecraft. Proposals should focus on development of revolutionary approaches to reduce overall system mass by incorporating scalable and modular techniques.

F3.09 Power Technologies for Human Missions
Lead Center: GRC
Participating Center(s): JSC, MSFC

Advanced concepts are required for current and future NASA missions that improve the performance of the power system and/or reduce the overall costs while improving the high degree of reliability and safety required for human-rated vehicles. NASA needs innovative developments in power technologies in the areas of static and dynamic power conversion from either reactor, isotopic or solar heat sources, photovoltaics and other direct conversion devices, energy storage, and power management and distribution and diagnostics and autonomous control systems which are capable of meeting the safety and reliability requirements of missions of human space flight.

NASA is interested in the development of highly advanced systems, subsystems and components for use with nuclear reactors, radioisotopes and solar power generation for future precursor and human missions. Principally these systems of interest are non-nuclear, however they may operate in close proximity to radiation sources. Anticipated power levels range from 100's of watts to multi-megawatts. Applications include: electric power for in-space propulsion, vehicle housekeeping, and science payloads, surface and atmospheric mobility, science stations, resource production, robotic outposts and human bases.

Major technologies being pursued are:

- High efficiency power conversion >20%, 2 kWe to MWe
- Low mass thermal management (radiators)< 6 kg/m2
- Electrical power management, control and distribution. >1000 V, kWe to MWe
- High energy density energy storage, primary and rechargeable

Supporting technology includes:

- High temperature materials/coatings >1300 K
- Deployment systems for large radiators, arrays, etc.
- Surface mobility for power system deployment
- Systems to mitigate planetary surface environments. Dust, wind, planetary atmosphere, etc.

In addition to overall system mass, volume and cost reductions, safety and reliability are of extreme importance. It is envisioned that these technologies will be used on robotic and eventually human missions and it is to the Agency's advantage to develop those technologies that easily bridge the gap of robotic to human missions with a minimum of redesign.

Technologies that enable challenging missions such as, electric power production for bimodal nuclear thermal propulsion, high-power nuclear electric propulsion, crew vehicle power and planetary surface power are of particular interest. Technologies that easily and efficiently scale in power output and can be used in a host of applications (high commonality) are desired.

Another focus for human space flight is supplying power for vehicle crew life support and for suits and tools. Most likely future missions will employ separate crewed vehicles will be used to descend and ascend from planet surfaces to the space transfer vehicle in orbit. For example, a Mars lander may need to be self-sufficient (survive on stored energy) for some extended period of time before the prime source of surface power is supplied. Smaller systems will be required for suit life support power and hand tools where energy storage systems are the most practical solution. Such solutions are also of interest for nearer-term human missions on the ISS, Shuttle, or Orbital Space Plane.

Innovative concepts are solicited to advance the technology of fuel cell power plants and associated planetary in situ reactant production plant subsystems, such as high temperature electrolyzers.

Technologies of interest include proton exchange membrane fuel cells, solid oxide fuel cells, integrated or separate reformers, and other advanced concepts that can provide notable improvements in conversion efficiency, operational life, reliability, load following performance, and mass/volume power density (W/kg and W/l). Oxidant streams of interest are focused on near-pure oxygen, but fuel streams of interest include near-pure hydrogen and reformate from near-pure hydrocarbons such as methane, ethanol, and methanol. Applications of interest for these systems encompass a range, from small power plants (~10 W) for in-cabin crew equipment, through mid-range ~10 kW for vehicle avionics, to high power (~70 kW, 270 V) systems applicable to electromechanical actuation for vehicle flight control.

In addition, concepts are solicited to advance the technology of primary and secondary (rechargeable) batteries. Of special interest are new technologies, which could exploit the advantages in cost, energy density (W-hr/kg and W-hr/l), and reliability that may be possible with larger batteries built up from many small cells in series and parallel. Technologies of interest include lithium ion, lithium polymer, and other advanced concepts that can provide dramatic increases in energy density and rate capability while maintaining safety and reliability levels appropriate to in-cabin and exterior applications on crewed vehicles.
The applications of interest range from in-cabin crew equipment like cameras, tools and computers to large vehicle support systems, from low (<1C) to high (20C) discharge rates, and from low (100 W-hr) to high (100 kW-hr) capacities.

TOPIC F4 Habitation, BioAstronautics and Extravehicular Activity

The goal of this topic is to assure robust and reliable capabilities to support health and safety of human explorers during long-duration space missions. In addition, it is the goal of this topic to drive down the cost of human exploration missions and campaigns beyond Earth orbit and to develop and demonstrate critically-needed capabilities for human activities in space. Some selected objectives of this topic include 1) developing innovative, affordable and highly operable new technologies for extra-vehicular activity (EVA) systems and advanced space habitation systems, and 2) establishing a foundation for profitable commercial development of space applications of these technologies in the mid- to far-term.

F4.01 Extravehicular Activity Productivity
Lead Center: JSC

Advanced extravehicular activity (EVA) systems are necessary for the successful human exploration and development of many destinations and applications beyond low Earth orbit. Complex missions to the Moon, Mars, Earth-Moon L1, Sun-Earth L2, and other remote sites require innovative, flexible and affordable approaches which maximize human productivity and provide the capability to safely perform useful work. Requirements include maximum commonality to many applications/destinations, reduction of system hardware weight and volume; increased hardware reliability, durability, and operating lifetime (before resupply, recharge and maintenance, or replacement is necessary); reduced hardware and software costs; increased human comfort; and less-restrictive work performance capability in the space environment, in hazardous ground-level contaminated atmospheres, or in extreme ambient thermal environments. All proposed Phase I research must lead to specific Phase-II experimental development that could be integrated into a functional EVA system. Additional guidance in the form of the latest Agency Strategic Plan and relevant EVA implementation tactics can be found at http://www.nasa.gov/about/budget/ and http://www.jsc.nasa.gov/xa/advanced.html. Areas in which innovations are solicited include the following:

Environmental Protection
- Passive and active radiation protection technologies that protect the suited crewmember from radiation particles at Libration Points, as well as planetary surface environments.
- Dust and abrasion protection materials to exclude dust and withstand abrasion.

EVA Mobility
- Light weight honeycomb or appropriate core structural material for use in a space suit hard upper torso shell structure that would provide integral micrometeoroid/orbital debris and limited radiation particle protection.

Life Support System
- Long-life and high-capacity oxygen storage, supply and recharge systems for normal and emergency supply of oxygen for breathing.
- Low-venting or non-venting regenerable individual life support subsystem(s) concepts for crewmember cooling, heat rejection, and removal of expired water vapor and CO_2.
- High reliability pumps and fans which will provide flow for a space suit but can be stacked to give greater flow for a vehicle.
- CO_2 and humidity control devices which, while minimizing expendables, function in a CO_2 environment.
- Space water membrane evaporators for a space suit.
- Thermal control systems which can provide either heating or cooling to the EVA crewmember depending on the environment and metabolic rate. Systems must be lightweight, but can require power below 150 W and total energy below 1200 W hrs. A system level portable life support system radiator with an area of approximately 1-meter square can also be used.

Sensors/Communications/Cameras
- Space suit mounted displays for use both inside and outside the space suit. Outside mounted displays must be low profile and compatible with space environment. Internal displays must be 100 percent 02 safe, unobtrusive and ultimately project onto the helmet visor.
- CO_2, bio-med, and core temperature sensors with reduced size, lightweight, increased reliability, and packaging flexibility.
- IR camera that displays temperature of environment for safe handling of objects, geology science support and is integratable onto a space suit or rover.

Integration
- Minimum gas loss and low power airlock providing quick exit and entry and can accommodate an incapacitated crewmember.
- Simple, lightweight, non-metallic, environmentally hardened manual or powered tools for driving fasteners in zero gravity.
- Innovative self-locking, multi-use captive fasteners for EVA.
- Tether hooks for equipment or EVA crewmembers.
- Low profile, low power and flexible body/limb mobility sensors, signal conditioners and software for immediate mobility data analysis. Can be used internally or externally of space suit for mobility joint analysis and testing.
- Portable and autonomous system for real time mapping capability and crewmember position and location determination during EVA zero gravity or planetary surface exploration without the need for a Global Positioning Satellite (GPS) system.

F4.02 Crew Habitability Systems
Lead Center: JSC

Advanced habitation systems include the overall habitat system and its crew supporting habitability functions within. Habitability systems technology are being sought to enable Human Exploration and Development of Space Enterprise future orbital, planetary and deep space applications. Space station and planetary habitation and habitability systems in areas such as crew work, food, hygiene, rest, and logistics, maintenance and repair systems are being sought out for innovative solutions with reliability, durability, repairability, radiation protection, packaging efficiency and life-cycle cost effectiveness. Integration of workstations, integrated sensors, circuitry, automated components, integrated outfitting and advanced workstation evolution to aid and enable the crew to work autonomously are considered necessary for advanced habitation. Development in crew food systems in the areas of food heating, preparation, dining and trash management enable a cohesive habitable environment for the crew. Technology development in crew hygiene systems such as waste collection, personal hygiene, multi-use equipment and hygiene evolution enables a habitable environment for the crew.

The Space Station and Space Launch Initiative are of most interest and consideration of flight-testing in space should be considered. The Near-Earth missions such the Moon and Mars are also of interest. Areas in which advanced habitability system innovations are solicited include the following technologies for use in space (zero gravity) and/or the planetary surfaces:

Advanced Habitability Systems
Crew Food Systems: Create food systems to package, preserve quality food and lightweight, low power, food preparation systems to support on-orbit crew meal storage, preparation and dining activities.

- Food Heating Systems (Conduction, Convection, Microwave)
- Wardroom, Deployable Outfitting
- Trash Management, Recycling, Dual Use

Crew Hygiene Systems: Create crew hygiene systems that are lightweight, low power, low volume systems to support on-orbit crew waste and hygiene activities.

- Waste Collection, Gas/liquid separator, Urine Separator
- Crew Hygiene, No-rinse Hygiene Products, Non-foaming gas/liquid separator (handle soaps)
- Integrated Systems & Outfitting

Crew Rest Systems: Create crew rest systems that are lightweight, low power, low volume systems to support on-orbit sleeping and privacy activities.

- Crew Quarters, Radiation Protection, Acoustic Control, Quiet Air Ventilation
- Relaxation/Recreation, Interactive VR Systems
- Integrated Systems & Outfitting

TOPIC F5 Space Assembly, Inspection and Maintenance

One goal of the space assembly, inspection and maintenance topic is to enable a much more robust set of options for affordable implementation of ambitious new modular space exploration systems and missions. Another goal is to drive down the cost of human exploration missions and campaigns beyond low Earth orbit. The objectives of this topic include 1) developing and validating technologies for the space assembly of large systems -- including both science mission systems (e.g., observatories) and human operational systems, 2) enabling autonomous and/or tele-presence systems inspection, 3) advancing remote or shared control of these capabilities in near-Earth and interplanetary space, 4) developing and validating the capability to extend the life and reduce the costs if a new generation of space systems through repair, refueling, upgrades and re-use of components from one system to another, 5) minimizing the impact of space system failures by enabling easy access for repair -- thus reducing system-level functional redundancy (and associated costs), 6) enabling a reduction in the total mass launched to orbit for given mission architectures, and 7) establishing a foundation for profitable commercial development of space applications of these technologies in the mid- to far-term. The space program can enrich society by directly enhancing the quality of education. Terrestrial applications of technologies developed for space have saved many lives, made possible medical breakthroughs, created countless jobs, and yielded diverse other tangible benefits for Americans. The further commercial development of space will yield still more jobs, technologies, and capabilities to benefit people the world over in their everyday lives. A goal of NASA is therefore to share the experience, the excitement of discovery, and the benefits of human space flight with all.

F5.01 Automated Rendezvous and Docking and Capture
Lead Center: JSC
Participating Center(s): MSFC

In support of future robotic and human missions, the need for additional automation in rendezvous and docking has been identified. This subtopic addresses hardware and software technologies necessary to develop a robust automated guidance, navigation, and control (GN&C) capability bringing together to mate two vehicles from initially large distances (> 1000 kilometers). The "target" vehicle may be orbiting the planet for several years prior to the rendezvous. The "chaser" vehicle may begin the rendezvous after completing orbital insertion. Because of intended use for future human missions, the rendezvous and docking capability must be low risk ensuring a very high level of mission success. The proposed system should be modular and adaptable to smaller robotic missions in order to validate the technology and spread the investment and experience base.

For the purposes of this solicitation, the International Space Station (ISS) is the target vehicle. Proposed solutions should not impact trajectory control operations for current or planned space vehicles visiting the ISS (ie: Shuttle, Soyuz, Progress, ATV, HTV). The proposed system may include active components on the target vehicle if a high level of mission success can be ensured. Preferred solutions do not require extravehicular activity (EVA) to install hardware on the external surfaces of the target spacecraft.

Innovations are currently sought to solve the following specific technology challenges:

- Definition and development of a small lightweight relative navigation system addressing spacecraft-to-spacecraft ranges of 100 kilometers to less than 100 meters. This system should provide precision relative state position and velocity data needed for trajectory control and be capable of supporting trajectory operations for various rendezvous and proximity operations mission profiles, including circumnavigation of the target and final separation and departure operations.
- Definition and development of a small lightweight relative navigation system providing position/velocity trajectory control and relative attitude control during the final 100 meters of the approach through mating.

F5.02 Robotics for Crew Assistance, and for On-orbit/Planetary Assembly, Maintenance and Servicing
Lead Center: JSC
Participating Center(s): MSFC

Proposals are sought which include improvements to robotic joints, actuators, end-effectors, mobility devices and mechanisms for planetary and orbital aid to human explorers. Proposals should address issues associated with environmental compatibility. Specific areas of interest include the following:

- Novel drive systems, suspension systems and manipulator systems.
- Technologies or systems that provide a reduction to the weight and or volume of robotic systems such as:
    - Reduced scale high power-to-weight ratio actuators including magnetostrictive motors and synthetic muscles.
    - Miniaturized actuator control and drive electronics.
    - Miniaturized sensing systems for manipulator position, rate, acceleration, force and torque.

- Robotic systems that can grapple, manipulate and operate existing EVA tools while maintaining a small, human sized form factor.
- Compact low power devices for operation with, as well as site setup and preparation for, human presence both in orbital and planetary surface exploration. Examples include site clearing and setup devices, equipment deployment and retrieval devices, sample collection and manipulation devices, and the actuation components for these devices.
- Free flyer docking and recharge mechanisms

Proposals are solicited for innovative, integrated, sensor concepts that serve to maximize functionality, minimize weight, size, cost and failure probability, or increase mission performance or versatility of Extra-Vehicular Robots (EVR). Categories of EVR include, but are not limited to, semi-autonomous robot for assisting human exploration of planetary surfaces, free-flyers for external inspection of manned spacecraft and humanoid robots for external servicing of manned spacecraft.

A robot to assist human exploration of planetary surfaces might carry tools and samples for a field geologist, capture video/snapshots for him and transmit them to a base location for viewing or scout ahead to locate sites for follow-up EVA. Some specific technology needs are:

- Free flyer docking and recharge mechanisms Small, low power machine vision systems for tracking a moving, articulated object such as a geologist exploring a planetary surface on foot in order to keep the robot's cameras pointed at the geologist, record his activities, etc.
- An aided dead reckoning/landmark navigation system to keep a record, referenced to the terrain, of where the geologist, or the robot, is now and where they have been.

A free-flying, remotely controlled imaging platform capable of transmitting images to its operator could provide images on demand of the exterior of the Space Shuttle, the International Space Station or a future Space Solar Power Satellite to inspect for damage, plan or supervise repair work, etc. Technology needs include:

- Model based landmark navigation to allow a free-flying camera platform to find its way around the outside of the ISS without requiring expensive external beacons, including the ability to update the model as it changes.
- Machine vision techniques, including construction of image mosaics, for detection of unspecified changes in objects being inspected under diverse or changing lighting/viewing conditions.
- Sensing to minimize the risk of collision between the imaging and target vehicles, such as:
  - Small, lower power, range/range-rate sensor
  - Small, lower power "ranging" sensor that produces a depth map of the scene
- System on a Chip (SOC) imager that captures InfraRed (IR) images of a scene

A humanoid robot designed to have the dexterity of a space suited astronaut would be capable of operating tools and performing repair on a manned spacecraft that were originally designed for human operation. Specific technology needs include:

- Miniature robust sensors/sensor material for measuring position/strain that are designed for integration into mechanisms versus being an add-on unit.
- Sensors with integrated multiplexing to reduce wire count.
- Pre-tactile sensor components and techniques that fill the gap in object perception between vision and contact sensing.
- Sensor material must be space qualifiable for temperature extremes and out-gassing.

An effective human/robotic interface enables humans and computers to seamlessly control anthropomorphic robotic systems. Proposals are sought which improve the robotic teleoperator's efficiency through advanced display systems, haptic feedback systems and telepresence control interfaces. Specific technology requirements include the following:

- Unencumbering, lightweight teleoperator worn tactile and force feedback devices that provide operator awareness of manipulator and payload inertia, gripping force, and forces and moments due to the robot's contact with external objects.
- Stereographic display systems that provide high-fidelity depth perception, large field of view (>100 degrees Horizontal Field-of-view), and high resolution (<3 arc minutes per pixel).
- Innovative miniaturized display hardware for use with Helmet Mounted Display (HMD) systems that project data in a Head Up Display (HUD) format. Emphasis is placed on compact, low mass hardware that can be used with HMD displays and efficiently display data (graphical and alpha-numeric) without detracting from the HMD displayed video.
- Techniques for capturing 360 degree video (2pi steradian solid angle) at a work site and redisplaying as a mosaiced virtual environment to the crewmembers back at the base camp. Mosaic construction must take into account camera motion and changes in lighting over extended periods of time.
- Supervised and traded control systems that allow for seamless human/robot interaction. The ability to accommodate both planned and unplanned human and autonomous operations within a task is essential.
- Virtual reality interfaces that make it practical for an IVA astronaut or a suited EVA astronaut to operate on-orbit free-flyer camera platforms and planetary robotic camera platforms.
- Innovative systems that permit control of a robotic system through a combination of gesture and voice commands. Innovative concepts include machine vision, artificial intelligence based systems (with provision for crew oversight), as well as other non-vision forms of sensing and perception that provide command inputs to the robot.
- 3D path planning and intelligent trajectory assessment feedback during teleoperations.

F5.03 Structural Concepts, Materials, and Assembly for Modular Systems
Lead Center: MSFC
Participating Center(s): GSFC, JPL

Space telescopes to detect distant unknown planets, future manned and robotic missions beyond LEO, and space-based infrastructures such as solar power or radar systems require large structures. The size-constraints, mass-capability, and cost of launching large monolithic structures into space limit the development and realization of these capabilities. If a different design approach using modular building blocks rather than monolithic structures is used, these large space systems become more tractable. Modular systems also enable distributed science or technology applications, using fleets of identical satellites that fly in formations. Other advantages of modular systems include low system impact of a single launch vehicle loss, since modular systems are launched on multiple vehicles at multiple times. Replacement of satellites or modules over the system lifetime is in many cases a more reasonable approach to maintaining a system, and graceful degradation of the system capability can be more readily managed with modular units. Hardware costs of multiple identical units can be reduced through economies of scale. Modular approaches also accommodate cost-phased programs that develop and fly a “pilot” satellite, which can initially prove capability, and then be added to later as demand for capability increases.

This subtopic solicits innovate structural concepts, materials, and assembly techniques that support the development of modular space systems. Structural concepts include inflatable, erectable, deployable or easily connected modules to create large space structures, utilizing membranes, composites, or other material concepts. Modular units can provide reconfigurable structures, such as multiple-energy configurations using cables and linkages, compliant structures or mechanisms that adapt to varying surfaces, or multi-purpose integrated structures, such as load-bearing modular power distribution or thermal management systems.

Topics of interest include construction approaches for deployable modular units that form solar arrays, radiators, or antenna, approaches for large integrated components such as habitation modules or propellant tanks, and approaches for erectable modules that form backbones or support trusses. Modular assembly infrastructure, such as cranes, robotic units, end-effectors, mobile foot restraints, motion bases, assembly fixtures and jigs, and on-orbit storage and maintenance facilities are also of interest. Assembly technologies such as innovative connectors and joining or bonding techniques, module positioning and alignment concepts, component deployment or erection concepts, and component/module inspection and verification techniques are solicited. New materials that enable the packaging, deployment, and structural accuracy of modular units are of interest. Concepts are solicited for smart and multifunctional modular structures, including the use of embedded sensors and actuators. Modeling and structural testing techniques and analyses that support the design of specific modular structural concepts or their assembly are of interest. Structures and materials that support reconfigurable modular architectures are solicited.

TOPIC F6 Human Exploration and Expeditions

The goals of this topic include working collaboratively with technology developments in the Space Science Enterprise (and other organizations) to enable future human exploration missions to effectively address -- and at a fundamental level -- the "grand" science challenges facing NASA, driving down down the cost of human exploration missions and campaigns beyond Earth orbit, and sharing the experience of exploration with the public. In pursuing these goals, the objectives under this topic include 1) developing and validating the capability for human explorers to gain deep lunar and planetary sub-surface knowledge and access -- both remotely and through sampling -- ranging down to 1000s of meters, 2) enabling safe and affordable human exploration of other planetary surfaces -- locally but over global distances involving traverses of up to 1000s of kilometers, 3) integrating and validating the technologies needed to revolutionize public engagement in "virtual exploration" -- ranging from higher rate communications, to the creation of virtual reality simulations, to innovative human-machine interfaces, and 4) establishing a foundation for profitable commercial development of space applications of these technologies in the mid- to far-term

F6.01 Crew Training and On-Board Crew Support
Lead Center: JSC
Participating Center(s): MSFC

Dramatic improvements will be needed in crew and ground operations performance and productivity as NASA develops new operational capabilities to support multiple manned missions, and long duration and long distance missions. Robotic, vehicle and support systems will be required to be more robust, autonomous and intelligent, and more maintainable. These capabilities will allow operators to "buy time" by increasing system mean time between failures, predicting when intervention will be needed, managing degraded operations, and using functional redundancy. Advanced capabilities for information and data analysis and presentation, onboard planning, execution and fault management will be needed to assist the crew. Sophisticated training and maintenance support systems and a robust knowledge base will be needed onboard, and will need to be well integrated with increasingly advanced control and maintenance systems.

Ground support operations will need to be redesigned to support the increasing autonomy of space systems and onboard crew. There will need to be advanced support for distributed and adjustable command responsibility, and distributed and flexible training. Significantly more productive and intuitive approaches are needed for updating, adapting, testing and certifying advanced distributed operations software and knowledge bases during missions. Specific areas of interest in the areas of crew training, and in flight and ground operations, include:

Crew Training and Maintenance Support Systems

- Flexible training and tutoring systems for mission operations support, including distributed cooperative training, virtual reality training, intelligent computer-based training, and authoring tools.
- Integration of training with advanced control and maintenance systems.
- Tools to collect/capture and tailor design-time information for use in developing training materials.
- Procedures or technology for evaluating effectiveness of innovative training methods.
- Data Management, Data Analysis, and Presentation and Human Interaction.

- Methods for selecting and summarizing vehicle systems and payload data relating to status and events, to support crew and ground awareness, operational decision-making, and management by exception and opportunity rather than by continuous or scheduled monitoring.
- Human interaction methods for collaboration, cooperation and supervision of intelligent semi-autonomous systems.
- Goal-driven collaborative data analysis systems capable of adaptation and learning.
- Simple systems for notification and coordination, including natural language interfaces.
- Immersive environments: real-time environments to enhance a human operator's ability to interact with large quantities of complex data, especially at distant locations.
- Intelligent data analysis techniques: capabilities to interpret, explain, explore, and classify large quantities of heterogeneous data.

Robust Planning, Operations, Fault Detection, and Recovery with Distributed Adjustable Command Responsibility

- Algorithms for network security that will protect networks at the gigabit and terabit throughput with minimal degradation to throughput
- Onboard planning, sequencing, monitoring, and re-planning of activities, including systems and crew activities.
- Flexible management of the actions of subsystems within the larger context of system flight rules and constraints.
- Flexible and robust fault management approaches that use system models, "buy time" for human intervention and maintenance, and learn from human operators during and after the interventions.
- Approaches to distributed and adjustable command responsibilities among systems, crew and ground.
- Model-based continuous estimation of the likelihood of critical events, including human errors, to provide warnings of potential events and their consequences, and to suggest appropriate counter-measures.
- Integration of systems for fault management, maintenance and training.

Operations Knowledge Management and Software Updating.

- Systems and processes for crew and ground operators to quickly and effectively define, update, test and certify operational knowledge and rule bases before and during missions, designed for re-use in autonomous systems and in training.
- Tools for incorporating and using engineering data and specifications (about equipment and its operating modes and failures and about operations procedures) into operations knowledge and model-based autonomous systems.
- Tools and environments to support modification and validation of knowledge bases (models of activities, equipment and environment)in intelligent autonomous software by operators, to capture methods and knowledge used by operators during interventions and to collaboratively adapt to un-anticipated circumstances.
- Simulation environments and tools for use in designing and testing intelligent semi-autonomous systems.

F6.02 Distributed/International Ground Operations
Lead Center: JSC
Participating Center(s): MSFC

As the operations for the International Space Station (ISS) evolves and the International partners become more integrated into the Operations of the ISS, new methods of information sharing and team interactions will be required. The current virtual team tools will not be sufficient to support the distributed international operations team interaction. Operations will also evolve in the ISS to allow the expertise of the Flight Controller to be distributed outside of the facility in order to reduce the need for constant monitoring in the Mission Control Center. Additionally, new methods for distributed functionality of the Mission Control Center in the event of an emergency are needed. Specific areas of interest in the areas of distributed/international operations include:

Distributed Architecture

- The capability to command and control and access an orbiting vehicle telemetry from a single computer
- The capability to remotely synchronize storage and central servers miles away and to switch operations to the distant servers without any loss of data

Distributed Operations

- The capability for a distributed immersive virtual environment where 3D models could be manipulated at any location and would result in the model being manipulated at all locations (e.g. rotated) and any annotations or pointing to a segment of the virtual model would be displayed at all locations.
- The capability for a virtual meeting presence, where instead of a video teleconference, you are able to have the other meeting attendees sitting around a table as if they are at that location, but are actually remotely located. (e.g., across the table would be a 3D image of the other meeting participant reacting and interacting as if they were in the same room)
- Wireless access to voice, video and data in a hand held device
- International communication tools that would allow real time translation of spoken word from one language to another.

TOPIC F7 Space Transportation

The goal of the Space Transportation topic is to identify and develop specific new space transportation technologies that can significantly increase the safety and reliability of ambitious future human exploration missions and campaigns beyond Earth orbit, while dramatically reducing the transportation-related cost of human exploration initial missions and sustained campaigns. This includes both systems and infrastructures associated with Earth-to-orbit transportation, in-space transport, and excursions from space to and from targets in space (including the Moon, Mars and asteroids). The objectives under this topic include 1) developing and demonstrating selected, highly innovative technologies needed to assure that future human exploration space transportation systems and infrastructures are safe and "robustly" reliable, 2) developing and validating technologies for the affordable transportation to - and from - targets in space beyond low Earth orbit, 3) enabling reliable and affordable transportation to all points of interest globally on the Moon or Mars, 4) establishing a foundation for profitable commercial development of space applications of these technologies in the mid- to far-term, 5) revolutionary propulsion systems and advanced space transfer technologies with application to mid- and far-term space exploration missions. Propulsion technologies that push the state-of-the-art in electric, electromagnetic, thermal and chemical systems, and 6) fission propulsion systems technologies that enable rapid and affordable in-space transportation, potentially leading to ambitious exploration of the solar system and beyond.

F7.01 High Power Electric Propulsion For Human Missions
Lead Center: GRC
Participating Center(s): JSC, MSFC

High power electric propulsion (e.g., ion, Hall, MPD, pulsed inductive, VASIMR and other plasma thrusters) is an essential technology for orbit insertion and planetary transfers of future nuclear and non-nuclear human exploration spacecraft. This subtopic solicits innovative component technologies related to high power electric propulsion systems for these applications. Innovations may increase system efficiency, increase system and/or component life, increase system and/or component durability, reduce system and/or component mass, reduce system complexity, reduce development issues, or provide other definable benefits. For this subtopic high power electric propulsion is defined as systems with power levels of 100-kW to several megawatts and higher. Desired specific impulses range from a value of 2000 s for Earth-orbit transfers to over 6000 s for planetary missions. System efficiencies in excess of 50% are desired. System lifetimes commensurate with mission requirements (typically 10,000+ hours of operation) are desired. Component technologies for high power applications of particular interest are those that can be commercially spun-off or can also be applied to lower power electric propulsion devices/applications. Proposed high power electric thruster component technologies must have near-term applications that can be pursued in a Phase-II effort. Examples of component technologies of interest include but are not limited to:

- High voltage propellant isolators
- Long-life, high current cathodes
- Innovative plasma neutralization concepts
- Metal propellant management systems/components
- Cathodes for metal propellants
- Low mass, high efficiency power electronics for RF discharges
- Low voltage, high temperature wire for electromagnets
- High temperature permanent magnets and/or electromagnets
- Application of advanced materials for electrodes and wiring
- Highly accurate propellant control devices/schemes
- Miniature propellant flow meters
- Lightweight, long-life storage systems for krypton and/or hydrogen
- Fast acting, very long life valves and switches for pulsed inductive thrusters
- Superconducting magnets
- Lifetime models for hollow cathodes (ion, hall) and/or refractory metal cathodes (MPD)
- Lightweight thrust vector control for high power thrusters
- High fidelity methods of determining the thrust of ion, Hall, MPD, VASIMR engines without using conventional thrust-stands.
- Heat transfer and rejection components for high temperature and cryogenic regimes (applications of advanced materials, heat pipes, etc.)

F7.02 Propulsion Systems Ground Test Operations
Lead Center: SSC
Participating Center(s): JSC, MSFC

Proposals are solicited for innovative technologies applicable to ground testing of rocket engines. The goal is to reduce overall propulsion test operations costs (recurring costs) and/or increase reliability and performance of ground test facilities.

Specific areas of required technology innovation include the following:

- Improved cryogenic high-pressure/high-flow rate instrumentation. Temperature sensors that are exposed to the high pressure (up to 15,000 psi) and high flow rates (up to 2000 lb/sec, 300 ft/sec) required in cryogenic (down to 34R) rocket engine testing must be built with significant mass to survive the testing environment. Such robust sensors tend to have slower response rates. There is a need for temperature sensors with millisecond response times that can withstand the aforementioned rocket engine testing environment.
- Improved low-cost cryogenic insulation. A requirement exists for more durable insulation materials for cryogenic (liquid oxygen and liquid hydrogen) tanks, pipes, and valves. This insulation must be resistant to deterioration in an environment of intense sunlight, high humidity, and frequent, heavy rainfall. It must also be resistant to detachment during thermal contraction and expansion cycles of the insulated components.
- Improved cryogenic propellant conditioning methods. New propulsion systems using cryogenic fueled rocket engines are tested using low and high pressure propellant feed systems.
- Economical techniques to maintain the lowest possible liquid propellant feed temperatures (LN, LOX, LH) are sought, including techniques to subcool the propellant.
- Model development and validation of flare stacks, flare stack flame geometry, and flare stack atmospheric effects. When using hydrogen as a rocket engine propellant, hydrogen from boil-off, or hydrogen exhaust from testing components cannot be vented to the atmosphere. Flare stacks are used to burn off this excess hydrogen during both standby and testing operations. New techniques

for modeling and designing flare stacks are needed to develop flare systems having improved operational ranges, reduced cost for supplemental purge gas usage, and low environmental impact. These flare systems must operate over a wide range of hydrogen flow rates, which span the range of a few cubic feet per minute to hundreds of pounds per second.

F7.03 Energy Conversion, Electromagnetic Launch Assist and Energy Storage
Lead Center: MSFC

Today's conventional launch systems employ world-class, state-of-the-art materials and propulsion technologies. However, the cost of launch services remains prohibitive for many commercial enterprises and safe, reliable, cost-effective alternatives remain unavailable.

The most reliable, thus cost effective launch vehicles, obtain the necessary performance by incorporating multiple-stage propulsion systems. A fully Expendable Launch Vehicle or ELV, characteristically offers a lower priced launch service than NASA's Space Shuttle. However, common to both systems is the vertical trajectory, or initial flight path. This approach to orbit requires the vehicle's propulsion system to maintain a thrust greater than it's own opposing weight until it escapes the influence of earth's gravity.

While ELV's offer reduced launch costs, the savings resulting from higher launch rates (economy of numbers) eventually approach a limit. This limit arises as the result of replacing major launcher elements after each launch, or more likely, the entire launch vehicle. In spite of advances in automated manufacturing and common launcher elements, the costs associated with delivering payloads to Low Earth Orbit (LEO), or Geo-synchronous orbit (GEO), are at best in the $600-$1000 per lb. range. Consequently, prospective users resort to alternatives such as building land lines instead of launching satellites, or postpone launch plans altogether until costs become more favorable.

Future launch systems demonstrating the best mission success or safety record will also have the lowest Total Life Cycle Cost (TLCC).

An electromagnetic accelerator (EMA or EM catapult) can be employed to substantially reduce the landing gear and wing weights of vehicles designed to be launched horizontally. An EMA is essentially a linear motor scaled to accelerate the launch vehicle to a safe release velocity. Launch vehicles weighing 100 M tons or more GLOW (Gross Lift Off Weight), can be reliably accelerated to velocities beyond 130 m/s. In addition, the accelerator may be designed to provide a refused take off mode or abort, effectively recovering much of the energy expended during the aborted launch.

In order to meet NASA's desired goals of reducing payload costs and increasing launch vehicle safety, proposals for the following technology areas are needed:

- Linear motor technologies that enable reliable operations under harsh use conditions.
- Technologies enabling safe and efficient accelerations of heavy loads at high velocities.
- Technologies improving reliability and efficiency of energy storage and transfer processes.
- Technologies providing safe, reliable and environmentally benign electrical energy generation.
- System methodologies integrating command, control and communication functions that support autonomous systems operation.
- Diagnostic methods incorporating algorithms of critical hardware and software parameters for detection of off-nominal system performance and reconfiguration provisions to provide fail-safe systems operation.
- Methods for assimilating health-monitoring information within subsystems or across subsystems to enable integrated system health management and self-correcting systems.
- Methods that enable the coordination of diagnostic activities between automated systems and humans for rapid detection of anomalies, troubleshooting, and recovery of critical system functions.
- Component technologies providing evolvable and adaptable features for maintaining state-of-the-art performance and capabilities.

9.1.5 SPACE SCIENCE

The space science technology development program develops and makes available new space technologies needed to enable and enhance exploration, expand our knowledge of the universe, and ensure continued national scientific, technical, and economic leadership. It strives to improve reliability and mission safety, and to accelerate mission development. Since the early 1990s, the average space science mission development time has been reduced from over 9 years to 5 years or less, partly by integration and early infusion of advanced technologies into missions. For missions planned through 2004, we hope to further reduce development time to less than 4 years. Our technology program encompasses three primary capabilities, in space where necessary, so that they can be confidently applied to space science flight projects. Finally, we apply these improved and demonstrated capabilities in the space science programs and transfer them to U.S. industry for public use through programs such as the Small Business Innovation Research Program. For more information on space science at NASA, see:

http://spacescience.nasa.gov/

TOPIC S1 Sun Earth Connection

The overarching goal of the Sun-Earth Connection (SEC) theme in Space Science is an understanding of how the Sun, heliosphere, and planetary environments are connected in a single system. The three principal science objectives spring from this goal: 1) Understanding the changing flow of energy and matter throughout the Sun, heliosphere, and planetary environments; 2) Exploring the fundamental physical processes of plasma systems in the solar system; 3) Defining the origins and societal impacts of variability in the SEC. SEC missions investigate the physics of the Sun, the heliosphere, the local interstellar medium, and all planetary environments within the heliosphere. They address problems such as solar variability, the responses of the planets to such variability, and the interaction of the heliosphere with the galaxy. Increasingly, SEC investigations have focused upon space weather, the diverse array of dynamic and interconnected space phenomena that affect both life and society. Technology plays an important role in maximizing the science return from all SEC missions.

S1.01 Particles and Fields Measurements for Missions to the Heliosphere, Planetary Magnetospheres and Upper Atmospheres
Lead Center: GSFC
Participating Center(s): JPL

The Sun-Earth-Connections theme studies the Sun with its surrounding heliosphere carrying its photon and particle emissions and the subsequent responses of the Earth and planets. 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/ionosphere systems. Remote sensing of photons and neutral atoms are required for the physics and chemistry of the Sun, the heliosphere, magnetospheres, and planetary atmospheres and ionospheres. Since 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:

Photon Remote Sensing (Radar to Infrared through x-ray and gamma-ray wavelengths)

- Advanced light weight diffraction limited mirrors.
- Advanced optical spectrograph components.
- Advanced detectors for visible through x-ray wavelengths.
- Improved techniques for spectrometric imaging of IR emissions from planetary atmospheres and ionospheres, such as large array (8 Megapixel) CCD cameras (0.35-2 micron), holographically enhanced Fabry-Perot interferometers, and tunable IR lasers (2-5 micron) based on, e.g., quantum cascades.
- Improved techniques for spectrometric imaging of visible and UV emissions from regions of energetic plasma phenomena interacting with atmospheric gases, such as aurora and day-glow cameras.
- Improved techniques for spectrometric imaging of x/Gamma-ray emissions from planetary and cometary atmospheres and ionospheres, such as solid state photomultiplier devices for use in combination with scintillation detectors.

Plasma Remote Sensing (e.g., neutral atom cameras)
- Advanced neutral atom imagers for energies from a few eV to 100 keV to remotely sense ion populations in the heliosphere and in the magnetospheres of the planets. 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.

In situ Plasma Sensors
- Improved techniques for imaging of charged particle (electrons and ions) velocity distributions.

- Improved techniques for the regulation of spacecraft floating potential near the local plasma potential, with minimal impacts on the ambient plasma and field environment.
- Low power digital time-of-flight analyzer chips and waveform generators with sub-nanosecond resolution and multiple channels of parallel processing.
- Miniaturized, radiation-tolerant, autonomous electronic systems for the above.

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.
- Miniaturized, radiation-tolerant and autonomous electronic systems for the above.

Electromagnetic Radiation Sensors

- Radar sounding and echo imaging of plasma density and field structures from orbiting spacecraft.

S1.02 Deep Space Propulsion
Lead Center: MSFC
Participating Center(s): GRC, GSFC, JPL, JSC

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

Solar Electric Propulsion
Innovations in electric propulsion system technologies are being sought for space science applications. One area of emphasis pertains to high-performance propulsion systems capable of delivering specific impulse (Isp) greater than 3500 seconds, using electrical power from radioisotope or solar energy sources. Thruster technologies include, but are not limited to, ion engines, Hall thrusters, and pulsed electromagnetic devices. Other subsystems of interest include the power source, propellant storage and feed, power processing, power management and distribution, heat-to-electrical power conversion, and waste heat disposal. Development of ultra-lightweight inflatable/deployable solar arrays, solar concentrators, and radiators is of significant interest for power generation and thermal subsystems. Innovations considered here may focus on the component, subsystem or system level, and must ultimately result in significant improvements in spacecraft capability, longevity, mass, volume and/or cost.

Solar Sails
Solar sails are envisioned as a low-cost, efficient transport system for future near Earth and deep space missions. NASA mission's enabled/enhanced by solar sail propulsion include Tech Pull Missions such as Geotail, Comet Sample and Titan Flyby to be launched between 2009 and 2012. Another category of NASA missions is the Particle Acceleration Solar Orbiter including the L1-Diamond and the Solar Polar Imager, all which shall be launched between 2015 and 2028. They are enabling for several strategic missions in the Sun-Earth Connection Space Science theme, including Solar Polar Imager and Interstellar Probe, the latter being a sail mission to explore interstellar space. Missions in the Exploration of the Solar System theme would be broadly enhanced by the availability of proven, sail technology. Innovations are sought that will lower the cost and risk associated with sail development and application, and enhance sail delivery performance. Innovations are sought in the following areas: systems engineering, materials, structures, mechanical systems, fabrication, packaging and deployment, system control (attitude, etc.),

maneuvering and navigation, operations, durability and survivability, and sail impact on science. Development of ultra-lightweight inflatable/deployable support structures is of significant interest, including rigidization approaches. Innovations in ultra-light reflective thin films are also sought. Three parameters have been used as sail performance metrics in mission applications: sail size, sail survivability for close solar approaches, and areal density (ratio of mass of the sail to area of the sail). In addition, important programmatic metrics are cost, benefit, and risk. Technologies of interest should be geared toward a wide range of sail sizes, solar closest approach distances, and aerial densities, and may be optimized for one portion of the range rather than trying to cover the whole range. Sail sizes may range from very small (meter-sized for use with very tiny picosat payloads or for use as auxiliary propulsion), to medium (50-100 m size for achieving high-inclination solar orbits or non-Keplerian near-Earth orbits) and ultimately to the very large (hundreds of meters for levitated orbits, high delta V, and for use in leaving solar system at high speed). Sail weight should include, but not be limited to, ultra lightweight sail materials (<1 gram/m^2). Closest solar approaches may range from 1 AU down to 0.1 AU. Aerial densities for a solar sail subsystem (excluding payload) may range from 1 to 15 g/m^2. Unconventional sail architectures are also sought (e.g., heliogyros, spinners, rigid sails, tensegrity structures, solar photon thruster, dual mode with aerobraking, solar thermal, microwave beam, etc.)

Chemical and Thermal Propulsion
Innovations in low thrust chemical propulsion system technologies are being sought for space science applications. Technologies of interest include, but are not restricted to, bipropellant engines with Isp greater than 360 seconds. Another area includes considered here may focus on the component, subsystem or system level, and must ultimately result in significant reductions in spacecraft system mass, volume and/or cost. lightweight, compact and low-power propellant management components, such as valves, flow control/regulation, fluid isolation, and lightweight tankage. For thermal propulsion, lightweight deployable solar concentrator innovations are of significant interest, including materials, packaging/deployment, and rigidization. Innovations considered here may focus on the component, subsystem or system level, and most ultimately result in significant reductions in spacecraft system mass volume and/or cost.

Aeroassist
Aeroassist is a general term given to various techniques to maneuver a space vehicle within an atmosphere, using aerodynamic forces in lieu of propulsive fuel. Aeroassist systems enable shorter interplanetary cruise times, increased payload mass and reduced mission costs. Subsets of aeroassist are aerocapture and aerogravity assist. 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. Without aerocapture, a substantial propulsion system would be needed on the spacecraft to perform the same reduction of velocity. Aerogravity assist is an extension of the established technique of gravity assist with a planetary body to achieve increases in interplanetary velocities. Aerogravity assist involves using propulsion in conjunction with aerodynamics through a planetary atmosphere to achieve a greater turning angle during planetary fly-by. In particular, this subtopic seeks technology innovations that are in the following areas:

Aerocapture:

- Aerogel TPS Systems: Development of advanced thermal protection systems using aerogel materials.
- Deployable Decelerator Systems: Development of either forward or trailing decelerators, which can be inflatable or mechanically deployed. Concepts should show the ability to withstand aerodynamic stresses/temperatures during deployment and aerocapture sequences.

Aerogravity Assist:

- Aerogravity Assist Systems: System concept studies should include mission architecture and vehicle design. Concept should show evolution of the design from concept phase, through technology development/test and mission utilization.

Emerging Propulsion Technologies
This effort will focus on technologies supporting innovative and advanced concepts for propellantless propulsion and other revolutionary transportation technologies. The categories under Emerging Propulsion Technologies include, but are not limited to: electrodynamic and momentum transfer tether propulsion; beamed energy; plasma sails; and low to medium power electric propulsion. The electrodynamic tether propulsion method exchanges momentum with a planet's rotational angular momentum through electrodynamic interaction with the planetary magnetic field. Momentum exchange tethers or MXER concepts use orbital energy to provide a high thrust to a payload in LEO. Beamed energy includes lasers or microwave energy to directly propel a spacecraft or to supply power that is utilized for propulsion onboard the spacecraft. Plasma sail propulsion involves momentum exchange with solar wind ions through electrodynamic or electrostatic interaction. The low to medium electric propulsion is a general category for fresh variations of electric thrusters (Hall, MHD, PIT, etc.) that support near or mid-term solar powered spacecraft (e.g., below ~50 kW). Unique, innovative and novel propulsion ideas are sought but with reasonable expectations to progress to hardware prototypes. The categories may be as low as TRL 2 but rapid demonstration to TRL 4 is expected. Distinctive variations of existing propulsion methods or chief subsystem component improvements are also suitable for submission. Proposals should provide development of specific innovative technologies or techniques supporting any of the above approaches. A clear plan for demonstrating feasibility, noting any test and experiment requirements, is also recommended. Key to each idea is an unambiguous knowledge of past research/concepts conducted on related work and specifically how this new proposal differs to the extent that it appears to offer a significant benefit. Identification of the fundamental technology to be developed is also crucial.

S1.03 Multifunctional Structure and Sensor Systems
Lead Center: JPL
Participating Center(s): GSFC, LaRC, MSFC

NASA seeks innovative concepts for multifunctional or integrated structure and sensor/electronic systems to reduce spacecraft size and mass, and to enable lower-cost and more capable aerospace vehicles, instruments and structures. A multifunctional system combines several functions, which are usually performed by separate subsystems, into a single highly integrated system. Additionally, multifunctional systems would enable more effective health monitoring where, in this case, "health monitoring" refers to the state of the spacecraft, subsystem or structure. To achieve this will require revolutionary advances over the capabilities of traditional spacecraft systems. Microspacecraft systems (as small as 10 kg, using 10 W, or less) of all varieties will enable new missions that are currently impractical. These systems will include, but are not limited to, orbiters, landers, atmospheric probes, rovers, penetrators, aerobots (balloons), planetary aircraft, subsurface vehicles (ice/soil), and submarines. Also of interest are distributed sensor systems integral with structural elements for the monitoring of the state of those elements or for the construction of new classes of scientific instruments based upon the unique features of the integrated system. New technologies are needed in the areas of integration and packaging of MEMS sensors and actuators integral with advanced lightweight materials for structure and propulsion or thermal control.

Potential mission applications for the technology products developed in this area include micro/nano-spacecraft, thin-film gossamer spacecraft, adaptive large-aperture telescopes, antennas, and airframes. High-priority technology development needs include the following:

- Techniques for the structural integration of low-volume electronics packaging such as chip-on-structure, chip-on-flex (flexible substrate), and imbedded electronics.
- Concepts for integrating electronics, MEMS, power distribution, energy storage, thermal management, and radiation shielding with ultra-lightweight composite structures.
- Multifunctional membranes that incorporate thin-film electronics and MEMS sensors, photovoltaic cells, or electrochromic materials.
- Adaptive and reconfigurable structures that can respond reactively to environmental stimuli for self-repair of damage.
- Avionics, including highly integrated "systems-on-a-chip" technologies that integrate areas such as telecommunications, power management, data processing and storage, on-chip energy storage, on-chip magnetics or data sensors with structure and/or actuators.

- Micro-Electro-Mechanical Systems (MEMS) including: microactuation, navigation sensors, health-monitor sensor systems, low power and low-mass on-chip communication systems, and micro fluid storage and control systems.
- Thermal management, including active and passive techniques.
- Integration of functions such as engineering sensors and science instruments, structure, thermal, cabling, propulsion, etc.
- Technology for integrating three-dimensional VLSI, chip stacking, multi-chip-module stacking and other advanced packaging techniques with stuctural elements.
- Concepts and designs for test and validation of design integrity and performance of IP based ASICs, mixed signal ASICs and MEMS.

S1.04 Spacecraft Technology for Micro/Nanosats
Lead Center: GSFC
Participating Center(s): JPL

NASA seeks research and development of components, subsystems and systems that enable inexpensive, highly capable small spacecraft for future SEC missions. The proposed technology must be compatible with spacecraft somewhere within the micro/nano range of 100 kg down to 1 kg. All proposed technology must have a potential for providing a function at current performance levels with significantly reduced mass, power, and cost, or, have a potential for significant increase in performance without additional mass, power and cost. These reduction and/or improvement factors should be significant and show a minimum factor of 2 with a goal of 10 or higher.

A proposed technology must state the type or types of expected improvements, (performance, mass, power, cost), list the assumptions for current state of the art, and indicate the spacecraft range of sizes for which the technology is applicable.

The integration of multiple components into functional units and subsystems is desirable but not a requirement for consideration.

- Avionics and architectures that support command and data handling functions, including input/output, formatting, encoding, processing, storage, and A to D conversion. System level architecture, software operating systems, low voltage logic switching, radiation-tolerant design and packaging techniques are also appropriate technologies for consideration.
- Sensors and actuators that support guidance, navigation, and control functions such as Sun/Earth sensors, star trackers, inertial reference units, navigation receivers, magnetometers, reaction wheels, magnetic torquers, and attitude thrusters. Technologies with applications to either spinning or three axis stable spacecraft are sought.
- Power system elements including those that support the generation, storage, conversion, distribution regulation isolation and switching functions for spacecraft power. System level architecture, low voltage buss design, radiation tolerant design and novel packaging techniques are appropriate technologies for consideration.
- New and novel application of technologies for manufacturing, integration and test of micro/nano size spacecraft are sought. Limited production runs of up to several hundred spacecraft can be considered. Efficiencies can derive from increased reliability, flexibility in the end-to-end production process as well as cost, labor and schedule.
- Technologies that support passive and active thermal control suitable for micro and nano size spacecraft are sought. These functions include heat generation, storage, rejection, transport and the control of these functions. Efficient system level approaches for integrated small spacecraft that may see a wide range of thermal environments are desirable. These environments may range from low heliocentric orbits to two-hour shadows.
- Elements that support Earth-to-space or space-to-space communications functions are sought. This includes receivers, transmitters, transceivers, transponders, antennas, RF amplifiers and switches. S and X are the target communications bands.

- Systems architectures and hardware that lead to greater spacecraft and constellation autonomy and therefore reduce operational expenses are desired. Technologies that derive added capability for a fixed bandwidth, efficient utilization of ground systems, status analysis and situation control or other enhancing performance for operations are sought.
- Structure and mechanism technologies and material applications that support the micro/nano class of spacecraft are desired. Exoskeleton structures, spin release mechanisms, and bi-stable deployment mechanisms are typical of the desired technology.
- Propulsion system elements that provide delta-V capability for spinning and/or three axis stable spacecraft are sought. This includes solid, cold-gas and liquid systems and their components such as igniters, thrust vector control mechanisms, tanks, valves, nozzles, and system control functions

S1.05 Information Technology for Sun-Earth Connection Missions
Lead Center: GSFC

A large number of multiple-spacecraft missions are planned for the future of SEC science. Cost-effective implementation of these missions will require new information technology: tools, systems and architectures for mission planning, implementation, and operations; and science data processing and analysis that facilitates scientific understanding. Specific research areas of interest for these SEC multi-spacecraft missions include but are not limited to:

Information Technology for mission planning and implementation

- Tools or systems that improve the system engineering, integration and test of multi-spacecraft missions;
- Tools that capture and represent scientific objectives as drivers for automated systems.

Information Technology for cost-effective multi-satellite mission operations

- Software tools/approaches for the economical operation of multi-spacecraft missions, including tools/approaches supporting both autonomous ground-based and space-based systems for multi-satellite operations;
- Agent-mediated grid computing supporting both on-the-ground and/or in-space distributed dynamic problem-solving;
- Automated approaches to on-board science data filtering and processing;
- Automated on-board instrument management and control;
- Innovative approaches to allow a PI to efficiently and effectively interface/interact with a highly-automated ground/space science data processing systems;
- Tools/approaches for inter-spacecraft communication and collaborative activity planning and management;
- Tools for synchronous multi-spacecraft operations;
- Tools for optimization of autonomous systems based on scientific objectives;
- Tools to reduce the cost of instrument and mission control software development.

Data analysis

Items of interest in this area focus on innovative approaches and the tools necessary to support space and solar physics Virtual Observatories (physically distributed heterogeneous science data sources considered as a logical entity) such as:

- Tools for enabling automated systematic identification, access, ad hoc science analysis, and distribution of large distributed heterogeneous data sets from space and solar physics data centers;
- Tools and techniques to significantly improve science data fusion and synthesis from multiple science sources and disciplines;
- Technologies and tools supporting management, storage, search and retrieval of heterogeneous, distributed data sets;
- Technologies and tools supporting inclusion of individual researcher provided, ad hoc, science analysis modules as a component of search criteria for remote data mining at space and solar physics data centers;
- Tools to facilitate data transfer and analysis for educational and public outreach.

S1.06 UV and EUV Optics and Detectors
Lead Center: GSFC
Participating Center(s): MSFC

From the Sun's atmosphere to the Earth's aurora, remote imaging, spectroscopy, and polarimetry at ultraviolet (UV) and extreme ultraviolet (EUV) wavelengths are important tools for studying the Sun-Earth connection. A far ultraviolet (FUV) range is sometimes interposed between UV and EUV, but the terminology is arbitrary: the pertinent full range of wavelength is approximately 20-300 nm.

Proposals should explain specifically how they intend to advance the state of the art in one or more of the following areas:

Imaging mirrors

- Large aperture: 1-4 m
- Low mass: 5-20 kg m-2
- Accurate figure: ~0.01 wave rms or better at 632 nm. Figure accuracy must be maintained through launch and on orbit (including, for mirrors subjected to direct or concentrated solar radiation, the effects of differential heating).
- Low microroughness: ~1 nm rms or better on scales below 1 mm.

Optical coatings and transmission filters

- Coatings (filters) with improved reflectivity (transmission) and selectivity (narrow bands, broad bands, or edges). Technologies include (but are not limited to) multilayer coatings, transmission gratings, and Fabry-Pérot étalons.

Diffraction gratings

- High groove density (> 4000 mm-1) for high spectral resolving power in conjunction with achievable focal lengths and pixel sizes
- High efficiency and low scattter (microroughness)
- Variable line spacing
- Echelle gratings
- Active gratings (replicated onto deformable surfaces)

Detectors

- Large format (4K x 4K 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)

TOPIC S2 Structure and Evolution of the Universe

The goal of the Space Science Enterprise's Structure and Evolution of the Universe (SEU) Theme is to seek the answer to three fundamental questions: 1) What is the Structure of the Universe and what is our Cosmic Destiny? 2) What are the cycles of matter and energy in the evolving Universe? 3) What are the ultimate limits of gravity and energy in the Universe? SEU's strategy for understanding this interactive system is organized around four fundamental Quests, designed to answer the following questions: 1) Identify dark matter and learn how it shapes galaxies and systems of galaxies, 2) Explore where and when chemical elements were made, 3) Understand the cycles in which matter , energy and magnetic fields are exchanged between stars and the gas between stars, 4) Discover how gas flows in disks and how cosmic jets formed, 5) Identify the sources of gamma-ray bursts and high energy cosmic rays and 6)Measure how strong gravity operates near black holes and how it affects the early universe.

S2.01 Sensors and Detectors for Astrophysics
Lead Center: JPL
Participating Center(s): GSFC

Future NASA astrophysics missions like Sofia, Herschel, Planck, FAIR, MAXIM, EXIST and ARISE (http://spacescience.nasa.gov/missions/index.htm) need improvements in sensors and detectors. Beyond 2007, expected advances in detectors and other technologies will allow the Filled Aperture Infrared instrument (FAIR) to extend HST observations into the mid and far infrared (40-500 micron) region; the MicroArcsecond X-ray Imaging Mission Pathfinder (MAXIM) will demonstrate the feasibility of x-ray interferometry with a resolution of 100 micro-arc seconds, which is 5000 times better than the Chandra observatory; the Energetic X-ray Imaging Survey Telescope (EXIST) will conduct the first high sensitivity, all-sky imaging survey at the predominantly thermal (x-ray) and non-thermal (gamma-ray) universe requiring a wide-field coded aperture telescope array; and the ARISE mission will create an interferometer including radio telescopes in space and on Earth.

Space science sensor and detector technology innovations are sought in the following areas:

Mid/Infrared/Far Infrared/Submillimeter
Future space-based observatories in the 10 to 40 micron spectral regime will be passively cooled to about 30K. 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 superconductng electronics are applicable areas. Future space observatories in the 40 micron to 1 mm spectral regime will be cooled to even lower temperatures, frequently <10K, 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 less than 10^(-20) W Hz-1/2 over most of the spectral range in a 100x100 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 desireable, operating in the same frequency range near the quantum limit.

X-ray/Gamma-ray
Large format gas micro-structure detectors for use with "lobster eye" x-ray optics are needed. Desirable characteristics include any of the following: low energy band-pass (0.25 - 4 keV), large area (> 10 cm), good spatial resolution (< 300 microns), integrated read-out (e.g., micro-structure detector manufactured on or bonded to two dimensional thin film transistor arrays). Also of interest are detectors that can be extended to 3 dimensions and large volumes (meter scale) for gamma-ray tracking. Applications for detectors are expected in low rate environments, making background suppression important. For soft x-ray detectors, the capability of distinguishing x-ray interactions from particle tracks is essential, while for gamma-ray applications the ability to reconstruct events via track recognition is required.

Space Very Long Baseline Interferometry (VLBI)
The next generations of Very Long Baseline Interferometry (VLBI) missions in space will demand greatly improved sensitivity over current missions. These new missions will also operate at much higher frequencies (at first to 86 GHz and eventually to 600 GHz). These thrusts will require development of improved space-borne low-power ultra-low-noise amplifiers to serve as primary receiving instruments.

S2.02 Terrestrial and Extra-Terrestrial Balloons and Aerobots
Lead Center: GSFC
Participating Center(s): JPL

Innovations in materials, structures, and systems concepts have enabled buoyant vehicles to play an expanding role in NASA's Space and Earth Science Enterprises. 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. Smaller scale but similarly designed balloons and airships will also 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. Robotic balloons, known as aerobots, have a wide range of potential applications both on Earth and on other solar system bodies. NASA is seeking innovative and cost effective solutions in support of terrestrial and extra-terrestrial balloons and aerobots in the following areas:

Stratospheric Long Duration Balloon (LDB) Support

Materials

- Innovative membranes for terrestrial applications to support the Long Duration Balloon (LDB) and Ultra Long Duration Balloon (ULDB) development efforts. The material of interest shall meet all environmental, design, fabrication and operational requirements and must be producible in large quantities in a lay flat width of at least 1.6 meters.
- Innovative concepts for reducing the UV degradation of flight components including balloon membranes, load carrying members, and parachute components.

Support Systems

- Innovative concepts for trajectory control for effectively maneuvering large terrestrial and small extra-terrestrial aerobots in both the horizontal latitude and vertical altitude planes.
- Innovative low mass, high density and high efficiency power systems for terrestrial balloons that produce 2 kW or more continuously.
- Innovative power systems that enable long duration, sunlight independent missions for a duration of 30 days or more.
- Innovative, low cost, low power, low mass, precision instrument pointing systems that permit arcsecond or better accuracy.
- Innovative, low cost phased array antenna systems which support TDRSS return link S-Band or Ku-Band communications.
- Innovative sensor concepts for balloon gas or skin temperature measurements.

Design and Fabrication

- Innovative, efficient, reliable and cost-effective balloon fabrication and inspection techniques to support the current ULDB development efforts.
- Innovative balloon design concepts for ULDB missions that can provide any or all of the following:
    - Reduce material strength requirements
    - Increase reliability
    - Enhance performance
    - Reduce manufacturing time
    - Reduce manufacturing cost
    - Improve mission flexibility

Titan missions support

Titan is the second largest moon in the solar system and the only one that features a sufficiently dense atmosphere for buoyant vehicle flight. Targeted for exploration by Cassini-Huygens in 2004 and beyond, Titan is expected to be a geologically and chemically diverse world containing important clues on the nature of prebiotic chemistry. NASA is starting to lay the ground work for post-Cassini-Huygens exploration of Titan using highly autonomous, self-propelled aerobots capable of surveying many widely separated locations on Titan and potentially including surface sampling and composition analysis. Innovative technologies are sought in the following areas:

- Concepts, devices and materials for sealing (repairing) small holes in the balloon envelope material during flight at Titan. Repair of these holes may be required to enable the long mission lifetimes (6-12 months) desired at Titan. Although the balloon envelope material for Titan has not yet been specified, repair strategies should be generally compatible with polymer materials and the 90 K environment. It is imperative that proposed solutions be low mass (on the order of a few kilograms) and low power (a few Watts).
- Concepts and devices for the processing of atmospheric methane into hydrogen gas and its use as a makeup gas to compensate for leakage during operational flight at Titan. It is imperative that proposed solutions be low mass (on the order of a few kilograms) and low power (a few Watts).
- Low permeation envelope materials in the range of 100-150 g/m^2 or less along with seaming approaches that can yield airship hulls suitable for deployment and operation at temperatures of 90 K. These materials must be storable in a densely packed configuration for the expected 7-10 year cruise to Titan.

Venus missions support
Venus is the second planet from the Sun and features a dense, CO_2 atmosphere completely covered by clouds. Although already explored by various orbiters and short-lived atmospheric probes and landers, Venus retains many secrets pertaining to its formation and evolution. NASA believes future Venus exploration will include longer duration in situ platforms such as balloons that can fly under the clouds. Innovative technologies are sought in the following areas:

- Concepts and materials for high temperature Venus balloon envelopes including the seaming technology required for balloon fabrication. These materials must be storable in a packaged condition for up to 1 year, have an areal density in the range of 50-150 g/m^2 and be compatible with the Venus environment of up to 460º C and sulphuric acid aerosols. Materials for both zero-pressure and superpressure balloons are desired with sizes in each ranging from 5 to 20 m in diameter.
- Concepts and devices for surface deployment of Venus balloons. Unlike the VEGA balloons flown by the Soviets in the upper atmosphere of Venus in 1985, some future Venus missions will require surface deployment of a balloon for the purpose of lifting samples into the upper atmosphere. The balloons will have the general properties as described above. The short lifetime of landed assets on Venus constrains balloon deployment approaches to be essentially launch-on-demand and therefore tolerant of Venus surface wind conditions which are thought to be up to 1.5 m/s.

S2.03 Multiple Coordinated Observatories
Lead Center: GSFC
Participating Center(s): JPL

A revolution is taking place in the way we conduct a range of space science missions. Specifically, the next decade will bring over 20 missions which involve formations of coordinated, observing platforms, or virtual platforms (VPs) in order to enable very long baseline imaging systems, high resolution interferometric imaging of extended scenes, time-synchronous observation of phenomena in space, and complex communications networks to name a few. These distributed systems will operate under virtual infrastructures capable of responding to changing needs and conditions while evolving over time to introduce new capabilities. Representative mission scenarios include maintaining a specified satellite formation geometry at key points in the trajectory, maintaining the relative motion among co-orbiting spacecraft throughout the orbit, or maintaining relative positioning and attitude for targeting starts and other points distant in this or other solar system. Some of the more challenging scenarios involve the measurement of gravity waves and the imaging of black holes. These missions have relative measurement and/or control requirements on the order of nano- or even picometers, sometimes at tens, thousands, and even millions of kilometers apart. Frequently, these requirements go beyond the capability of current technology in the ability to sense and control position and orientation. Additionally, distributed spacecraft concepts of collective pointing and phasing of a number of observing systems relative to a target of interest or coordinated pointing (pointing the formation to collect related data from different selected angles) are critical to many of these mission scenarios. In addition to the dynamic behavior of each individual spacecraft, the collective behavior of all the spacecraft in the formation will determine the quality and the magnitude of the science return.

The requirements for coordinating these platforms have necessitated a major change in how we analyze, design, operate, and maintain space-based observatories. In particular, in many cases, several of the spacecraft bus components, which were at one time virtually decoupled from the payload or science sensor, are now fully integrated and fully coupled together operationally. This is the case for a wide range of interferometry missions where the interferometric measurements, which provide the primary science product, are the only measurements available at the precision required to maintain the spacecraft formation.

In this subtopic we invite proposals that address a key element required for formations of spacecraft that collectively perform micro-arcsecond class imaging. Specifically, we are looking for the following:

- Sensor concepts and algorithms (to include novel architectures employing existing component technologies such as star trackers) which enable determination of line-of-sight (LOS) of multiple vehicles relative to an inertial source in space to micro-arcsecond class accuracy and precision. The vehicles can be separated by distances along the LOS between 100's to 10,000's of kilometers. The LOS is defined not by the attitude or orientation of individual vehicles but by the angle between a line drawn from the focal plane to the source and the line along the focal length of a distributed telescope consisting of sub-elements on multiple vehicles.
- Control architectures and algorithms to control the LOS to micro-arcsecond tolerances.
- Novel simulation and analysis architectures that enable, modeling, simulation, measurement, and control design of the LOS.

In particular, we are interested in technologies that are robust, fault-tolerant, and that lead to affordable and implementable solutions for future missions.

S2.04 Cryogenic Systems
Lead Center: GSFC
Participating Center(s): ARC, JPL, JSC, MSFC

Cryogenic systems have long been used to perform cutting edge space science, but at high cost and with limited lifetime. Improvements in cryogenic system technology enable further scientific advancement at lower cost and/or lower risk. Both the lifetime and the reliability of the cryogenic systems are critical performance concerns. Of interest are cryogenic coolers for cooling detectors, telescopes and instruments. 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 50 milli-Kelvin and below, and cryogen-free systems which integrate these coolers together.
- Essentially vibration-free cooling systems such as reverse Brayton cycle cooler technologies
- Highly reliable, efficient, low cost Stirling and pulse tube cooler technologies in the 15K, 35K and 70K regions.
- Highly efficient magnetic and dilution cooling technologies, particularly at very low temperatures
- Hybrid cooling systems that make optimal use of radiative coolers.
- Miniature, MEMS and solid-state cooler systems.

S2.05 Optical Technologies
Lead Center: GSFC
Participating Center(s): JPL, MSFC

The NASA Space Science Enterprise is studying future missions to explore the Structure and Evolution of the Universe (SEU). To understand the structure and evolution of the universe, a variety of large space-based observatories are necessary to observe cosmic phenomena from radio waves to the highest energy cosmic rays. It will be necessary to operate some of these observatories at cryogenic temperatures (to 4K) beyond geo-synchronous orbits. Apertures for normal incidence telescope optics are required up to 40 m in diameter, while grazing incidence optics are required to support apertures up to 10 m in diameter. For some missions, these apertures will form a constellation of telescopes operating as interferometers. These interferometric observatories may have effective apertures up to 1000 m diameter. Low mass of critical components such as the primary mirror, its support and/or deployment structure is extremely important. In order to meet the stringent optical alignment and tolerances necessary for a high quality telescope and to provide a robust design, there are significant benefits possible from employing systems that can adaptively correct for image degrading sources from inside and outside the spacecraft. This includes correction systems for large aperture space telescopes that require control across the entire wavefront, typically at low temporal bandwidth. The following technologies are sought:

- Grazing incidence focusing mirrors with response up to 150 keV
- Large, ultra-lightweight grazing incidence optics for x-ray mirrors with angular resolutions less than 5 arcsec.
- Wide field of view optics using square pore slumped micro-channel plates or equivalent
- Develop fabrication techniques for ultra-thin-flat silicon (or like material) for grating substrates for x-ray energies < 0.5 keV
- Large area thin blocking filters with high efficiency at low energy x-ray energies (< 600 eV).
- Ultraviolet filters with deep blocking (<1 part in 105) of longer and shorter wavelengths, including "solar blind" performance; novel near to far IR filters with increased bandwidth, stability, and out of band blocking performance
- Develop novel materials and fabrication techniques for producing ultra-lightweight mirrors, high-performance diamond turned optics (including freeform optical surfaces), and ultra-smooth (2-3 angstroms rms) replicated optics that are both rigid and lightweight. Lightweight high modulus (e.g., silicon carbide) optics and structures are also desired.
- High-performance (e.g., high modulus, low density, high thermal conductivity) materials and fabrication processes for ultra-lightweight, high precision (e.g., subarcsecond resolution or <=1 nm figure quality) optics.
- Advanced, low-cost, high quality large optics fabrication processes and test methods including active metrology feedback systems during fabrication, and artificial intelligence controlled systems.
- Large, ultra-lightweight optical mirrors including membrane optics for very large aperture space telescopes and interferometers
- Cryogenic optics, structures, and mechanisms for space telescopes and interferometers
- Ultra-precise, low mass deployable structures to reduce launch volume for large-aperture space telescopes and interferometers
- Segmented optical systems with high-precision controls; active and/or adaptive mirrors; shape control of deformable telescope mirrors; image stabilization systems
- Advanced, wavefront sensing and control systems including image based wavefront sensors
- Wavefront correction techniques and optics for large aperture membrane mirrors and refractors (curved lenses, Fresnel lenses, diffractive lenses).
- Nanometer to sub-picometer metrology for space telescopes and interferometers
- Develop ultra-stable optics over time periods from minutes to hours
- Advanced analytical models, simulations, and evaluation techniques and new integrations of suites of existing software tools allowing a broader and more in-depth evaluation of design alternatives and identification of optimum system parameters including optical, thermal, structural, and dynamic performance of large space telescopes and interferometers

- Develop portable and miniaturized state-of-the-art optical characterization instrumentation and rapid, large-area surface-roughness characterization techniques are needed. Also, develop calibrated processes for determination of surface roughness using replicas made from the actual surface. Traceable surface roughness standards suitable for calibrating profilometers over sub-micron to millimeter wavelength ranges are needed
- Develop instruments capable of rapidly determining the approximate surface roughness of an optical surface, allowing modification of process parameters to improve finish, without the need to remove the optic from the polishing machine. Techniques for testing the figure of large, convex aspheric surfaces to fractional wave tolerances in the visible are needed.

S2.06 Advanced Photon Detectors
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/millions of resultant spatial resolution elements.

Innovative technologies are sought to enhance the scope, efficiency and resolution of instrument systems at all energies/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 a housing for containing the proof mass in a suitable environment (i.e., high vacuum, low magnetic and electrostatic potentials, etc.).
- Advanced 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, 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 mm2 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 super-conducting 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 keV to 10 keV,
  - 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. We seek 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 to 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.

TOPIC S3 Astronomical Search for Origins

NASA's Origin's Program seeks the answers to two broad questions related to life on Earth as we know it. How we got here and are we alone? The answers lie in an understanding of how galaxies, stars, and planetary systems formed in the early universe. We must determine whether planetary systems and Earth like planets are typical companions of average stars and if life beyond Earth is a rare, possibly nonexistent, occurrence or if it is robust and has spread throughout the galaxy. Origin's primary mission goals are to study the early universe, find planets around other stars, and search for life beyond Earth.

S3.01 Precision Constellations for Interferometry
Lead Center: JPL

This subtopic seeks hardware and software technologies necessary to establish, maintain and operate hyper-precision spacecraft constellations to a level that enables separated spacecraft optical interferometry. Also sought are technologies for analysis, modeling and visualization of such constellations.

In a constellation for large effective telescope apertures, multiple, collaborative spacecraft in a precision formation collectively form a variable-baseline interferometer. 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 to 3 orders of magnitudes 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.

Innovations that address the above precision requirements are solicited for distributed constellation 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/decentralized formation estimation.

- Distributed sensor fusion.
- RF/optical precision metrology systems.
- Formation sensors.
- Precision micro-thrusters/actuators.
- Autonomous re-configurable formation techniques.
- Optimal, synchronized, maneuver design methodologies.
- Collision avoidance mechanisms.
- Formation management and station keeping.
- Six degrees of freedom precision formation testbeds.

S3.02 Astronomical Instrumentation
Lead Center: JPL
Participating Center(s): ARC

Much of the scientific instrumentation used in future NASA observatories for the Origins Program theme will be similar in character to instruments used for present day space astrophysical observations. However, the performance and observing efficiency of these instruments 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 near-infrared to past 100 microns. Measurement techniques include imaging, photometry, spectroscopy, coronography, and polarimetry. Of particular interest are:

Advanced Detectors
These efforts should propose breakthrough capabilities in spectral coverage, large array size with uniform high quantum efficiency, ultra-low dark current, elevated operating temperatures, spectroscopic capabilities, or their ability to operate effectively and reproducibly over long periods (ex. 5-10 years of space observations at low power, extreme temperatures, etc.). [cf. SEU Subtopic S2.01 Sensors and Detectors for Astrophysics]

Cryogenic Readout Electronics
Proposed space observatory sizes require driving analog detector signals over ever increasing distances to the warm (> 250 K) readout electronics. Novel, low power components which can be located near the detector are sought to either 1) drive long (> 5 m) signal cables with excellent fidelity (~16 bit accuracy) or, 2) move more of the signal chain, perhaps including the A/D converters, into the cold area (< 50 K).

High Performance Filters
There is a critical need for new sources of custom infrared bandpass filters with good in-band transmission and very low out-of-band transmission at wavelengths longward of 1 micron and extending to approximately 30 microns. Desirable passbands range from 50% to less than 1% of the central wavelength with in-band transmissions > 70%. Both fixed and tunable filters operating at temperatures < 50 K are desirable.

Other Optical and Opto-mechanical Instrument Components
Given the call for multiple capability instruments, there is a growing need for breakthrough concepts in instrument optics which minimize the volume requirements while adding capabilities (spectral, or otherwise) to the instrument. These elements may include gratings, prisms, dichroics, or other novel components. [cf. S2.05 Optical Technologies]

Mechanical Coolers
The best detectors for wavelengths > 5 microns usually need to be cooled to < 10 K. There are a number of proposed Origins missions which have cooling requirements ranging from 50 mK to 20 K; highly stable (both mechanical and temperature stability), long life coolers are needed for these. Efforts may address the component level such as materials for magnetic refrigerants or novel heat switches, or they may address entire systems such as pulse tube, J-T, sorption, or sub-kelvin coolers. [cf. S2.04 Cryogenic Systems]

S3.03 High Contrast Astrophysical Imaging
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. Examples include planetary systems beyond our own and the detailed inner structure of galaxies with very bright nuclei. Contrast ratios of one million to one billion over an angular spatial scale of 0.05 arcseconds to 1.5 arcseconds are typical of these objects. Achieving a very low background against which to detect a planet 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 any star light cancellation scheme.

This innovative research focuses on advances in coronagraphic instruments, interferometric star light 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. In some architectures, both the telescope and instrument package need to be optimized for high contrast imaging. Any auxiliary instrumentation secondary to high contrast imaging must not compromise the high contrast optimization of the telescope. For infrared applications, operation at cryogenic temperatures is required.

There is interest in component development, innovative instrument design, as well as in the fabrication of subsystem devices to include the following areas:

Large Optics Fabrication for High Contrast Imaging:

- Development and demonstration of fabrication processes scalable to large aspheric mirrors (4 to 10 m diameter) that maximize suppression of mid-spatial frequency (20 mm to 1000 mm) figure errors without increasing high frequency surface errors (5 nm rms goal with areal density goal of ~25kg/m^2). Reducing print-through, minimizing thermal sensitivity, and methods of correcting primary surface figure are of top interest.
- Ultra-low scatter and high throughput, uniform optical coatings.
- Validation of optical surface uniformity over mission life.

Wavefront Sensing and Control Components:

- Development of small stroke, high precision deformable mirrors (DM) and associated driving electronics scalable to 10^4 or more actuators (both to further the state-of-the art towards flight-like hardware, and to explore novel concepts). Multiple DM technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices.
- 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, 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.
- Thermal control through fabrication of nanotube materials. Currently the state-of-the art of nanotube fabrication produces tube bundles of length approximately 5 centimeters. Development of advanced new fabrication techniques producing longer, weavable bundles would enable strong, lightweight cloth with very high thermal conductivity.

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 um.
- 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 um wavelength.

S3.04 Large-Aperture Lightweight Cryogenic Telescope Mirrors
Lead Center: MSFC
Participating Center(s): JPL

Planned future NASA infrared, far infrared and sub-millimeter missions such as the Single Aperture Far-IR telescope and infrared space interferometers require large-aperture lightweight cryogenic optics. Potential mission concepts require 2-meter class mirror segments that can be assembled into 10 to 30 meter class telescopes. Other concepts may desire 4-meter class mirrors. Depending upon the science mission, these mirrors must be diffraction limited at 5 to 20 micrometers and operate at temperatures from 4 to 10K. It is anticipated that these mirrors will need active cooling. The desired areal density is 3 to 8 kg/m^2. High stiffness is also important.

Building on the mirror development effort conducted for the James Webb Space Telescope, this topic is soliciting proposals that will advance the state of the art in manufacturing actively cooled large-aperture lightweight cryogenic optics. The goal for this effort is to mature technologies that can fabricate 50 to 100 square meters of flight qualified mirrors at a cost of less than $300K per square meter. Proposals that fabricate demonstration mirrors with direct scalability to flight mirrors will be given preference.

TOPIC S4 Exploration of the Solar System

NASA's program for Exploration of the Solar System 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. Numerous new technologies will be required to enable such ambitious missions.

S4.01 Science Instruments for Conducting Solar System Exploration
Lead Center: JPL
Participating Center(s): ARC

Achieving the Solar System Exploration goals requires innovative miniaturized science instruments and instrument components that offer significant improvement over the state of the art in terms of size, mass, power, cost, performance, and robustness. This subtopic supports the development of advanced instrument technology that has potential for scientific investigation on future planetary missions. New measurement concepts, advances in existing instrument concepts, advances in critical components such as detectors, sample handling techniques and technologies that enable integrated instrument architectures are all of interest. Offerors are encouraged to relate their proposed technology development to future planetary science goals as much as possible. Information on planetary science goals may be found at the NASA web site http://solarsystem.nasa.gov.

A wide range of remote sensing and in situ instruments is of interest: geological, chemical, biological, physical, and environmental. New instruments and components are needed that will: lead to new discoveries in the extremes of planetary environments, open new areas of scientific endeavor, refine and reinvigorate measurements that have been limited by past technology challenges. Instruments that enable astrobiology-related measurements seeking to understand the origin and evolution of life and pre-biotic processes are encouraged. New in situ analysis techniques are desired to identify and quantify biogenically important elements (C, H, N, O, P, and S), their compounds (e.g., CH_4, NOx, H_2O), and mineralogical biosignatures within extraterrestrial atmospheres, soils, ices, rocks, and minerals.

Future Mission Needs
The following future mission needs will receive emphasis during proposal selection:

- Mars Surveyor Missions: Missions to Mars will include both orbiters and landers with launches occurring approximately every 26 months. The high-level science drivers for Mars include characterizing the ancient and present climate as well as climate processes, determining the evolution of the Martian surface and interior, determining if life ever arose on Mars, and characterization of the environment in preparation for human exploration.
- Inner and Outer Solar System Missions: Other planetary mission opportunities might include an Europa orbiter, Europa lander, Venus in situ explorer, a Titan lander, a comet nucleus sample return, Pluto fly-by, lunar sample return, Jupiter explorer, and multiple asteroid landers. Instruments for these possible missions are particularly challenging because of the extreme environmental constraints. Europa measurement needs include characterization of the near-surface composition, determination of the compositional, geophysical, and geological context at large- and small-scales, and a search for indications of a Europan biosphere. Titan drivers include a determination of the distribution and composition of organics, and atmospheric dynamics. Venus technology drivers include survival in high temperatures and harsh atmosphere. Missions to comets, with the potential for finding pre-biotic molecules, face challenges due to micro-gravity and extremely cold and dusty environments.
- Discovery Program Missions: Discovery program missions represent a series of competed, focused missions to a variety of solar system objects. They may include orbiters, landers, flybys, balloons, and airplanes to study a wide variety of science goals involving geology, geochemistry, geophysics, atmospheres and climates, and particles and fields. Instrumentation and instrument concepts that address this broad range of needs will be considered.
- Mars Scout Program Missions: Mars Scout program missions represent a series of competed, focused missions to Mars. They are competed approximately every 4 years, with the next new opportunity planned for launch in 2011. They may include orbiters, landers, flybys, balloons, and airplanes to study a wide variety of science goals involving geology, geochemistry, geophysics, atmospheres and climates, and particles and fields. Instrumentation and instrument concepts that address this broad range of needs will be considered.

Example Measurement Needs
Meeting the needs for the Solar System exploration goals requires a significant portfolio of advanced scientific instrumentation. Examples of instruments that might meet some of the Solar System Exploration goals include, but are not limited to, the following.

- Chemical sensing instrumentation for the surface and subsurface chemical, mineralogy, and isotopic analysis of soils, rocks, and ices. Examples include Raman spectrometers, laser-induced breakdown spectrometers, water/ice detectors, age-dating systems, electrochemical systems, thin film sensors, liquid and gas chromatography systems, gas chromatograph-mass spectrometers and other mass analyzing systems.
- Instrumentation focused on exobiological assessments for the identification and characterization of biomarkers of extinct or extant life, or prebiotic molecules. Examples include ultraviolet-Raman, infrared reflectance and transmittance, fluorescence microscopy, total organic carbon analyzers, microcalorimetry concepts, NMR spectroscopy, chromatography systems, CHONS isotope analy-

sis, biosensor concepts, ion mobility spectrometers or other molecular identification instrumentation capable of operating alone or as part of a gas chromatograph system.
- Sensing instrumentation that integrates such functions as separation, reagent addition, and detection, especially using emerging "lab-on-a-chip" technologies.
- Sub-optical microscopy instrumentation to characterize morphology, elemental and mineralogical composition, such electron microscopy techniques and atomic force microscopy.
- Instrumentation for the chemical and isotopic analysis of planetary atmospheres.
- Physical and environmental sensing systems, such as seismic and meteorological sensors, humidity sensors, wind and particle size distribution sensors.
- Particles and fields measurements, such as magnetometers, and electric field monitors.
- Enabling in situ instrument component and support technologies, such as 2-10 micron laser sources, miniaturized pumps, sample inlet systems, valves, and fluidic technologies for sample preparation.
- Advanced detectors and focal plane arrays in the regimes of radar/sub-mm through IR/Vis/UV.

Requirements
While both remote and in situ sensing instruments are of interest, NASA's space science missions will increasingly rely upon in situ characterization of the atmosphere, surface and subsurface regions of planets, satellites, and small bodies. These instruments may be deployed on surface landers and rovers, subsurface penetrators, cryobots, and airborne platforms. These instruments must be capable of withstanding operation in space and planetary environmental extremes, which include temperature, pressure, radiation, and impact stresses. A reasonable target for an in situ science instrument concept is 1-kilogram mass, 1-liter volume, and 1 watt-hour of energy, although for mission critical capabilities additional resources might be available.

Outcomes
Research should be conducted that will lead to, when possible, delivery of a demonstration unit or software package for JPL testing.

S4.02 Robotic Technologies
Lead Center: JPL

This sub-topic is comprised of two elements: 1) Technologies for Severe Environments and 2) Technologies for Aerial Mobility. Both areas are focused on the future in situ exploration needs for Titan and Venus, worlds featuring dense atmospheres with low and high temperature extremes respectively. Note that some technologies developed for the cryogenic environment of Titan will also be applicable to other severe low temperature destinations like asteroids, comets, and Europa.

Titan is the second largest moon in the solar system and the only one that features a sufficiently dense atmosphere for buoyant vehicle flight. The atmosphere is predominantly nitrogen with a surface temperature of approximately 90 K. Targeted for exploration by Cassini-Huygens in 2004 and beyond, Titan is expected to be a geologically and chemically diverse world containing important clues on the nature of prebiotic chemistry. NASA is starting to lay the ground work for post-Cassini-Huygens exploration of Titan using autonomous, self-propelled aerobots capable of surveying many widely separated locations and potentially including surface sampling and composition analysis. Venus is the second planet from the Sun and features a dense, CO_2 atmosphere completely covered by clouds with sulfuric acid aerosols, a surface temperature of 460 ºC 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 use of long lived (days or weeks) balloons and landers.

Technologies for Severe Environments
There is no single severe environment technology solution that satisfies the operational requirements of these missions. A traditional approach to survivability in extreme temperature/pressure environments is to use passive (insulation and heat sinking) or active thermal control so no components are exposed to the environment and the whole system is maintained at conventional temperature and normal pressure. Another

approach is to develop hardware components that can reliably operate and survive in extreme temperatures thus eliminating the need for thermal control. Finally the hybrid combination of these two approaches is an architecture where all temperature-sensitive components are maintained inside an insulated thermal enclosure and any hardware that is located outside has to be capable of survival in that environment (some limited local thermal control may be also possible). This approach requires less-complicated and lighter thermal control and enables more advanced surface and aerial operations. Note that some technologies developed for the cryogenic environment of Titan will also be applicable to other severe low temperature destinations like asteroids, comets, Europa, etc.

This topic seeks technology innovations in the following areas:

- Advanced thermal control for Venus including lightweight (50 kg/m^3), insulated pressure vessels able to protect the electronics and instruments enclosed inside for a few hours at 460 ºC and 100 bar; new lightweight thermal insulation materials (0.1 W/mK at 460 ºC), thermal storage (with 300-1000 kJ/kg energy density), thermal switches (over 1 W/K for "on" and 0.01 W/K for "off" mode), and high performance heat pipes (0.05 W/mK at 460 ºC and 100 bar).
- Science and engineering sensors able to operate at 460 ºC and 100 bar.
- High temperature electronics and electronic packaging for sensor and actuator interfaces at 460 ºC including low noise (10 nV/sqHz) preamplifiers and drivers (with 0-100 V digital output for driving piezoelectric, electrostatic, or electromagnetic actuators).
- High temperature primary and rechargeable batteries (200 W-hr/kg, 100 cycles) for operation at 460 ºC.
- Low-temperature, low mass, high reliability, integrated electronics able to operate at -180 ºC for extended period of time (years).

Technologies for Aerial Mobility
In addition to the severe environment technologies above, innovative technologies are also sought in the following areas of robotic technologies for aerial mobility:

- Concepts and devices for low mass (few kilogram), high efficiency propellers and electric drive motors in the 90 K Titan environment. Desired maximum wind-relative flight speeds at Titan are expected to be the range of 1-3 m/s with a total vehicle drag of 10-20 N and available electrical power of 20-50 W.
- Autonomy technology applicable to self-propelled Titan aerobots in the area of science-based object recognition and tracking using various sensing modalities (passive imager, thermal imager, spectrometers, etc.). Aerobot altitudes ranging from 0 to 8 km can be assumed for observation of the surface, with ground relative speeds of 0 to 10 m/s. It will be important to validate proposed algorithms and software through simulation and/or experiment.
- Autonomy technology for onboard real-time aerobot system identification. This capability will be important for long-lived aerobots that may suffer from mechanical degradation, buoyancy gas loss, precipitation accumulation (icing) or other factors that change the dynamic behavior of the vehicle over time. It will be important to validate proposed algorithms and software through simulation and/or experiment.
- Sample handling and acquisition systems including high temperature drills, motors, and actuators able to operate in the 460 ºC surface environment of Venus.
- Concepts and devices for surface sample acquisition from an aerobot in the 90 K surface environment of Titan. These can include, but are not limited to, station keeping, landed or anchored (tethered) aerobots. Both liquid and solid (rock or drilled core) samples are of interest.

S4.03 Advanced Miniature and Microelectronics, Nanosensors, and Evolvable Hardware
Lead Center: JPL
Participating Center(s): ARC, GRC

The strategic plan within the Office of Space Science at NASA calls for intense exploration of a wide variety of bodies in the Solar System within a modest budget. To achieve this will require revolutionary advances over the capabilities of traditional spacecraft systems and a broadening of the tool set through the introduction of new kinds of space exploration systems. These systems will include, but are not limited to, orbiters, landers, atmospheric probes, rovers, penetrators, aerobots (balloons), planetary aircraft, subsurface vehicles (ice/soil), and submarines. Also of interest are delivery of distributed sensor systems consisting of networks of tiny (<<1 kg) individual elements which combine sensors, control, and communications in highly integrated packages, and which are scattered over planetary surfaces, atmospheres, oceans, or subsurfaces. New technology is needed in all spacecraft areas for mass, power, and volume reductions, and for application to harsh environments such as extreme temperature, radiation, and mechanical shock.

Advanced Miniature and Micro Avionics and Electronics
Advances in microelectronics, avionics architecture, packaging and thermal control are sought. Applicable technology areas include:

- Avionics, including highly integrated, ultra low power and extreme long life components.
- Avionics and communication components including sensors, actuators, ultra stable oscillators, mixers, and micropower sources, able to operate in extreme environments: low temperature, high temperature, high radiation.
- Thermal management for electronics, including active and passive techniques.
- Three-dimensional VLSI, chip stacking, multi-chip-module stacking and other advanced packaging techniques.
- Low power, COTS-based radiation tolerant and advanced power management techniques.
- Radiation hard, high density, non-volatile mass memory.
- Radiation hard microelectronics and integrated circuits.
- Fault tolerance and onboard maintenance design and analysis techniques for severely constrained environments and extreme long life missions.
- Concepts and designs for test and validation of design integrity and performance of IP based ASICs, mixed signal ASICs and MEMS.
- High resolution, high sampling rate, low power and radiation-hardened analog-digital converters, and digital signal processing hardware components with algorithm design environments for rapid design and prototyping.

Nanotechnology
The nanosensing and the bio-nanotechnology for sensing aspect of this subtopic seeks to leverage breakthroughs in the emerging fields of nano-technology and biotechnology to develop advanced sensors and actuators with increased sensitivity and small size for solar system exploration. Technologies should provide enhanced capabilities, such as high-Q RF signal processing, single molecule sensing and manipulation, on-chip biomolecular analysis, harsh environment operable nanosystems, and semiconductor laser diodes and detectors in the 2-5 um wavelength range. Of particular interest are carbon nanotube-based sensors and actuators, quantum dots based opto-electronics devices, quantum sensors and measurements, magnetic field sensors and nanocrystal based evolvable computing and memory architectures.

Evolvable Hardware
We are also interested in novel and innovative technologies for evolvable space systems. The main focus is on a complete system approach, which would lead to demonstrations of autonomously evolving systems using reconfigurable recourses such as Field Programmable Gate Arrays (FPGA) or Field Programmable Transistor Arrays (FPTA).

S4.04 Deep Space Power Systems
Lead Center: GRC
Participating Center(s): JPL, JSC, MSFC

Innovative concepts utilizing advanced technology are solicited in the areas of energy conversion, storage, power electronics, and power system materials. Power levels of interest range from tens of milliwatts to several kilowatts. NASA Space Science missions require energy systems with high energy density, reliability and low overall costs (including operations). Advanced technologies are sought in the following areas:

Energy Conversion
Advances in photovoltaic technology are sought, including ultra light-weight thin and concentrator arrays with substantial increases in specific power (w/kg) and decreased cost. Must accommodate radiation resistance, low temperature/low intensity, and high temperature/ high intensity operation.

Advances in radioisotope power conversion to electricity (tens of milliwatts to hundreds of watts with efficiencies > 20 %). Includes advances in AMTEC, thermophotovoltaics, thermoelectrics, Stirling, and microfabricated power systems.

Energy Storage
Includes advances in primary and secondary (rechargeable) battery technologies. Technologies include lithium ion batteries, lithium polymer batteries and other advanced concepts providing dramatic increases in mass and volume energy density (w-hr/kg) and (w-hr/liter). Must be able to operate in harsh environments, including high radiation and low/high temperature regimes.

For operation on planetary surfaces, the use of regenerative fuel cells, both conventional and unitized - passive designs, with substantial increases in mass and volume specific energy for those situations where there are substantial time periods of charging/recharge (anywhere from hours to days).

Power Electronics
Advanced electronic technologies with reduced volume and mass capable of high-temperature, low-temperature (cryogenic), or wide-temperature operation, radiation resistance, and/or electromagnetic shielding with thermal control.

Thermal control integral to electrical devices capable of > 100 W/cm2 heat flux.

Advanced electronic materials, devices and circuits including transformers, integrated circuits, capacitors, ultra capacitors, electro-optical devices, micro electro-mechanical systems (MEMS), sensors, low loss magnetic cores, motor drives, electrical actuation.

Advanced PMAD control technologies including fault detection, isolation, and system reconfiguration, including "smart components," built-in test, health management, and power-line or wireless communication.

Power System Materials
Advances are sought in materials, surfaces, and components that are durable for soft x-ray, electron, proton, and ultraviolet radiation and thermal cycling environments, lightweight electromagnetic interference shielding, and high-performance, environmentally durable thermal control surfaces.

S4.05 Astrobiology
Lead Center: ARC
Participating Center(s): JPL

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.

A second element of Astrobiology is the understanding of the evolutionary development of biological processes leading from single cell organisms to multi-cell specimens and to complex ecological systems over multiple generations. Understanding of the effects of radiation and gravity on lower organisms, plants, humans and other animals (as well as elucidation of the basic mechanisms by which these effects occur) will be of direct benefit to the quality of life on Earth. These benefits will occur through applications in medicine, agriculture, industrial biotechnology, environmental management and other activities dependent on understanding biological processes over multiple generations.

A third component of Astrobiology includes the study of evolution on ecological processes. Astrobiology intersects with NASA Earth Science studies through the highly accelerated rate of change in the biosphere being brought about by human actions. One particular area of study with direct links to Earth Science is microbe-environment interactions.

NASA seeks innovations in the following technology areas:

- For Mars exploration, technologies that would enable to provide a broad survey of areas in the vicinities of a rover or lander to narrow down a field of search for biomarkers.
- For Mars exploration, technologies that (using x-ray, neutron, ultrasonic and other type of tomography) would enable a non-invasive, non-destructive analysis of subsurface environment and areas inside rocks and ice to depths 10-20 cm with spatial resolutions 2-10 micron. Such technologies should provide capability for analysis of structures inside opaque matrices created by endolithic organisms or fossil structures, and possible elemental analysis of such structures.
- Technologies that would enable the aseptic acquisition of deep subsurface samples, the detection of aquifers, or enhance the performance of long distance ground roving, tunneling, or flight vehicles are required.
- For Europa exploration, technologies to enable the penetration of deep ice are required.
- Desirable features for both Mars and Europa exploration include the ability to carry an array of instruments and imaging systems, to provide aseptic operation mode, and to maintain a pristine research environment.
- Low-cost, lightweight systems to assist in the selection and acquisition of the most scientifically interesting samples are also of significant interest.
- High sensitivity, (femtomole or better) high resolution methods applicable to all biologically relevant classes of compounds for separation of complex mixtures into individual components.
- Advanced miniaturized sample acquisition and handling systems optimized for extreme environment applications.
- High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodies within individual compounds and structures.
- High spatial resolution (5 angstrom level) electron microscopy techniques to establish details of external morphology, internal structure, elemental composition and mineralogical composition of potential biogenic structures.
- Innovative software to support studies of the origin and evolution of life. The areas of special interest are (1) biomolecular and cellular simulations; (2) evolutionary and phylogenetic algorithms and interfaces; (3) DNA computation; and (4) image reconstruction and enhancement for remote sensing.
- Technologies capable of measuring a range of volatile compounds at small spatial scales. Improved sensor designs for a wide range of analytes, including oxygen, pH, sulfide, carbon dioxide, hydrogen, and small molecular weight organic acids both on and near surfaces that could serve as habitats for microbes.
- 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.
- Spectral/imaging technology with high resolution and low power requirements.

- Habitat support - technologies for supporting miniature closed ecosystems, data collection and transmission technologies in concert with the automated chemical instrumentation described above.
- Miniature to microscopic, high resolution, field worthy, smart sensors or instrumentation for the accurate and unattended monitoring of environmental parameters that include, but are not limited to, solar radiation (190-800 nm at <1nm resolution), ions and gases of the various oxidation states of carbon and nitrogen (at the nanomolar level for ions in solution and at the femtomolar or better level for gases), in a variety of habitats (e.g., marine, freshwater, acid/alkaline hot springs, perma-frost).
- High resolution, high sensitivity (femtomole or better) methods for the isolation and characterization of nucleic acids (DNA/RNA) from a variety of organic and inorganic matrices.
- Mathematical models capable of predicting the combined effects of elevated pCO_2 (change in CO_2 over the eons) and solar UV radiation on carbon sequestration and N2O emissions from experimental data obtained from field and laboratory studies of C- cycling rates, N-cycling rates, as well as diurnal and seasonal changes in solar UV.
- 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.
- Robotic system designed to provided access to environments such as deep ocean hydrothermal vents.

TOPIC S5 Mars Exploration

Technology enables us to answer our scientific questions. Without the continual development of new technologies, our thirst for knowledge will go unfulfilled. That's why the Mars Exploration Program continually invests in innovation and the people who make it possible. Our goal is to invent new technologies, rigorously test them here on Earth or in space and apply them to Mars Exploration. The technologies developed and tested in each mission will help enable even greater achievements in the missions that follow. See URL: http://mars.jpl.nasa.gov/technology/ for additional information.

S5.01 Detection and Reduction of Biological Contamination on Flight Hardware and in Return-Sample Handling
Lead Center: JPL
Participating Center(s): ARC

As solar system exploration continues, NASA remains committed to implementation of its planetary protection policy and regulations. Missions designed to return the first extraterrestrial samples since the Apollo moon landings are currently in space--the Stardust and Genesis spacecraft will return cometary and solar wind particles to Earth within this decade. A mission to return samples from Mars is being planned for the next decade. Other missions will seek evidence of life through in situ investigations far from Earth. Thus, one of the great challenges is to develop or find the technologies that will make compliance with planetary protection policy routine and affordable. Planetary protection is directed to 1) the control of terrestrial microbial contamination associated with robotic space vehicles intended to land, orbit, flyby, or otherwise be in the vicinity of extraterrestrial solar system bodies, and 2) the control of contamination of the Earth by extraterrestrial solar system material collected and returned by such missions. Implementation of these requirements will ensure that biological safeguards to maintain extraterrestrial bodies as biological preserves for scientific investigations are being followed in NASA's space program.

To fulfill its commitment, NASA seeks technologies that will support its needs in the areas of cleaning (non-destructively and without residues), cleaning validation, maintenance of biologically clean work areas, encapsulation and containerization, and archival preservation of organic and inorganic samples. Examples of such technologies include:

- Non-destructive low temperature sterilization techniques for electronics assemblies, surface and/or volume (encapsulated microbes) sterilization
- Non-abrasive cleaning techniques for narrow aperture occluded areas
- Adaptation of a flight-optics cleaning method to provide a sample for microbiological assay
- Ultra clean assembly processes for non-assembly line (unique and/or limited production) hardware
- Direct and rapid in situ monitoring of particles and biological contamination on surfaces with various shape, finish, electrical conductivity, etc.
- Effective new sampling methods with improved precision and accuracy for use on spacecraft surfaces to provide samples for detection of biological contamination
- Rapid cleaning validation methods with high sensitivity for the major classes of biomolecules: proteins, amino acid, DNA/RNA, lipids, polysaccharides, ATP
- Techniques for in situ cleaning and sterilization to prevent cross-contamination between planetary surface samples
- Containerization and encapsulation of samples to be returned to Earth, including innovative mechanisms for isolation, sealing, and leak detection

With regard to Mars sample handling, a leading concept for sample handling is based on Biosafety Level Four (BSL-4) laboratories. However, current technology does not adequately address the need for decontamination measures to destroy more resistant microbes than those commonly studied in BSL-4 labs. Sterilization techniques are needed for suits, laboratory cabinets, tools, and containers. Optimized cleaning techniques and cleaning verification are also areas requiring advances in technology.

To the extent possible, sample operations should be done with robotic or teleoperated systems. The use of robotic sampling devices could result in the elimination of gloves in glove boxes, which are known sources of leaks and contamination. We seek robotics devices that include the following:

- Offer great dexterity at scales ranging from micrometers to tens of centimeters
- Are constructed of clean and cleanable materials
- Function without lubricants
- Are extremely reliable
- Can be repaired without loss of sample integrity

Finally, we seek technology to advance the state of the art in seals. The repeated operation of seals on airlocks between cabinets creates a significant opportunity for failure of the seals. Mechanical and robotic systems for sample handling will require the development of highly reliable seals to maintain the integrity of the containment systems.

S5.02 Mars In Situ Robotics Technology
Lead Center: JPL

Two important areas for future planetary exploration are covered in this subtopic:

Mars Mobility Technologies
During future exploration of planetary, lunar, small solar system body (such as comets and asteroids) surfaces, new tools in the areas of surface robotics systems, sub-surface systems, aerial systems, and autonomous software need to be developed. These technology tools and software are required for advanced scientific exploration to provide access to challenging surface sites, collect sub-surface samples, investigate a site through an aerial survey, and provide long-duration survival on planet surfaces. In particular, this subtopic seeks technology innovations that are in the following areas:

- Airborne Systems including autonomous fixed-wing aircraft, airships or blimps for long-duration scientific investigations, and aerobots and balloons for atmospheric and surface exploration.
- Surface Systems including science rovers for detailed in situ investigation, advanced surface mobility systems for access to high-risk terrain, manipulation and sample-handling systems for precision placement of instruments and sampling systems, and multiple, cooperating robotic sys-

tems for the development of a sustained robotic presence through robotic colonies and sensor webs.

- Sub-Surface Systems including shallow sampling systems for robust collection of rock and soil samples from less than 1 meter in depth, deep drilling systems for exploration of sub-surface strata including the search for possible sub-surface water aquifers, low-cost, low-mass penetrator systems that are capable of conducting limited scientific discovery over a wide terrain area, sub-surface mobility systems that allow for the autonomous exploration of sub-surface material including soil, rock, and ice, and autonomous underwater robotic systems for exploration of possible sub-surface oceans on the moons of Jupiter.
- Autonomous Software Technologies including autonomous navigation techniques, algorithms for multiple cooperating systems, behavior-based control systems, advanced path planning techniques, software for intelligent systems, robotic reconfiguration strategies, and autonomous scientific data collection.

Mars Entry, Descent and Landing Technologies for Low Cost Missions

Entry, Descent, and Landing (EDL) systems are an enabling component of future Mars surface and airborne explorations. EDL systems are naturally comprised of a wide variety of tightly integrated subsystems. These subsystems can include, but are not limited to: entry body, thermal protection, entry guidance avionics, super-sonic parachute, sub-sonic parachute, terrain sensors, and touch-down sub-system. In addition to these hardware specific sub-systems, guidance and hazard detection algorithms are an integral element of future EDL systems. Innovations are sought which provide benefits in the following general areas, increased payload delivery mass, improved delivery accuracy, and improved hazard detection and avoidance approaches. The intended outcome of these improvements is to deliver larger payloads with greater targeting accuracy to landing sites with significant terrain hazards. In particular, this subtopic seeks technology innovations that are in the following areas:

- Improved guidance algorithms for hypersonic entry and/or terminal descent.
- Innovative navigation technologies for increased navigation accuracy from approach to touchdown, including the use of a Mars orbiter for onboard, realtime navigation of a lander.
- Entry body systems, and sub-systems including lightweight aeroshells, and thermal protection.
- Parachute decelerator systems including supersonic and sub-sonic parachutes. Particular areas of interest include approaches that can lead to increased supersonic parachute deployment criteria, i.e., increased Mach-Q space. Also of interest are para-guidance technologies and guidance algorithms.
- Terrain hazard detection approaches that provide real-time three-dimensional terrain mapping capability during parachute descent and powered terminal descent.
- Lightweight touchdown system terrain hazard tolerance approaches including airbag, shock struts, and structural crush zones. In future EDL systems the touchdown system, i.e. the lander, are intended to be tolerant to landings in moderately cratered terrains with their incipient surface rock distributions.
- EDL telecommunication innovations are sought which facilitate real time EDL engineering telemetry either via a direct-to-Earth link or to an overhead cruise/relay stage. Additionally, telecommunications innovations are sought which facilitate tracking of a lander through the ionized plasma which surrounds the lander during a portion of hypersonic entry.

S5.03 High Rate Telecommunications for Mars Planetary and Proximity Ranges and Other Deep-Space Missions
Lead Center: JPL

This subtopic seeks innovative technologies for both RF and Optical Communications supporting missions to Mars including both planetary and proximity ranges, and for other planetary missions and local planetary networks.

RF Communications

- Ultra-small, low-cost, low-power, innovative deep-space transponders and components, including integrated circuits such as microwave monolithic integrated circuits (MMICs) and Bi-CMOS circuits.
- Low-mass deployable antennas in the 5 to 10 m range, for X- and Ka-band transmission.
- Sub-micro-radian antenna pointing techniques for Ka-band spacecraft antennas.
- Steerable autotracking X-band antennas, 10-30 cm in diameter, and qualifiable for Mars surface environment, and for high performance surface-to-orbiter relay links of future Mars landers.
- High rate (10-200 Mbps) turbo encoder/decoder chips and wavelet compression chips.
- Signal processing circuits for receivers that provide carrier tracking, command, and ranging capabilities. Low-voltage, multi-function MMIC designs to provide low-noise down-conversion, automatic gain-control, up-conversion, and transceiver functions at (Ka-band).
- MMIC modulators with drivers to provide large linear phase modulation (above 2.5 radians), high-data rate BPSK/QPSK modulation at X-band (8.4 GHz) and Ka-band. Miniature, ultra-stable, and voltage-controlled oscillators for deep space communications and GPS applications.
- Miniature, low-loss X-band and Ka-band switches, and diplexers.
- Miniature, high-efficiency power amplifiers, and RF power devices operating in the X- and Ka-band, transmitters with output power levels in the 20 W to 1000 W range that can survive the space environment with a minimum mean-time-to-failure of ten years.

Optical Communications

- Efficient (greater than 20% wall plug), lightweight (less than 1 kg including drivers), flight-qualifiable actively pulsed, variable high repetition-rate (1 to 60 MHz), high peak power diode-pumped based laser transmitters with greater than 5 Watt of average output power. Pulse generation time delay uncertainty should be less than 0.2 nsec with pulse-width no greater than 2 ns. A modulation extinction ratio greater than 1000 is highly desirable.
- Novel pulse position modulation (PPM) driver circuits with less than 0.2 ns timing resolution for modulation orders from M=2 to 512.
- Efficient electro-optic Pockell cell drivers for up to 50 MHz repetition rate and 1 to 5 kV voltage switching.
- Acquisition and tracking technologies including algorithms for sub-micro-radian laser beam pointing from deep-space ranges.
- Compact, room temperature, low power consumption, high update rate (multi kHz for 10x10 windows), high quantum efficiency and fill factor acquisition, and tracking focal plane array (FPA) detectors in the visible and near infrared (up to 12 microns). The FPAs ideally would incorporate on-chip processing for window control, pixel gain/offset correction window, background/pattern noise calibration, bright spot location for initial acquisition, and pixel summation mode. Multiple windowing capability with different integration times for each window is also highly desirable.
- Lightweight high precision (less than 0.1 micro-rad over 1-500 Hz) inertial reference sensors (angle sensors, gyros) for use on-board spacecraft.
- Photon counting detectors with greater than 1 mm active area diameter, bandwidth greater than 500 MHz, quantum efficiency greater than 50% at 1064 nm, very low additive noise and gain greater than 1000.
- Novel schemes for stray-light control and sunlight mitigation especially for large ground-based optical antennae that must operate when pointed to within a few (about 3) degrees of the Sun. Also, transmit/receive isolation methods providing at least 140 dB of isolation at 1064 nm.
- APD detector with greater than 0.3 mm diameter and bandwidth of greater than 3 GHz for detection of signals at 1550 nm.

9.2 STTR Research Topics

Each STTR Program Solicitation Topic corresponds to a specific NASA Center. One or two subtopics per Topic (rotating from year to year) reflect the current highest priority technology thrusts of that Center.

TOPIC T1 Ames Research Center

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

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 re-configure 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.
- Onboard, real-time health management systems that perform quickly enough to monitor a flight control system (including spacecraft and fixed/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 increase identification of aviation threats and enhance scientific understanding.
- Techniques for interconnecting and understanding large heterogeneous or multi-dimensional 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.
- Software generation tools which capture designer intent and performance expectations and that embed extra knowledge into the generated code for use by automated software analysis tools doing validation and verification, system optimization, and performance envelope exception handling.
- Tools and techniques for program synthesis and program verification of high-assurance software systems.
- Innovative communication, command, and control concepts for autonomous systems that require interaction with humans to achieve complex operations.

TOPIC T2 Dryden Flight Research Center

T2.01 Atmospheric Flight Operations

Accurate simulation of aerospace vehicles' flight characteristics is of great importance for both initial design and subsequent flight-testing. This topic focuses on R&D for multi-disciplinary modeling and simulation and for development of efficient software tools for aero-structures-controls-propulsion interaction simulation of flight vehicles. The benefit of this effort lies in ensuring flight safety, particularly during flight tests.

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

R&D in finite element based numerical simulation algorithms in computational fluid dynamics (CFD), structures, heat transfer and propulsion disciplines, among others: In particular, emphasis is placed in 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 regular daily basis. Furthermore, the effective use of high-performance computing equipment and computer graphics development is also considered as 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, numerical finite element based interaction simulation software.

TOPIC T3 Glenn Research Center

T3.01 Aeropropulsion and Power

The research sponsored by the Propulsion and Power Project focuses on ensuring the long-term environmental compatibility and efficiency of aircraft propulsion and power systems. The project addresses critical propulsion and power technology needs across a broad range of investment areas including revolutionary advances in combustion-based aeropropulsion systems/technologies and unconventional propulsion and power systems/technologies. High-risk, high-potential research investments include fuel-cell-based propulsion systems, high-temperature nanotechnology, and pulse detonation engine components and subsystems. Ultimately, the Propulsion and Power Project seeks to demonstrate (in a laboratory environment) key component technologies to enable: non-conventional combustion-based propulsion systems and electric/hybrid propulsion and power systems. Propulsion and Power Project directly supports the NASA objectives of: "Protect the Environment - Protect local environmental quality and the global climate by reducing aircraft noise and emissions" and "Explore New Aerospace Missions - Pioneer novel aerospace concepts to support earth and space science missions."

Innovations sought include:

- Alternative fuels and/or alternative propulsion systems, i.e., aeronautical propulsion technology concepts with horizons of 20 to 40 years from today with potential for two times payload-range performance. Such high-payoff propulsion systems would set new, revolutionary directions well beyond the evolutionary approaches. These alternative fuel and/or alternative propulsion systems may include, but are not limited to:
  - Revolutionary engine design (technologies beyond the conventional Brayton cycle gas turbine engine). For example, micromachined SiC microengines that may have potential for use in a distributed propulsion architecture.
  - Nano and autonomous systems. For example: nanotechnology fibers, tubes, spheres and high temperature shape memory alloys and piezoelectric materials for their unique role in tribology, structures and composite reinforcements and control systems for autonomous, adaptive engine control and sealing.
- Non-combustion (electric) propulsion and power systems, e.g., hydrogen-based and electric aeropropulsion (propulsion systems capable of flight while producing zero CO_2 emissions), and new missions enabled by quiet, clean, electric propulsion. Key technologies to enable design of an alternately fueled, fuel cell or hybrid propulsion system. These technologies may include, but are not limited to:
  - Hydrogen tankage,
  - Fuel cell systems, components, and subcomponents,
  - Power management and distribution materials, components, and configurations.

T3.02 Space Power and Propulsion

The research sponsored by GRC Space Power and Propulsion focuses on the development of innovative technologies and systems that will result in robust, light weight, ultra highly efficient, lower cost, power and in-space propulsion systems that are long-lived in the relevant mission environment to enable future missions. These technologies enable effective generation and utilization of power and in-space propulsion resulting in significant increases in vehicle payload fraction for future human and robotic spacecraft. This includes analysis of systems and requirements to provide tactical and strategic guidance for technology advancement. The goal is to provide critical advanced power technology and space propulsion systems to meet the needs of all NASA Enterprises and Strategic Technology areas, including significant reduction in launch vehicle and spacecraft costs, increased mission capabilities and flexibility, while enabling cost effective utilization and/or exploration.

Innovations sought include:

- Advanced solar array technologies
- Energy storage systems (e.g., new batteries including polymer-based rechargeable energy systems, regenerative fuel cells, and flywheels)
- Dynamic power systems for nuclear power conversion
- Power distribution techniques
- Advanced power systems and power system control
- Integrated vehicle health management
- Ion propulsion
- Hall propulsion
- Pulsed plasma thruster propulsion
- Pulsed inductive thruster propulsion
- Magneto plasma dynamic propulsion
- Monopropellant and bipropellant propulsion
- Micro propulsion

TOPIC T4 Goddard Space Flight Center

T4.01 Astronomy, Physics and Earth Sciences

The mission of the Earth Science Enterprise is 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 leveraging breakthrough technologies from terrestrial applications, as well as the vantage point of space, we seek to observe, analyze, and model the Earth system to discover how it is changing and the consequences for life on Earth.

The mission of the Space Science Program is to solve mysteries of the universe, explore the solar system, discover planets around other stars, search for life beyond Earth, chart the evolution of the universe and understand its galaxies, stars, planets, and life. The Space Science Program seeks to understand the universe from the beginning of time, looking ever deeper with increasingly more capable telescopes to scan the entire electromagnetic spectrum from gamma rays to radio wavelengths.

This STTR solicitation is to help provide advanced remote sensing technologies to enable future Earth and Space Science measurements.

Analytical Instrumentation for Planetary Atmospheres Research
Innovations and the application of new technologies are sought for improving the operating characteristics of gas chromatograph-mass spectrometer systems in harsh environments. Reductions in volume, weight, power and cost while increases in performance, serviceable, functionality of system components is highly desirable. The overall goal is to develop an instrument with increased performance in the areas of improved collection, detection and measurement. Specific area of interest include:

- Miniaturized and ruggedized Gas Chromatograph columns
- Micro valves
- Improved stability and performance of secondary electron multipliers

- Performance increases in the areas of size and conversion efficiently of high voltage DC/DC converters
- Rigid miniature vacuum pumps

Active Optical Systems and Technology for UAVs and Ballooncraft
Lidar remote sensing systems are required to meet the demanding requirements for future Earth Science missions. It is envisioned that lidar systems will be used in the following application areas: high spatial and temporal resolution observations of the land surface and vegetation cover (biomass); profiling of clouds, aerosols and atmospheric state variables including temperature, humidity, winds and trace constituents including tropospheric and stratospheric ozone and CO_2 (profiling and total column); measurement of the air/sea interface and mixed layer. New systems and approaches are sought in these areas, which will:

- Enable a new measurement capability
- Enhance an existing measurement capability by significantly improving the performance (spatial/temporal resolution, accuracy, range of regard)
- Substantially reduce the resources (cost, mass, volume or power) required to attain the same measurement capability

Systems and approaches will be considered which demonstrate a capability that is scalable to space or can be mounted on a relevant platform (UAV, long duration balloon, or aircraft) for calibration/validation of a spaceborne system.

Ballooncraft Remote Sensing Detector Systems and Components
Innovative developments are being sought that incorporate new architectures, new technologies and advanced remote sensing techniques to make space science measurements. It is anticipated that these new sensors will be flown aboard spaceflight of balloon-borne platforms, and therefore emphasis on low weight, small volume and low power is very important. The innovations sought include:

- Far infrared detector systems for operation at temperatures less than or approximately equal to 80K
- 3D (2 spatial 1 energy) photon counting detectors for spectroscopic imaging in the visible & UV
- Energy resolving sensors that operate above 4K. These should have at least 4 energy bands and can operate anywhere between x-ray and Sub-mm
- High spatial resolution (0.1 arc second or better), light weight, ground testable optical systems for visible, UV, and EUV solar investigations
- Widely tunable (>60 nm), single frequency, compact (< 1 cubic inch volume) semiconductor lasers
- High quantum efficiency (> 10%), photon counting, near infrared (1- 2 micron) detectors for use in laser systems
- Devices permitting the measurement of DC/AC electric and magnetic fields
- High speed, low power, low signal analog electronics for high energy detector systems
- Precision lightweight optics (precision defined as surface figure <0.01 waves rms @ 633nm, surface roughness <2 angstroms, lightweight defined as approaching NGST metric 15 kg/m^2) for application to astronomical investigations
- Inflatable structures and antennas
- Lightweight x-ray telescope optics
- Lightweight, low power cryogenic coolers for miniature systems
- Superconducting devices with increased performance for cooling, detection, electronics, or other novel remote sensing applications

Ballooncraft Trajectory Control and Station-Keeping
Trajectory Control and Station-Keeping are critical items for future Ultra Long Duration Balloon remote sensing concepts.

- Trajectory control would allow for some authority of the path of the system which may be required / desired for several reasons such as science mission, geopolitical, or improved recovery options. Activities include concept studies for alternative systems, propeller design and fabrication, functional flight testing, airship design and analysis, material development, and performance modeling.

Unmanned Aerial Vehicle (UAV) Technologies for Remote Sensing
Avionics, real-time telemetry acquisition and remote sensing spectral imaging devices to support Unmanned Aerial Vehicles' (UAV) basic and applied science and application demonstrations (offerors need only to respond to a minimum of one of the below):

- Low cost avionics instrumentation for precise navigation and aircraft control, must have an attitude sampling rate greater than 25Hz and an accuracy greater than .2 degrees in roll and pitch.
- Real-time sensor fusion algorithms that combine low-cost inertial, GPS, magnetometer and other sensor inputs to deliver aircraft state vectors at a rate greater than 50Hz.
- Uncooled Infrared/thermal spectral imager instrument to be less than 2 lbs. and no larger than .05 cubic meters in volume. Must operate autonomously in coordination with the on-board flight plan. It must have a built-in data acquisition system. The spectral bands must all be co-registered and the data must be GPS time tagged. Spectral bands should be centered at 3.75, 3.96 and 11microns as well as a band in the visible at .6 microns. Quantization bit resolution should be 10-bit minimum.

Microwave measurements using large aperture systems
New breakthrough technologies are sought for the construction of extremely large (tens of meters and larger diameter) microwave antenna systems. The systems must be compact upon launch, they must achieve high precision surface form factors, and they must include beam-scanning capabilities. The antenna compactness on launch can be achieved either through folding technologies or from some assemblage of small components into the larger final system in space. The microwave antenna surface characteristics must be accurate enough to produce microwave beam patterns with adequately small side lobes. The beam scanning must be facile and over many beam widths so as to enable cross-track scanning if in LEO, or scanning over the full globe if at GEO. The beam widths must be small enough to resolve the few kilometer scales needed for many geophysical observations. The microwave wavelengths will be determined according to the geophysical measurement of interest. The antenna concepts may include large single apertures or apertures composed of multiple elements that are operated synergistically so as to product the desired performance.

TOPIC T5 Johnson Space Center

T5.01 Advanced Crew Support Technology

Advanced Crew Support Technologies will be essential for providing next-generation systems that will enable humans to live and work safely and effectively in space. Special emphasis is placed on those technologies that will have a dramatic impact on the reduction of required mass, power, volume, crew time, and increased safety and reliability. Areas being solicited include Advanced Life Support, Extravehicular Activity, Direct Energy Conversion and Energy Storage, and Nanomaterial Applications. Research and technology development with dual use to earth based applications that improve environmental sustainability are of interest.

Advanced Life Support (ALS)
Advanced life support systems are essential for future spacecraft and to enable human planetary exploration. Subsystems are needed to fully recycle air and water, recover resources from solid wastes, grow plants for food, and control the thermal environment, while reducing the overall system mass. Requirements include safe operability in micro-and partial-gravity, high reliability, minimal use of expendables, ease of maintenance, and low system volume, mass, and power. Specific areas of interest include:

- Waste Management: Technologies to safely and effectively manage wet and dry solid wastes expected on near term missions (plastics, food scraps, clothes, paper, tape, hygiene materials, feces), performing the following functions: volume reduction, stabilization, storage, water recovery and/or conversion into recoverable water, ventable gases and minimal storable steril solids.
- Thermal Control: Research and technology development is needed to explore innovative heat pump technologies, heat pump technologies for microgravity applications, and integration of heat pumps into spacecraft thermal systems. Proposals are also sought for the development of durable, optical radiator coatings that would enable an externally mounted radiators on a reusable launch vehicle.
- Crop Systems: Proposals focused on development of a crop system that could operate in microgravity for production of fresh salad vegetables for augmenting the diet of crews are sought. Such a vegetable production unit or salad machine would provide a psychological enhancement to offset the habitat isolation and provide a facility for technology risk mitigation for future spacecraft and planetary habitat crop systems.

Advanced Extravehicular Activity (AEVA)
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 & 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 protection from micrometeoroid and orbital debris, and radiation protection.
- 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.

Direct Energy Conversion and Energy Storage
Basic research is solicited in the areas of direct energy conversion and energy storage technology. Power levels of interest range from tens of milliwatts to several kilowatts. Direct energy conversion and storage systems for crewed missions have unique and rigorous requirements beyond those for uncrewed missions, particularly in terms of the safety and reliability constraints of crew-rated vehicles. Crewed missions also offer unique opportunities for health monitoring and preventative maintenance of these power systems. Research and technology development with dual use for earth-based applications would be desirable.

- Energy Storage: Research is solicited to advance the technology of primary and secondary (rechargeable) storage devices. Interest is focused on advanced concepts that can provide dramatic increases in mass/volume energy density (w-hr/kg and w-h/l) and rate capability while maintaining safety and reliability levels appropriate to in-cabin and exterior applications on crewed vehicles. Rates of interest range from 1C to 20C.
- Direct Energy Conversion: Research is solicited to advance the technology of direct chemical-to-electric energy conversion devices such as fuel cells, associated fuel reformers, and technologies associated with production or regeneration of fuel cell reactants. Interest is focused on advanced concepts that can provide notable improvements in conversion efficiency, operational life, reliability, load following performance, gravity independent reactant and effluent separation, and mass/volume power density (W/kg and W/l). Oxidant streams of interest are focused on near-pure oxygen, but fuel streams of interest include near-pure hydrogen and reformate from near-pure hydrocarbons such as methane, ethanol, and methanol. Power levels of interest range from small fuel cell generators (~10W) for use with in-cabin crew equipment (e.g., computers, cameras, etc.), through mid-range (100 W to 1 kW) systems for crewed vehicle avionics, EVA suits and tools, and mobile science and crew rovers, to high power systems (~70 kW), applicable to surface habitat backup power and electromechanical actuation systems for vehicle flight control. Voltage

ranges of interest range from small, low voltage battery replacement applications up through high (270 V) voltage electromechanical actuation applications.

Nanomaterials Applications
Accomplishments in the field of nanomaterials in recent years have brought them to the development level where they can be considered for human spaceflight applications. Research is solicited for proposals in areas that are unique or unusual to human spaceflight, focusing on materials to be used for advanced life support, advanced extravehicular activity, direct energy conversion and energy storage. For the purpose of this solicitation, proposals for nanomaterials applications must apply to the previous sections of ALS, AEVA and Direct Energy Conversion and Storage. For example, research and technology development could include nanomaterials for application to spacesuit materials, thermal control coatings and insulators, carbon dioxide and trace contaminant removal, or energy storage, among many other applications specific to crew support technology. Proposals must utilize unique properties of nanomaterials that are not possible with conventional materials. Special emphasis will be placed on applications using single wall carbon nanotubes.

T5.02 Robotics and Virtual Digital Human Technologies

Human Operations in Space
This NASA Center of Excellence for Human Operations seeks innovative solutions to the challenges facing human space explorers in their quest for maintaining a presence in orbit about our planet and in establishing a permanent presence on the surface of neighboring planets. Proposals are solicited for innovative concepts for a) innovative sensor designs, b) human/robot interfaces and c) improved robotic mechanisms.

Some specific **sensor** technology needs are:

- Small, low power machine vision systems for tracking a moving, articulated object such as a geologist exploring a planetary surface to record his activities.
- An aided dead reckoning / landmark navigation system to keep a record of where the geologist (or the robot) is now and where they have been.
- Model based landmark navigation to allow a free-flying camera platform to find its way around the outside of the ISS without requiring external beacons, including the ability to update the model as it changes.
- Machine vision techniques, including the construction of image mosaics, for detection of unspecified changes in objects being inspected under diverse or changing lighting and viewing conditions.
- Sensing to minimize the risk of collision between the imaging and target vehicles, such as:
  - Small, lower power, range/range-rate sensor
  - Small, lower power "ranging" sensor that produces a depth map of the scene
- System on a Chip (SOC) imager that captures InfraRed (IR) images of a scene.
- Miniature robust sensors/sensor material for measuring position and strain.
- Sensors with integrated multiplexing to reduce wire count.
- Pre-tactile sensor components (non-vision or contact sensing based).

Specific technology needs for **human/robot interfaces** include:

- Lightweight tactile and force feedback devices that provide operator awareness of manipulator inertia, gripping force, and forces and moments due to the robot's contact with external objects.
- Stereographic display systems that provide a large field of view (>100 degrees Horizontal Field-of-view), and high resolution (<3 arc minutes per pixel).
- Innovative miniaturized display hardware for use with Helmet Mounted Display (HMD) systems that project data in a Head Up Display (HUD) format.
- Techniques for capturing 360 degree video at a work site and redisplaying as a mosaiced virtual environment to the crewmembers back at the base camp.

- Supervised and traded control systems that allow for seamless human/robot interaction. The ability to accommodate both planned and unplanned human and autonomous operations within a task is essential.
- Virtual reality interfaces that make it practical for an IVA astronaut or a suited EVA astronaut to operate on-orbit free-flyer camera platforms and planetary robotic camera platforms.
- Innovative systems that permit control of a robotic system through a combination of gesture and voice commands. Innovative concepts include machine vision, artificial intelligence based systems (with provision for crew oversight), as well as other non-vision forms of sensing and perception that provide command inputs to the robot.
- 3-D path planning and intelligent trajectory assessment feedback during teleoperations.

Specific areas of improvement for **robotic mechanisms** include the following:

- Novel drive systems, suspension systems and manipulator systems.
- Technologies or systems that provide a reduction in the weight and or volume of robotic systems such as:
    - Reduced scale high power-to-weight ratio actuators including magnetostrictive motors and synthetic muscles.
    - Miniaturized actuator control and drive electronics.
    - Miniaturized sensing systems for manipulator position, rate, acceleration, force and torque.
- Robotic systems that can grapple, manipulate and operate existing EVA tools while maintaining a small, human sized form factor.
- Compact, low power devices for operation with as well as site setup and preparation for human presence both in orbital and planetary surface exploration.
- Reduced-part-count miniaturized propulsion hardware (e.g., compressed gas storage with output pressure regulation via valve control only)
- Free flyer docking and recharge mechanisms.

An Integrated Approach with Virtual Digital Humans and Robotic Simulations
NASA is targeting a new level in space exploration operations. Critical advancements in crew and ground support technologies will be needed as NASA develops new operational capabilities to support multiple-manned, robotic, and long duration/distance missions. Two potential areas for research are the ever-evolving robotics and 3-D simulation technologies providing operational robustness and intelligence. Furthermore, advanced capabilities for information integration and real-time interaction provide foundation for more simulation interaction between the two technologies. More advanced inter-system support capabilities (performance, maintenance, etc.) coordinated with a reliable knowledge base will be needed.

Proposals that improve operator efficiency via advanced displays, controls and telepresence interfaces and improve the ability of humans and computers to seamlessly control robotic systems are sought. Specific technology requirements include the following:

- Tactile feedback interface for collision awareness between workspace and avatar objects, and robot structure
- Force feedback device for operator awareness of manipulator and payload inertia, gripping force, and forces and moments due to contact with external objects.
- Stereographic display systems for high-fidelity depth perception, field of view, and high resolution.
- Spatial tracking for user appendages (i.e., head, arms, fingers, eyes) and avatar/robot motion

Based on the new Mission Control Center System (MCCS) Architecture framework, integrated support for virtual-digital-human-in-the-loop and teleoperational interface is also the focus of this solicitation. Proposals offering innovation in the form of 3-D visualization and simulation capabilities of robotic systems (direct manipulation, telerobotics, telepresence, etc.) with relation to the 3-D virtual-digital-human-in-the-loop concept are being sought. The application targets would be flight and ground operations development, analyses, training, and support. The main result desired is an interactive system that enhances operator and IVA/EVA task efficiency via the teleoperational technologies and distributed collaborative virtual environments. The introduction of the virtual digital human (VDH) in a virtual reality robotic scenario is necessary for task and robotic device operation, design, and testing.

The core element of this project is the implementation of the Virtual Digital Human (VDH). This innovative human modeling technology comprises a combination of anatomical, biomechanical and anthropometric functionality to fully simulate the somatic components and systems of the human body. Based on the tenets of the Visible Human Project, this VDH technology provides the opportunity to simulate real world problems on the VDH in a simulated, virtual environment (VE). The main objective is to apply a high-fidelity VDH in a scenario that "recreates" a real world. Scenes involving the VDH imply rich, complex problems to solve or just visualize. The VDHs will have a key role in Shared VEs and truly interactive scenarios. More complex VDH embodiment increases natural interaction within the environment. The users' more natural perception of each other (and of autonomous actors) increases their sense of being together, and thus the overall sense of shared presence in the environment.

Immersive technologies, such as virtual reality (VR), virtual digital human (VDH), and 3-D simulation modeling, have become a significant vehicle for NASA's effort to generate and communicate knowledge/understanding to K-12 levels through university/academic institutions to continuing education modalities. The ability to share aerospace-related operation simulations such as International Space Station and Space Shuttle/Space Transport System (STS) operations, Robotics, Intravehicular/Extravehicular activities, Mission Control Center (MCC) conduct, interplanetary space flight, and microgravity simulation provides opportunity for educational and commercial growth for NASA and its research and development partners.

TOPIC T6 Kennedy Space Center

T6.01 Batteryless, Wireless Remote Sensors

Proposals are solicited for development of innovative batteryless, wireless, sensor technologies in support of future space operations. Rapid turnaround, coupled with high safety standards, will necessitate that future launch vehicles be densely instrumented to provide high fidelity health information. This need is well recognized and advances in micromachined and wireless sensors are underway to meet future sensing goals. However, many of these new sensors still require significant on-board power, while batteries, for reasons of weight, longevity, and maintenance, are often not a feasible option in aerospace applications. Also, in many applications, no line of site is available to the sensors, limiting the interrogation to radio frequency (RF) signals.

Therefore, new classes of sensors are needed that can be interrogated remotely using RF signals and respond with a signal that encodes both the sensor's identity as well as an environmental parameter; and does this without batteries. Current literature describes two types of sensors that would meet this requirement, passive and semi-active. Passive sensors have no on-board static energy storage and respond in an echo mode. The incoming signal, for example an RF pulse, excites the sensor, it then reradiates some modified version of the received RF pulse encoding the necessary information. Semi-active sensors take energy from the interrogation signal and store this to enable the sensor to operate and transmit a signal, before shutting down. It is not clear which of these two classes is more advantageous; passive sensors may not require as intense an RF signal to operate, but data encoding to operate large numbers of sensors may require logic that can only be incorporated onto a semi-active device.

One class of passive sensors that has received attention lately is the use of surface acoustic waves. In this case, interdigital electrodes located on a piezoelectric material (e.g., quartz) act as a receiving antenna. When an RF pulse appears, the electrodes cause a surface acoustic wave to propagate on the material. This wave then passes by other sets of electrodes causing small RF pulses to be emitted (or a reflector might be used to send the acoustic wave back to original electrodes) whose relative time delays (and possibly amplitudes) encode both the sensor's identification information as well as the parameter being sensed. Such sensors have been shown to monitor temperature and pressure (stress and strain), both of interest to the aerospace community.

As stated above, an alternative to a passive sensor would be one that acquired its power from the incoming RF pulse, rectifying and filtering it to charge a capacitor. This energy would then be used to turn on circuitry, read a sensor, and then broadcast an encoded signal back to a receiver. This might allow smaller and denser packing of sensors than that achieved by the use of SAW devices, but would likely require higher RF powers. Also, higher power RF transmitters pose safety problems both to individuals as well as to flight equipment, so such an approach would need to be carefully thought out.

Innovations are sought for the following sensor applications:

- Hundreds of temperature sensors might be mounted under the vehicle skin with an internal RF interrogator that scanned through each sensor once per second, constantly monitoring the heat load on the vehicle or hundreds of strain sensors being used to track the pressure distribution exerted on the vehicle. In these cases the distance to the sensors might not be more than 20 to 30 feet from the RF source/receiver, though shorter interrogation distances might be possible. The goal though is to minimize running cables throughout the vehicle, yet still obtain a large amount of vehicle health data.
- Such sensors would be incorporated into the thermal protection system (TPS) of a future vehicle, e.g., located under foam, or even under the tiles of the Space Shuttle. In this application a field inspector would carry a transmitter/receiver with a short (3-4 feet) sensing range that could scan the flight hardware during ground processing. Possibly, such sensors could be used to sense water intrusion under the TPS, abnormal stresses, or out of range temperatures during fueling operations.
- There is a need for better pressure monitoring within the tires of future vehicles, as well as the Shuttle, and locating a passive sensor within each tire would provide assurance to the pilot that he can land. It is known that SAW devices are in development for this application and it might be that a first aerospace use of such sensors will be for tire pressure monitoring.

T6.02 Development of High Temperature Acoustic Liners

Launch vehicles generate severe conditions of vibrations and acoustic loads, which can affect the launch pad, launch vehicle, payload, nearby ground structures and equipment. Intense acoustic loads and environment are generated by the interaction of the high velocity and high temperature rocket-engine exhaust stream mixing with the ambient atmosphere. These acoustic loads act as the primary source of structural vibrations and internal loads during launch. Substantial mitigation of the acoustic levels is critical to proper functioning of vehicle components, payloads, and launch support structures. Passive methods of sound mitigation are especially attractive as they are economical and efficient. Specific interests for the 2003 solicitation include, but are not limited to, those listed below:

- Develop high temperature acoustic liners for use in ducted exhaust system, capable of withstanding high exhaust temperatures up to 3000 °F over a range of frequencies.
- Develop and test a scale model to validate the impedance of the acoustic liner.

In addition, vibration and acoustic research in the following areas are also of interests:

- Study the effects of acoustic emissions on structures by testing and analysis
- Develop computational tool to investigate the rocket plumes impinging on covered and uncovered flame deflectors.
- Develop finite element method to predict the random vibration response on launch pad components including open trusses, frames, concrete slabs and beams, and corrugated metal enclosures
- Develop analytical tools to simulate the launch acoustic environment and its vibration effect on launch pad structures and equipment.
- Develop high-frequency acoustic sensors

TOPIC T7 Langley Research Center

T7.01 Personal Air Vehicle Research for Rural, Regional and Intra-Urban On-Demand Transportation

NASA is performing preliminary design studies of Personal Air Vehicle missions, concepts, and technologies for the purpose of augmenting on-demand personal transportation mobility and capacity. The intent of this research is to perform the analysis and demonstration required to provide radical improvements to the key metrics that currently inhibit market growth of these vehicles. Initial research efforts will focus on the near-term, next generation General Aviation class of vehicles, with follow-on efforts performing investigations on mid-term and long-term mission concepts. This PAV research will include focused efforts in the following areas, with the following research goals.

- Reducing small aircraft community noise by 30 PNLdb at a 500’ sideline measurement, equating to a ten-fold reduction in the perceived noise so that these aircraft are no noisier than current motorcycle regulations. The intent of this effort is to demonstrate that significant increases in small aircraft operations can be acceptable to communities, as these vehicles are designed with technologies that permit them to be good neighbors.
- Reducing the aircraft acquisition cost on the order of 60% from current price levels while still at relatively modest production volumes. This effort will include investigation of advanced quality assurance certification processes and procedures, instead of the current quality control methods. Significant industry investment has not occurred because a sizable market is not envisioned at cost levels where only a small fraction of the population can enter the market. Future production of such vehicles could be on the scale of limited production luxury cars, however the demonstration of affordable vehicles at relatively low volume is a critical step for market growth that would provide the capital for rapid expansion.
- Simplify the operation of small aircraft such that the specialized skills, knowledge and associated training are reduced to levels comparable to operating an automobile or boat. This reduction must be achieved during near-all-weather operations and with a level of safety that is superior to comparable operations today.

Mid-term and long-term efforts could also include investigation of technologies that provide improved performance and short field length takeoff and landing capability. Implicit to all these investigations will be enhancing the vehicle safety, versatility, ease of entry, interior environment, visibility, and maintenance and operations cost.

Information is desired on current research efforts in these focused areas for respondent's interested in partnering with NASA on collaborative investigation. It is anticipated that subsystem design and testing will be performed on selected technologies or concepts.

T7.02 Non-Destructive Evaluation, Health Monitoring and Life Determination of Aerospace Vehicles/Systems

Innovative and commercially viable concepts are being solicited for the development of resilient space qualified non-destructive evaluation (NDE) and health-monitoring technologies for on-orbit inspection and maintenance of aerospace systems. Advancements in integrated multi-functional sensor systems, autonomous inspection approaches, distributed/embedded sensors, roaming inspectors, and shape adaptive sensors are sought. Concepts in computational models for signal processing and data interpretation to establish quantitative characterization and event determination are also of interest. Evaluation sciences include ultrasonics, laser ultrasonics, optics and fiber optics, shearography, video optics and metrology, thermography, electromagnetics, acoustic emission, x-ray, management of digital NDE data, biomimetic, and nano-scale sensing approaches for structural health monitoring.

Technologies may be applied to:

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

Technologies may be used for:

- Characterizing material properties
- Assessing effects of defects in materials and structures
- Evaluation of mass-loss in materials
- Detecting cracks, porosity, foreign material, inclusions, corrosion, disbonds
- Detecting cracks under bolts
- Real time and in situ monitoring, reporting, and damage characterization for structural durability and life prediction
- Repair certification
- Environmental sensing
- Planetary entry aeroshell validation
- Micro-meteor impact 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
- In situ monitoring and control of materials processing

Structural applications to be considered for NDE and health monitoring development include a variety of high stress and hostile aero-thermo-chemical service environments projected for complex structural aerospace vehicle systems. There is additional specific interest in autonomous, non-contacting, remote, rapid, and less geometry sensitive technologies that reduce weight and acquisition costs or improve system sensitivity, stability, and operational costs.

TOPIC T8 Marshall Space Flight Center

T8.01 Realistic Non-Nuclear Testing of Nuclear Systems

NASA recently announced the Project Prometheus Program. One goal of the program is to use nuclear electric propulsion (NEP) to send a sophisticated probe to Jupiter's moons. A successful NEP flight will rely heavily on a viable approach to development and flight qualification testing of the NEP system. An important part of that testing approach will be realistic non-nuclear testing.

NEP systems can be designed to allow highly realistic non-nuclear testing. Such testing can be used to develop and qualify systems in all areas except those strongly affected by radiation damage. Realistic non-nuclear testing is particularly valuable for near-term missions, in that the relatively low required power levels lead to a relatively low neutron flux and hence reduced radiation damage concerns. Realistic non-nuclear testing is required for flight unit acceptance testing because full power nuclear tests cannot be performed on the actual NEP flight unit.

Specific areas of interest in this solicitation include innovative high fidelity, long-life thermal simulators (used to mimic heat from fission), innovative, non-obtrusive approaches to instrumentation (e.g. temperature, pressure, and strain measurement), and innovative testing approaches. Peak system temperatures during testing are expected to reach 1300 K, and peak thermal simulator temperature could be significantly higher.

TOPIC T9 Stennis Space Center

T9.01 Rocket Propulsion Testing Systems

Proposals are sought for innovative technologies and technology concepts 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. As a minor element in a proposal for this topic, the offeror may include specific educational related research, technology advances, or other deliverables that address and support the agency's education mission, such as the enhancement of science, technology, engineering, and mathematics instruction with unique teaching tools and experiences. Specific areas of interest in this subtopic include the following:

Facility and Test Article Health-Monitoring Technologies

- Innovative, non-intrusive sensors for measuring flow rate, temperature, pressure, rocket engine plume constituents, and effluent gas detection. Sensors must not physically intrude at all into the measurement space. Sub-millisecond response time is required. Temperature sensors must be able to measure cryogenic temperatures of fluids (as low as 160R for LO_X and 34R for LH_2) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/sec - 82 ft/sec for LO_X, 500 lb/sec - 300 ft/sec for LH_2). Flow rate sensors must have a range of up to 2000 lb/sec (82 ft/sec) for LO_X and 500 lb/sec (300ft/sec) for LH_2. Pressure sensors must have a range up to 15,000 psi. Rocket plume sensors must determine gas species, temperature, and velocity for H_2, O_2, hydrocarbons (kerosene), 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 LO_X and 34R for LH_2) under high pressure (up to 15,000 psi), high flow rate conditions (2000 lb/sec - 82 ft/sec for LO_X, 500 lb/sec - 300 ft/sec for LH_2). Response time must be on the order of a few milliseconds to the sub-milliseconds.
- On-line (real-time) sampling of percent concentration of pressurizing nitrogen in liquid oxygen systems. Instrumentation must be capable of sub-millisecond sampling of nitrogen percent concentration at cryogenic temperatures (as low as 160R for LO_X and 34R for LH_2), pressures up to 15,000 psi, and high flow rate conditions (2000 lb/sec - 82 ft/sec for LO_X, 500 lb/sec - 300 ft/sec for LH_2).
- On-line (real-time) sampling and analysis of high pressure, high flow liquid oxygen-nitrogen mixtures. There is a significant need for real time, totally non-intrusive instrumentation for high pressure, high flow rate LO_X systems, having the capability to detect the presence of other chemical species present in the LO_X, which may have been introduced through the pressurization process. An example would be the detection of N_2 in a LO_X flow, where N_2 is used to pressurize the LO_X delivery system. The technology should be expandable to include other propellants.

Improvement in Ground-Test Operation, Safety, Cost-effectiveness, and Reliability

- Smart system components (control valves, regulators, and relief valves) that provide real-time closed-loop control, component configuration, automated operation, and component health. Components must be able to operate in cryogenic temperatures (as low as 160R for LO_X and 34R for LH_2) under high pressure (up to 15,000 psi) high flow rate conditions (2000 lb/sec - 82 ft/sec for LO_X , 500 lb/sec - 300 ft/sec for LH_2). Components must be able to operate in the elevated temperatures associated with a rocket engine testing environment. Response time must be on the order of a few milliseconds to the sub-milliseconds.

- Improved long life, liquid oxygen compatible seal technology. Materials and designs suitable for oxygen service at pressures up to 10,000 psi. Both cryogenic and elevated temperature candidate materials and designs are of interest. Typical temperature ranges will be either minus 320° F to 100° F or minus 40° F to 300° F. Seal designs may include both dynamic and static use. Plastic, metal or electrometric materials or combinations thereof are of particular interest.
- Miniature front-end electronics to support embedding of intelligent functions on sensors. Requirements include computational power comparable to a 200 Mhz PC with approximately 32 MB of RAM and similar non-volatile storage, analog I/O (at least two of each, with programmable amplification and anti-aliasing filters, plus automatic calibration) digital I/O (at least eight), communication port for Ethernet bus protocol (one high speed and one low speed), support for C programming (or other high level language), and development kit for a PC. The package should occupy a space no larger than 4" x 4" x 2". The system should include an embedded temperature sensor, an embedded stable voltage calibration source, and programmable switching to connect calibration source inputs and outputs.
- New and innovative acoustic measurement techniques and sensors for use in a rocket plume environment. Current methods of predicting far-field and near-field acoustic levels produced by rocket engines rely on empirical models and require numerous physical measurements. New methods are required that can accurately predict the acoustic levels using fewer measurements. New, innovative techniques based on energy density measurements rather than pressure measurements show promise as replacements for the older models.
- Modeling of atmospheric transmission attenuation effects on test spectroscopic measurements. Atmospheric transmission losses can be significant in certain wavelength regions for radiometric detectors located far from the rocket engine exhaust plume. Consequently, atmospheric losses can result in over-prediction of the incident radiant flux generated by the plume. Accurate atmospheric transmission modeling is needed for high-temperature rocket engine plume environments. The capabilities should address both the losses from ambient atmosphere and localized environments, such as condensation clouds generated by cryogenic propellants.

Application of System Modeling to Ground Test Operations in a Resource Constrained Environment

- New innovative approaches to incorporating knowledge and information processing techniques (prepositional logic, fuzzy logic, neural nets, etc.) to support test system decision making and operations. A requirement exists to develop, apply, and train intelligent agents, behavioral networks, and logic streams for rocket engine testing modes of operations and practice. Applications must operate statistically well on small and disparate data sources. The resulting products are inferential, representative, and they capture tacit and explicit knowledge. Statistic analysis must be supported.
- Techniques to reduce required sample size to maintain acceptable levels of confidence in cost data. In order to leverage appropriate models and to manage the cost of data acquisition and maintenance, the minimization of required data sample sizes is critical.
- Measurements and data are the product of ground testing. High accuracy, precision, uncertainty bands, and error bands are important elements of the data which is generated, and this must be quantified. Techniques and models to determine these parameters for active test facilities are required.

Appendix A: Phase I Sample Table of Contents

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Appendix B: Example Format for Briefing Chart

NASA SBIR/STTR Technologies

Title of Proposal

PI: PI's Name / Firm – City, ST
Proposal No.: 03-I

SBIR
STTR

Identification and Significance of Innovation	<Place Picture Here>
Technical Objectives and Work Plan	NASA and Non-NASA Applications Contacts