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Small Business Innovation Research

Program Solicitation

Closing Date: June 15, 1994

National Aeronautics and
Space Administration
Washington, DC 20546-0001

Important Considerations

1. Proposals must meet the 1994 Solicitation requirements.

Please read this Solicitation carefully before developing a Phase I proposal. Verify that each proposal conforms to all requirements specified herein. Certain requirements and subtopics in the NASA 1994 Solicitation differ from those in previous years. For instance, this year offerors must send **eight copies** of each proposal. Proposals that do not meet all of the requirements of this Solicitation may not be responsive and may not be evaluated.

2. Commercial application potential is important.

This is an evaluation and selection consideration in both Phase I and Phase II.

3. SBIR Solicitation requirements vary among federal agencies.

Proposals prepared for other agencies should not be submitted to NASA without modification to conform with all requirements of this Solicitation.

4. Information requests must be limited during the Solicitation period.

To insure competitive fairness, NASA Field Installations and Headquarters Offices cannot accept inquiries for interpretations of the technical subtopics or for advice on specific proposals during the Phase I Solicitation and proposal evaluation periods.

5. There are constraints on submitting proprietary information.

Provisions for including proprietary information in SBIR proposals are described in Section 5.4 of this Solicitation.

6. Mandatory eligibility requirements apply.

Eligibility requirements for small businesses and Principal Investigators are given in Section 1.4.

7. The SBIR BBS and Internet FTP services will provide updates.

Beginning in late April, offerors are encouraged to check the SBIR electronic bulletin board system for news, additional information, and any Solicitation corrections needed.

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National Aeronautics and Space Administration

Small Business Innovation Research

1994 Program Solicitation

1.0 Program Description

1.1 Summary

The National Aeronautics and Space Administration (NASA) invites eligible small business concerns to submit Phase I proposals for its 1994 Small Business Innovation Research (SBIR) Program, which is described in this twelfth annual NASA SBIR Program Solicitation. The 1994 Solicitation period for Phase I proposals begins April 4, 1994 and ends June 15, 1994. Eligible firms with research or research and development capabilities (R/R&D) in any of the listed topic and subtopic areas are encouraged to participate. Through SBIR, NASA seeks innovative concepts addressing the program needs described in the SBIR Solicitation subtopics and offering commercial application potential.

This document contains program background information, outlines eligibility requirements for SBIR participants, describes the three SBIR program phases, and provides the information qualified offerors need to prepare and submit responsive proposals.

NASA plans to select approximately 380 proposals during September 1994 for negotiation of Phase I fixed-price contract awards. The Phase I performance period will be six months, and the contract awards will not exceed $70,000. NASA anticipates that during 1995 approximately half the successful Phase I projects from the 1994 program will be selected for Phase II development.

1.2 Program Features

1.2.1 Legislative Basis. The Solicitation is issued pursuant to the authority contained in 15 U.S.C. 638 (j)--P.L. 102-564, the Small Business Research and Development Enhancement Act of 1992, amending the Small Business Innovation Development Act of 1982, 15 U.S.C. 638, P.L. 97-219 . SBIR policy is provided by the Small Business Administration (SBA). The current Policy Directive for SBIR became effective on January 26, 1993.

1.2.2 Program Objectives. SBIR program objectives established by law include stimulating technological innovation in the private sector, strengthening the role of small business concerns in meeting federal research and development needs, increasing the commercial application of federally supported research results, and fostering and encouraging participation by socially and economically disadvantaged persons and women-owned small businesses in technological innovation.

1.2.3 Program Funding. Participating agencies conduct SBIR programs by reserving a small percent of their extramural research and development budgets for funding agreements with small business concerns for R/R&D during the first two phases of the three-phase process described here. In 1994 the percentage is 1.5 percent. Each agency, at its sole discretion, selects the technical topics and subtopics included in its Solicitation, selects its SBIR awardees, and may decide to make several awards or no awards under any subtopic. Follow-on Phase III activities are funded by the private sector or by the government using non-SBIR funds.

1.2.4 Program Management. The NASA SBIR program is an agency-wide effort that contributes to NASA's mission in planning, directing, and conducting research and development for civilian uses of space and aeronautics, and encourages or facilitates the commercialization of R&D funded by NASA. All NASA Field Installations (Field Centers) and Headquarters Program Offices participate. The NASA Headquarters Office of Advanced Concepts and Technology provides overall management and direction of SBIR while the NASA Field Installations identify R&D needs, evaluate proposals, and manage the individual projects. The NASA installations that implement the program are:

ARC: **Ames Research Center**, Moffett Field, California

DFRC: **Dryden Flight Research Center**, Edwards, California

GSFC: **Goddard Space Flight Center**, Greenbelt, Maryland

HQ: **NASA Headquarters**, Washington, DC

JPL: **Jet Propulsion Laboratory**, Pasadena, California

JSC: **Lyndon B. Johnson Space Center**, Houston, Texas

KSC: **John F. Kennedy Space Center**, Florida

LaRC: **Langley Research Center**, Hampton, Virginia

LeRC: **Lewis Research Center**, Cleveland, Ohio

MSFC: **George C. Marshall Space Flight Center**, Huntsville, Alabama

SSC: **John C. Stennis Space Center**, Mississippi

1.3 Three-Phase SBIR Program

1.3.1 Phase I. The purpose of Phase I is to determine the technical feasibility of the proposed innovation and the quality of the performance of the small business concern with a relatively small NASA investment before consideration of further federal support in Phase II. To be eligible for Phase I selection, a proposal must be based on an innovation having high technical or scientific merit that is responsive to a NASA need encompassed by a subtopic in this Solicitation. Proposals involving high risk are encouraged when the anticipated payoff potential is great. Unsolicited proposals (those not responsive to a subtopic) will be rejected.

Projects are expected to emphasize near-term applicability to NASA. Selection preference will be given to eligible proposals where the innovations are believed to have significant commercial application potential.

Phase I must concentrate on establishing the scientific or technical feasibility of the proposed innovation and providing a basis for continued development in Phase II. Proposals must conform to the format described in Section 3 of this Solicitation. Evaluation and selection criteria are described in Section 4.1. NASA is solely responsible for determining the relative merit and value of proposed Phase I projects, selecting proposals for award, and judging the value of Phase I results.

Phase I funding agreements with NASA are six-month, fixed-price contracts. Simplified contract documentation is employed. In 1994, NASA funding for each Phase I contract is limited to $70,000. It is planned that approximately 380 selections for contract negotiations will be made during September 1994 and that all Phase I contracts will be signed by mid-December.

SBIR contractors must have the capability for independent conduct of the R/R&D they propose, and Phase I projects must not require participation and involvement of NASA technical monitors, equipment, or facilities. Phase I contractors will have up to six months to complete their Phase I projects and to submit their Phase I final reports and Phase II proposals.

1.3.2 Phase II. The objective of Phase II is to continue development of selected innovations shown feasible in Phase I that have the highest potential value to NASA and to the U.S. economy. The government is not obligated to fund any specific Phase II proposal. Participation in NASA Phase II is limited to contractors conducting NASA Phase I projects. Phase II awards may not necessarily complete the research and development required to satisfy commercial or federal needs beyond the SBIR program, but completion of the research and development as well as commercializing the results should be pursued in Phase III.

Phase II projects are chosen from competitive evaluations of Phase II proposals submitted at the end of Phase I. Phase II proposals are more comprehensive than those required for Phase I and are prepared in accordance with instructions provided by the requests for Phase II proposals contained in the Phase I contract. Phase I contractors competing for Phase II must submit their Phase II proposals with their Phase I final reports.

The Phase II proposal evaluation and selection criteria noted in Section 4.2 are similar to those for Phase I but also include consideration of the results of Phase I. However, Phase II evaluations and selections will place greater emphasis on evidence of non-government commercial application potential than does Phase I. Proposed Phase II price will also be a significant consideration based on NASA's judgements of value and reasonability.

It is planned that in 1995 about half the Phase I projects resulting from this 1994 Solicitation will be selected for Phase II continuations. Fixed-price contracts are usually employed in Phase II, with performance periods up to

two years. Funding for each Phase II project selected in 1995 is expected to be limited to $600,000.

1.3.3 Phase III. Phase III is pursuit by SBIR contractors of commercial applications of their project results, using private sector funds, in support of the government's policy to stimulate technological innovation and provide for return on investment from government-funded R/R&D that is in aid of the national economy. Phase III may also be follow-on, non-SBIR-funded contracts with the government for SBIR-derived products or processes for use by the federal government.

Phase I, II, and III awards are considered competitive under the Competition in Contracting Act. NASA will give special acquisition preference for subsequent Phase III contracts to firms planning to pursue continued development of technology, product, or services developed under SBIR Phase I and II.

1.4 Eligibility To Participate in SBIR

1.4.1 Small Business Concern. Only firms qualifying as small business concerns as defined in Section 2.2 of this Solicitation are eligible to participate in the SBIR program. SBIR eligibility does not require that the offeror qualify as a socially and economically disadvantaged small business concern (see Section 2.3) or as a women-owned small business concern (see Section 2.5).

1.4.2 Place of Performance. For both Phase I and II, the R/R&D must be performed in the United States (see Section 2.6) .

1.4.3 Principal Investigator. Stringent requirements are enforced.

Functions. The functions of the Principal Investigator (PI) are planning and directing the SBIR 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.

Qualifications. The qualifications and capabilities of the proposed PI and the basis for PI selection are to be clearly presented in the proposal. The nature of the PI's activities and the amount of time that the PI will apply personally must be described (no specific minimum is required; the amount must be acceptable to the NASA contracting officer). NASA has the sole right to accept or reject a recommended PI based on factors such as education, experience, demonstrated ability and competence, and any other evidence related to the specific assignment.

Co-Principal Investigators. These are unacceptable.

Misrepresentation or Substitution. Misrepresentation of PI qualifications and eligibility or substitution of a PI by the offeror at any time without NASA's written approval will result in rejection of the proposal or termination of the contract.

Primary Employment. The offeror must certify in the proposal that the primary employment of the PI will be with the small business concern at the time of award and during the conduct of the project. Primary employment with the small business concern must average a minimum of 20 hours per week. Primary employment also requires the PI to spend with the small business concern more than half the total time that the person is employed or is obligated to spend with all concurrent employers, including consulting and self-employment outside the small business concern.

If the PI does not meet primary employment requirements when the proposal is submitted, the offeror must explain how they will be met if the proposal is selected for contract negotiations.

Employees of Academic and Non-Profit Organizations. An offeror proposing a PI who is also to be employed concurrently in any capacity by an academic or non-profit organization (the organization) must include, as part of the proposal, a written release statement by that organization. The PI release statement shall approve concurrent primary employment with the small business concern as defined above and accept less than half-time employment by the organization beginning no later than the time of NASA SBIR contract award to the small business concern and continuing thereafter during contract performance. It must specifically release the employee from all duties, responsibilities, and activities with the organization required by or implied by employment in that position as much as or more than half-time.

1.5 General Information

1.5.1 Information About The NASA SBIR Program. Published information about the SBIR program includes:

- "A Guide to Participation in the NASA SBIR Program"
- The current NASA SBIR Program Solicitation
- The NASA SBIR Product Catalog

- Project abstracts and program statistics
- Contract documents
- Lists of awards

The **SBIR electronic bulletin board system** (BBS) provides electronic access to the foregoing information and announcements of current interest. Potential offerors are encouraged to check the BBS occasionally in May and June. Users may also make requests and leave messages. The BBS currently operates at speeds up to 9600 baud, no parity, 8 data bits and 1 stop bit. The BBS is accessible toll-free at **800-547-1811**, except for Washington, DC. Nationwide commercial access is also available at 202-488-2939.

SBIR documents are also available via **Internet FTP**. The server is CONEY.GSFC.NASA.GOV (IP address is 128.183.101.43). The login is "anonymous"; the password is "guest" or the user's Internet e-mail address. In addition to the documents listed above, information and announcements are posed in a file named SBIR_READ.ME.

Mail or facsimile requests for information or publications may also be made to:

SBIR Program Office
Code CCR
NASA
Washington, DC 20546-0001
Fax: 202-488-7838

Telephone information inquiries may also be made using the NASA SBIR telephone number, 202-358-0691; hours are 8:00 A.M. to 4:30 P.M. Eastern time Monday through Friday. Telephonic requests for documents will not be accepted.

NASA SBIR General Information Contact. Requests for general information about the NASA SBIR program should be addressed **in writing** to Mr. John A. Glaab, SBIR Program Manager, at the address above.

1.5.2 Questions About This Solicitation. To ensure fairness, questions relating to the intent and content of subtopics and for advice on proposal writing can not be answered during the Phase I solicitation period ending June 15, 1994. Only questions requesting clarification of solicitation instructions and administrative matters will be answered.

1.5.3 Questions Regarding Proposal Status. Evaluation and selection of proposals for negotiation leading to contract award will require about three months after the Solicitation closes on June 15, 1994. Information about proposals status will not be available until final selections are publicly announced except for the postcards mailed by NASA to confirm the receipt of proposals, as noted in Section 6.5 of this Solicitation.

1.5.4 Technical Background Information. Numerous organizations, some of which are listed in this Solicitation, offer assistance to firms preparing SBIR proposals. NASA cannot accept responsibility for independent interpretations of the subtopics and the requirements set forth in this Solicitation, or for proposal assistance they may provide to offerors.

2.0 Definitions

The following definitions apply for purposes of this Solicitation.

2.1 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.

2.2 Small Business Concern: A business concern that, at the time of award of Phase I and Phase II funding agreements:

- Is independently owned and operated, is organized for profit, is not dominant in the field of operation in which it is proposing, and has its principal place of business located in the United States;

- Is at least 51 percent owned by, 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

- 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 term

"affiliates" is defined in greater detail in 13 CFR 121.3(a). The term "number of employees" is also defined in 13 CFR 121.2(b).

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.

2.3 Socially and Economically Disadvantaged Small Business Concern: A small business concern that (1) is at least 51 percent owned by an Indian tribe or a native Hawaiian organization or by one or more individuals who are socially and economically disadvantaged and (2) has its management and daily business controlled by one or more such individuals.

2.4 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; or 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).

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

2.6 United States: The 50 states, the District of Columbia, the territories and possessions of the United States, the Commonwealth of Puerto Rico, and the Trust Territory of the Pacific Islands.

2.7 Subcontract: Any agreement, other than one involving an employer-employee relationship, entered into by a federal government funding agreement awardee calling for supplies or services required solely for the performance of the original funding agreement. See also Sections 3.5 Part 9 and 5.12 of this Solicitation.

2.8 Innovation Research: R/R&D on an innovation. Innovation in the context of the NASA SBIR program includes, but is not limited to, invention. Innovation encompasses new, original, and imaginative approaches to the solution of new and old problems; major improvements or advances to existing technology; exploitation of new technological developments and some limited aspects of basic research when such objectives are stated in the technical subtopics.

Proposals for activities that do not require innovation as defined above are not acceptable in the SBIR program. This includes engineering development that does not involve a new concept, embodiment of new technology, or advances over current technology applications.

2.9 Commercialization: The process of developing markets and producing and delivering products or services for sale (whether by the originating party or by others). As defined by the Small Business Administration, commercialization includes both government and non-government markets.

3.0 Phase I Proposal Content and Preparation

3.1 Fundamental Considerations

3.1.1 Responsiveness. As required by the Small Business Administration, an SBIR Phase I proposal must address a NASA program need described in a specific subtopic in this Solicitation. *To encourage the broadest possible range of innovation, any proposal will be accepted for consideration under the subtopic to which it has been submitted if NASA decides it meets the underlying intent of the subtopic, even though the proposed concept is not included in the subtopic description. If such a proposal is judged to be not responsive to the subtopic's intent, it will be classed as an unsolicited proposal and rejected without evaluation, in accordance with SBA regulations.*

3.1.2 Proposal Objective. A Phase I proposal must provide sufficient information to convince NASA that the proposed work represents a sound approach to investigating the feasibility of a valuable scientific or engineering innovation that is responsive to a solicitation subtopic. A proposal must be self-contained and written with the care and thoroughness accorded papers for publication.

3.1.3 Project Requirements. Proposed SBIR projects must be limited to activities requiring significant scientific or technical innovation R&D, either experimental or theoretical. They may or may not involve construction and evaluation of a laboratory prototype, but all projects must demonstrate through prototypes, models, or study results the basis for delivery of a product or service at the conclusion of Phase II development. The project deliverable may be data, hardware, or software. A Phase I final report is required in every project.

Proposals must be based on advanced, innovative, and original technical concepts whose feasibility is to be

demonstrated in Phase I. High scientific and technical merit of the proposed innovation and significant value to the NASA program are essential qualities above all other considerations. Potential commercial applications of the technology that the small business can pursue through subsequent entrepreneurial activities are also important concerns that must be addressed in the proposal. Commercial potential is a selection factor.

3.1.4 Unacceptable Objectives. Proposals directed toward systems studies, market research, commercial development of existing products or proven concepts, straightforward engineering design for packaging or adaptation to specific applications, study or laboratory evaluations of products or concepts, and modifications of existing products without innovative changes are examples of projects that are not acceptable for SBIR pursuit.

3.1.5 Multiple Proposal Submissions. An offeror may submit any number of proposals to any number of subtopics, but every proposal must be based on a unique innovation, must be limited in scope to just one subtopic, and may be submitted only under that subtopic. Identical proposals and substantially similar proposals based on the same innovation submitted by an offeror to several subtopics will all be rejected without evaluation. Should an offeror believe its proposed innovation applies to more than one subtopic, the other subtopics may be noted in the proposal submitted. However, the large number of proposals submitted and the large number of NASA Installations involved may make it impractical to evaluate all such possibilities.

3.2 General Requirements

3.2.1 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**, including cover page, budget, and all enclosures or attachments. Pages are to be printed on one side only and may be single or double space. All material submitted except required listing of Phase II awards (See Section 3.7) will be included in the page count. Samples, videotapes, slides, or other ancillary items will not be accepted. **Proposals exceeding the 25 page limitation will be rejected without consideration.**

3.2.2 Type Size. No type size smaller than 10 point is to be used for text or tables, except as legends on reduced drawings. Pages are to be printed on one side only, and may be single or double spaced. Twenty-five page proposals prepared with smaller font sizes will be rejected without consideration.

3.2.3 Brevity and Organization. The proposal should be logically organized, direct, and concise. Offerors are requested not to use the entire 25-page allowance unless necessary.

3.3 Required Format

The following format is required for all Phase I proposals. A Phase I proposal consists of a cover page, a project summary, a technical proposal, and a proposed budget. Each of these must be addressed and presented in this order. All required items of information are to be covered fully, but the space allocated to each will depend on the project chosen and the offeror's approach. A proposal not addressing all parts will be considered non-responsive to this Solicitation and will be rejected without consideration. Promotional and other material not related to the project may not be included. Detailed descriptions of all parts of the proposal follow.

3.4 Proposal Cover and Project Summary

The Proposal Cover and the Project Summary are public information, and the government may disclose them. Do not include proprietary information on them.

3.4.1 Page 1: Cover. The offeror shall complete a copy of the Proposal Cover, Form 9.A in this Solicitation, and sign it in ink. This becomes the original cover sheet. The offeror shall include a photocopy of the completed Form 9.A as page 1 of each copy of the proposal. (The original 9.A is submitted as a separate page; see Section 6.1.) No other cover is permitted. While detailed instructions are provided with the form, special attention should be given to the following.

Proposal Title. This must be concise and descriptive of the proposed activity, product or innovation. Acronyms or phrases like "Development of" or "Study of" may not be used in the project title, nor may the NASA subtopic title be used as the proposal title.

Certifications. The offeror must respond to the following certifications cited briefly on the proposal cover.

6 (d) Limits on subcontracting. By answering yes, the offeror certifies that a minimum of two-thirds of the research and\or analytical effort for the proposed project will be performed by the small business concern, as described in Section 5.12.1.

6(e) Eligibility of the Principal Investigator. By answering yes, the offeror certifies that the proposed

principal investigator meets all the requirements described in Section 1.4.3 and, if the PI is currently the employee of an academic or a non-profit research organization, a copy of the release letter from that organization is also included.

6(f) Prior federal funding. By answering yes, the offeror certifies that they have received federal funds for substantially similar work and these projects are described in Part 10 of the proposal. By answering no, the offeror certifies that no such funds have been received.

6(g) Proposals to other agencies. By answering yes, the offeror certifies that they have submitted or plan to submit proposals of similar content to another federal agency and that these proposals are described in Part 10 of the proposal. By answering no, the offeror certifies that no such proposals are presently under consideration or will be submitted this year.

6(h) Subcontracts and agreements. By answering yes, the offeror indicates that a copy of any subcontracting or consulting agreements described in Part 9 of the proposal is included as required in Section 3.5. If such agreements are lengthy, the signature page should be included. These copies may be submitted in a reduced size.

3.4.2 Page 2: Project Summary. The offeror shall complete the project summary, Form 9.B as page 2 of the proposal. (Instructions are provided with the form.) One copy is submitted as a separate page; see Section 6.1.

The technical abstract section shall summarize (1) the **specific proposed innovation** and how it addresses the stated subtopic requirement, (2) the project objectives, (3) the effort proposed, (4) the results anticipated, and (5) the expected NASA applications and benefits. Potential commercial applications will be discussed in the appropriate section.

3.5 Technical Proposal

3.5.1 Page 3: Table of Contents. Page 3 of the proposal shall begin with a brief table of contents indicating the page numbers of each of the sections of the proposal.

3.5.2 Pages 3 and following. The Technical Proposal shall consist of the following eleven parts.

Part 1: Identification and Significance of the Innovation. The first paragraph of Part 1 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 need described in the subtopic. The initial paragraph shall contain no more than 150 words. **NASA may reject proposals that lack this introductory paragraph.**

In subsequent paragraphs Part 1 may also include appropriate background and elaboration to explain the proposed innovation.

Part 2: Phase I Technical Objectives. This shall include the specific objectives of the Phase I effort and state the technical questions the offeror must answer to determine the feasibility of the proposed innovation.

Part 3: Phase I Work Plan. The Phase I Work Plan must be complete and self-contained and shall include a detailed description of the proposed Phase I activities indicating what will be done and where the work will be carried out. The methods planned to achieve each objective or task should be discussed in detail. Schedules (Gantt charts or other suitable scheduled task displays), task descriptions and assignments, resource allocations, and planned accomplishments including project milestones shall be included.

Section 5.4.1 of this Solicitation contains policy on proprietary information. Offerors are advised to avoid including proprietary information if at all possible.

Part 4: Related R/R&D and Bibliography of Related Work. The purpose of Part 4 is to make clear the offeror's awareness of key recent developments by others in the specific subject area. It should include any significant R/R&D directly related to the proposal that has been conducted by the offeror or Principal Investigator. 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 5: Relationship with Phase II or other Future R/R&D. The offeror shall explain why the expected Phase I results would warrant Phase II continuation, and state the anticipated Phase II objectives (see Section 3.1.3). Any other planned R/R&D related to the proposed research should also be described.

Part 6: Commercial Applications Potential. The commercial potential of the proposed SBIR project is a significant proposal evaluation factor (see Section 4.1.2). Therefore, offerors will discuss in this section the

potential direct or indirect commercial applications they envision for their project results and their plans to pursue them. While a detailed business plan for the proposed commercial application is not required, offerors should discuss the potential market viability of their innovation and their expected approach to bringing it to market. This should include how the proposed product would be preferable to what is currently available or fill a new niche; a description of the potential market; and how direct or derivative applications of the innovation would be marketed.

Offerors should describe how they would seek the funding needed for non-government Phase III activities. They should read Sections 4.2.3 and 4.2.4, which describe Phase II evaluation of commercial potential, for guidance. If Phase III would be funded internally, offerors should describe their financial position. Any experience of the small business or its principals in marketing related products or in raising capital should be noted.

Part 7: Company Information. This shall provide information needed by evaluators to assess the ability of the firm to carry out the proposed Phase I and projected Phase II activities and lead to Phase III. While a corporate background or extensive experience is not a prerequisite for an SBIR award, the capability of the offeror to perform the proposed research must be indicated.

A description of the firm's business organization and operations, number of employees, R/R&D capabilities, and any relevant experience is to be provided. The offeror's physical facilities that will be used to support the proposed research, including any pertinent instrumentation or special equipment needed for the proposed research should be described. If the necessary facilities, equipment, and instrumentation are not presently available, the offeror must explain how they are to be obtained. NASA will not fund the acquisition of equipment, instrumentation, or facilities under SBIR Phase I contracts.

Part 8: Key Personnel. The offeror shall identify the key employees to be committed to Phase I activities. Key personnel are the Principal Investigator and other individuals whose expertise and functions are essential to the success of the project. Information on their education, experience, and any directly related accomplishments and publications is required. Extensive vitae and publication lists not pertinent to the proposed research shall not be included.

This section shall also establish the Principal Investigator's eligibility (see Section 1.4.3 of this Solicitation) and indicate the extent to which other proposals recently submitted or planned for submission in 1994 and existing projects commit the PI's time concurrently with this proposed activity.

Part 9: Subcontracts and Consultants. Up to one-third of the research and/or analytical effort in Phase I may be conducted under subcontract to other firms, nonprofit organizations, and individual consultants (see Section 5.12 of this Solicitation). Subcontracting is encouraged when it permits the firm to conduct more valuable R&D or improve the prospects for commercial success.

The offeror must describe any proposed subcontracting and identify the organizations and individuals with whom subcontracts are planned. The tasks to be subcontracted must be described in detail, including the functions, services, number of hours and labor rates, and extent of effort to be provided. The proposal must include a copy of an agreement by each subcontracting organization or individual that they will be available at the times required for the purposes and extent of effort described in the proposal.

Part 10: Related Proposals to and Awards from Other Agencies. The offeror will inform NASA of related proposals and awards so that duplications may be avoided. The offeror must first certify on the Proposal Cover whether the offeror (1) has received federal government awards for related work, or (2) 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 during 1994. For all such awards and for active or intended proposals in 1994 the following information is required:

(1) The agencies to which proposals for similar or related work have been or will be submitted, or from which awards for similar or related work have been received;
(2) Dates of such proposal submissions or awards;
(3) Solicitation numbers under which such proposals have been or will be submitted or such awards received;
(4) The specific research topic for each such proposal submitted or award received;
(5) Titles of research projects;
(6) Name and title of the Principal Investigator for each proposal that has been or will be submitted or award received.

Lack of the required certification on the cover page or failure to declare the existence of related, similar or duplicative awards or proposals may result in rejection of the offer or loss of an award. **If no such awards**

have been received or no such proposals have been submitted or are intended, the offeror shall so state.

Part 11: Previous NASA SBIR Awards Received. Offerors must state the total number of NASA SBIR Phase I and II awards received, and list those received during the last five years, showing contract numbers, the year of award, Phase I or II, the NASA Installations making the award, and project titles. If no NASA awards have been received, the offeror shall so state.

3.6 Proposed Budget

3.6.1 Summary Budget. Following the instructions provided with the form, offerors shall complete Form 9.C, SBIR Summary Budget, and include it (and any budget explanation sheets, if needed) as the last page(s) of the proposal. Enough information shall be submitted to explain how the offeror plans to use the requested funds and to enable NASA to determine whether the proposed budget is fair and reasonable. Special attention is directed to the following items:

3.6.2 Property. NASA will not fund instrumentation, equipment, or facility acquisition under Phase I. Any purchases of products under an SBIR contract using NASA funds should be American-made to the extent possible.

3.6.3 Travel. Requests for travel funds are not acceptable for Phase I, except for essential use of remote facilities if subsequently approved by NASA.

3.6.4 Profit. A profit or fee may be included in the proposed budget as noted in Solicitation Section 5.9.

3.6.5 Cost Sharing. See Section 5.8.

3.7 Addendum for Prior SBIR Phase II

The Small Business Administration requires offerors who have received more than 15 Phase II awards from all agencies since October 1, 1988, to report them and their progress toward commercialization. Awards shall be listed in a separate "Addendum: Phase II History" that will not be counted against the Phase I 25-page proposal limit. Information for each Phase II contract shall include:

(1) Name of awarding agency
(2) Date of award and date of completion
(3) Funding agreement number and amount
(4) Topic or subtopic name
(5) Project title
(6) Sources, dates and amounts of federal and/or private sector Phase III follow-on funding agreements
(7) Post-Phase II commercialization activities, including development, marketing, sales, and projections

The Addendum should be concise.

3.8 Check List

The Check List included in this Solicitation is provided to assist the offeror in completing a responsive proposal. It should not be submitted with the proposal.

4.0 Evaluation, Selection, Contracting, and Debriefing

4.1 Phase I

4.1.1 Evaluation Process. Proposals are first screened for compliance with administrative requirements of the Solicitation. Those that pass are then reviewed to determine whether they respond to the subtopic chosen by the offeror and whether they are based on stated innovations. Those found to be responsive are evaluated in greater depth by two or more scientists or engineers at the NASA Installation(s) responsible for the subtopic, using the factors listed under Section 4.1.2. Other NASA Installations may also conduct evaluations and make recommendations for selections of any proposals accepted for evaluation.

Proposals are expected to provide all information needed for complete evaluation, and evaluators are not required to seek additional information. Evaluators are required to use judgment in assessing proposal information, making use of their personal expertise, knowledge and experience. And when it is approved by the Installation, other qualified experts outside of NASA may be utilized to perform evaluations or to help NASA personnel determine or verify the validity or merit of any aspect of a proposal.

4.1.2 Phase I Evaluation Factors. NASA will give primary consideration to the scientific and technical merit of the Phase I proposal along with its potential for commercial application and will uniformly apply the following evaluation factors and procedures:

Factor 1. Scientific and technical merit of the proposed innovation; relevance to the subtopic; benefit

to NASA; and the specific objectives and approaches for addressing feasibility. Innovativeness and originality are essential considerations. **(50 points)**

Factor 2. Qualifications of the Principal Investigator and other key personnel, consultants, and subcontractors, if any; and adequacy of instrumentation and facilities to be available for the project. **(25 points)**

Factor 3. Soundness of the proposed work plan, budget, and schedule for meeting the Phase I objectives of determining the feasibility and merit of the proposed innovation as one basis for Phase II. **(25 points)**

Factor 4. Anticipated commercial benefits of potential applications in the private sector and their value the U.S. economy. **(Unscored factor)**

Technical Merit. Each proposal will be scored numerically using Factors 1, 2 and 3. The sum of these scores will be the Technical Merit weight of the proposal **(potential of 100 points)**.

Commercial Potential. The potential for commercial applications of the proposed project will be assessed for each proposal scored in the Technical Merit competitive range developed by the Installation. This assessment will be distinct from the technical evaluation and its numerical scoring, and will become an unscored evaluation factor expressing one of the following qualitative judgments:

Low potential
Moderate potential
High potential, or that
Insufficient information was provided by the offeror to permit a qualitative judgment to be made.

Installation Selection Recommendations. The SBIR Committee at each NASA Installation will prioritize (rank) its recommendations for selection and submit them to the SBIR Selection Official. Recommendations will note the Technical Merit score and Commercial Potential assessment for each proposal and any special considerations. The number of proposals recommended for selection by each Installation may exceed the number finally selected.

4.1.3 Selection. The SBIR Selection Official is not obligated to select any specific proposal for contract negotiation, but most selection decisions are aligned with priorities recommended by each Installation. Other factors influencing selection decisions include special consideration to proposals that have significant commercial applications potential; program balance; and critical agency requirements.

Firms selected for negotiations that may lead to contract awards will be notified by mail, and the list of selections will be made available electronically (see section 1.5.1) and by NASA Press Release announcement. Each notification letter will identify the Contracting Officer at the NASA Installation responsible for negotiating the Phase I contract.

4.1.4 Contracting. Fixed-price contracts for up to $70,000 and 6-month duration will be issued. Simplified contract documentation is employed. NASA will make the Phase I model contract and other documents available to the public electronically on the NASA SBIR BBS and through Internet FTP (see section 1.5.1) at the time of selection announcement. Documents that will be available will include:

(1) The names and contract information for SBIR contracting officers at the NASA installations
(2) Certifications and Representations required to support negotiations
(3) The model SBIR contract
(4) The full text of contract clauses included in the contract by reference

4.2 Phase II

4.2.1 Phase II Proposals. The object of Phase II is to continue the R/R&D effort from Phase I. Only NASA Phase I awardees may compete for NASA Phase II projects. The SBIR Phase I contract will serve as a request for proposal (RFP) for an SBIR Phase II follow-on contract. Phase II proposals are more comprehensive than those required for Phase I. Submission of a Phase II proposal is strictly voluntary and NASA assumes no responsibility for any proposal preparation expenses.

4.2.2 Evaluation and Selection. Anticipated Phase II evaluation factors are noted in Section 4.2.3. They are subject to revision before they are presented in the Phase II RFP. Each NASA Installation managing Phase I projects will use these factors to evaluate the Phase II proposals it receives that are responsive to the Phase II RFP. The Installation's SBIR Committee will then rank the evaluated proposals on technical merit and commercial potential, noting other considerations such as NASA priority and cost effectiveness. Their recommendations and supporting information will then be submitted to the SBIR Selection Official.

Final selections by the SBIR Selection Official will be based on recommendations from all Installations; NASA

Headquarters Program Offices assessments of project value to NASA programs and plans; and any other evaluations or assessments (particularly of commercial potential) that may become available to the Selection Official.

4.2.3 Phase II Evaluation Factors. The Phase II evaluation factors to be provided with the Phase I contract are expected to include the following:

Factor 1. Scientific/technical merit and feasibility of the proposed R&D, with special emphasis on its innovativeness, originality, and technical payoff potential if successful.

Factor 2. Results of Phase I, 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 3. Future importance and eventual value of the product, process, or technology results to the NASA mission.

Factor 4. Capability of the Small Business Concern. NASA will assess the capability of the concern 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, company staff, consultants and subcontractors) relative to the proposed research, and (c) the availability of any required equipment and facilities.

Factor 5. Commercial Potential. Consideration will be given to any or all of the following indications of commercial potential: (a) the small business concern's record of commercializing SBIR or other research, (b) the existence of funding commitments from private-sector or non-SBIR funding sources to help support Phase II, (c) the existence of non-federal follow-on commitments for pursuing Phase III activities, and (d) any other available indicators of commercial potential and the offeror's intent to pursue commercialization. Such indicators would include the size and strength of the expected market, the extent to which the proposed product exceeds the capabilities or value of other products on the market, proven experience in raising capital, and a plan for developing markets and sales.

4.2.4. Non-Federal Funding Support Commitments. Offerors for Phase II contracts are strongly urged to obtain valid non-federal funding support commitments for (1) Phase III follow-on activities and (2) additional support of Phase II from parties other than the proposing firm. Valid 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 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.

Evidence of funding support commitments from outside parties must be provided in writing to the proposing firms. They should accompany the Phase II proposal, but may be submitted until final Phase II selection decisions have been made by NASA. Letters of commitment should specify funding commitments, when available, and other resources to be provided, and other 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.

4.3 Debriefing of Unsuccessful Offerors

After final Phase I and Phase II selection decisions have been announced, an offeror may submit a written request for a debriefing (proposal critique). Telephone requests for debriefings will not be accepted. **Requests must be made within 45 days after notification has been mailed to the offeror** that their proposal was not selected for award. NASA is not obligated to accept late requests.

Debriefings are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal. NASA will provide comments by the evaluators, but debriefings are not opportunities to reopen selection decisions. Debriefings will not disclose the identity of the proposal evaluators nor provide proposal scores, proposal rankings in the competition, or the content of and comparisons with other proposals with which they were in competition.

Copies or evaluations of proposals submitted by a firm are exempt from Freedom of Information requests from anyone else, and such requests will not be honored without written permission of the offeror obtained by the requestor.

4.3.1 Phase I. For Phase I proposals, all requests for debriefing must be directed in writing, either by mail or fax, to the SBIR Program Office, NASA Headquarters. (See Section 1.5.1) Written debriefings, which include the comments of the evaluators, will be mailed only to the corporate official designated in the proposal.

4.3.2 Phase II. To obtain debriefings on Phase II proposals, offerors must mail written requests to the Contracting Officer at the NASA Installation to which their Phase II proposal was submitted. Debriefings may be made to either the corporate official or their designee identified in writing to the contracting officer.

5.0 Considerations

5.1 Awards

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.

In September 1994, NASA plans to announce the selection of approximately 380 proposals for negotiation of fixed-price Phase I contracts with values not exceeding $70,000. Following contract negotiations and awards, Phase I contractors will have up to six months to carry out their proposed Phase I programs and prepare their final reports and Phase II proposals. NASA intends that all Phase I projects resulting from this Solicitation will be placed under contract during December 1994.

NASA anticipates that during 1995 approximately 50 percent of the successfully completed Phase I projects resulting from this Solicitation will be selected for Phase II continuations based on the results of Phase I activities and competitive evaluations of Phase II proposals. Phase II funding agreements are usually fixed-price contracts with performance periods not exceeding 24 months and funding not exceeding $600,000.

5.2 Final Reports

A final report on the Phase I project must be submitted to NASA upon completion of the Phase I research effort. The format and number of copies shall be in accordance with Phase I contract terms. The report shall elaborate the project objectives, work carried out, results obtained, and assessments of technical feasibility. Rights to these data are outlined in Section 5.5 of this Solicitation.

To avoid duplication of effort, language used in the Phase I report may be used verbatim in the Phase II proposal.

The final report shall include a single page project summary, on a form provided by NASA for that purpose, identifying the purpose of the research, a brief description of the research carried out, the research findings or 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, separately for NASA and non-government commercial uses, will also be included. The project summary is to be submitted without restriction for NASA publication.

5.3 Payment Schedule for Phase I

Advance 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 and other deliverables as required by the contract.

5.4 Treatment and Protection of Proposal Information

In the evaluation and handling of proposals, NASA will make every effort to protect the confidentiality of the proposals and their evaluations.

5.4.1 Proprietary Information. It is NASA 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 proprietary information consisting of a trade secret, proprietary commercial or financial information, or private personal information is provided in an SBIR proposal, NASA will treat it in confidence to the extent permitted by law, provided this information is clearly marked by the offeror with the term "confidential proprietary information" and provided the following legend appears on the title page of the proposal follows:

> "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 proposer 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."

NASA recommends that offerors not include proprietary information in their proposals but that any proprietary information included be limited to that absolutely essential for their proposal. **Do not label the entire proposal proprietary.**

5.4.2 Non–NASA Reviewers. In addition to government personnel, NASA, at its discretion and in accordance with 18-15.413-2 of the NASA FAR Supplement, may utilize qualified individuals from outside the government in the proposal review process. Any decision to obtain 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.

5.4.3 Release of Proposal Information. By submission of a proposal, the offeror agrees to permit the government to disclose publicly the information contained on the Proposal Cover and the Project Summary. 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.

5.4.4 Final Disposition of Proposals. The government retains ownership of the copies of proposals accepted for evaluation, and they 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 non-selected proposals are destroyed.

5.5 Rights in Data Developed Under SBIR Contracts

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 Program (NASA Deviation). The clause provides for rights consistent with the following:

5.5.1. 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 summary accompanying any periodic progress reports and the final report required to be submitted (see Section 5.2) but, in any event, the requirement for them will be specifically set forth in any contract resulting from this solicitation.

5.5.2 Proprietary Data. In keeping with NASA's policy, data that constitute trade secrets or other information that is commercial or financial and confidential or privileged **and first developed at private expense** will not normally be acquired, but if acquired will be with "limited rights" or "restricted rights." Such rights do not include the right to use the data for manufacturing or re-procurement purposes.

5.5.3 Non-Disclosure Period. Except for program evaluation, NASA shall protect technical data for a period of not less than 4 years from the completion of the project from which the data were generated unless NASA obtains permission to disclose such data from the contractor. The government shall retain a royalty-free license for government use of any technical data delivered under an SBIR funding agreement whether patented or not.

5.6 Copyrights

With prior written permission of the contracting officer, the awardee normally may copyright and publish (consistent with appropriate national security considerations, if any) material developed with NASA support. NASA receives a royalty-free license for the federal government and requires that each publication contain an appropriate acknowledgement and disclaimer statement.

5.7 Patents

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. To the extent authorized by 35 U.S.C. 205, the government will not make public any information disclosing a government-supported invention for at least four years to allow the awardee a reasonable time to pursue a patent.

5.8 Cost Sharing

Cost sharing is permitted for proposals under this Program Solicitation. However, cost sharing is not required, nor will it be a factor in proposal evaluation. If included, cost sharing should be shown in the summary budget but not included in items labeled "AMOUNT REQUESTED." No profit will be paid under cost-sharing contracts.

5.9 Profit

Both Phase I and Phase II SBIR contracts may include a reasonable profit except where cost-sharing is proposed. The reasonability of proposed profit is determined by the Contracting Officers during contract negotiations.

5.10 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as a small business concern in accordance with the definition in Section 2.2. A statement of how the workload will be distributed, managed, and costed should be included in the proposal. A copy or comprehensive summary of the joint venture agreement or partnership agreement should be included.

5.11 Similar Proposals and Prior Work

If an award is made pursuant to a proposal submitted under this Program 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. See Section 3.5, Part 10.

Submission of related proposals to and receipt of related awards from other agencies, intentions to submit related proposals during 1994 to other federal agencies, and prior NASA SBIR awards received by the offeror must be identified in the Technical Proposal Parts 10 and 11 as noted in Section 3.5 of this Solicitation.

5.12 Limits on Subcontracting Research and Analytical Work

Subcontracts (defined in Section 2.7 of this Solicitation) may be placed with other firms, universities and other non-profit organizations, and individual consultants, but there are limits on subcontracting the research and analytical portions of both Phase I and Phase II contracts:

5.12.1 For Phase I, a minimum of two-thirds of the dollar amount of the research and/or analytical effort must be performed by the proposing small business concern unless otherwise approved in writing by the contracting officer.

5.12.2 For Phase II, a minimum of one-half of the dollar amount of the research and/or analytical effort must be performed by the proposing small business concern unless approved in writing by the contracting officer.

NOTE: The dollar amount of research and analytical effort is the total proposal cost without profit.

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 in the Phase I contract. 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 the SBIR contract.

5.13.12 Covenant Against Contingent Fees. No person or agency has been employed to solicit or 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 contract must be American-made whenever possible.

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 contract, the terms of the contract are controlling.

5.14.2 Evidence of Contractor Responsibility. Before award of an SBIR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to establish responsibility of the offeror.

5.14.3 Limitations on Awards. This Solicitation is not an offer by the Government to make any specific number of awards under either Phase I or Phase II. NASA is not responsible for any monies expended by the offeror before award of any contract resulting from this Solicitation. Also, awards under this Program Solicitation 94-1 are contingent upon the availability of funds.

5.14.4 Classified Proposals. NASA will not accept classified proposals.

5.14.5 Unsolicited Proposals. Unsolicited proposals will not be accepted under the SBIR program in either Phase I or Phase II. Unsolicited proposals include proposals unrelated to a subtopic need.

6.0 Submission of Proposals

6.1 What to Send

Offerors must submit the following items for each proposal:

6.1.1 The original proposal cover sheet signed in ink and included as a separate page. This is Form 9.A of this Solicitation.

6.1.2 One project summary as a separate sheet. This is Form 9.B of this Solicitation.

DO NOT STAPLE THE ABOVE ITEMS TOGETHER: LEAVE SEPARATE.

6.1.3 Eight copies of the entire proposal as described in Sections 3.3 through 3.7. Each proposal copy is to be stapled separately.

6.2 Physical Packaging Requirements

6.2.1 Bindings. Do not use bindings or special covers. Staple the pages of each copy of the proposal in the upper left-hand corner only.

6.2.2 Packaging. Secure packaging is mandatory. NASA cannot process proposals damaged in transit. All items (6.1.1 through 6.1.3) for any proposal must be sent in the same package. If more than one proposal is being submitted, it is requested that all proposals be sent in the same package.

DO NOT SEND DUPLICATE SETS of any proposal as "insurance" that they will be received.

6.3 Where to Send Proposals

6.3.1. U.S. Postal Service. All proposals that are mailed through the U.S. Postal Service by first class or certified mail are to be sent to NASA Headquarters, addressed as follows:

SBIR Program Manager
Mail Code CCR
National Aeronautics and Space Administration
Washington, DC 20546-0001

Do not mark proposals "Confidential" or use registered mail.

6.3.2. Express Mail and Commercial Service. Proposals sent by express mail or commercial delivery services (e.g. Federal Express) or hand-carried are to be delivered to the following address between the hours of 8 A.M. and 4:30 P.M.:

SBIR Proposal Receiving Station
250 E Street, S.W., Suite 380
Washington, DC 20024

The following telephone number may be used when required for reference by delivery services: 202-488-2931. **NASA cannot receive proposals on Saturdays, Sundays, or federal holidays.**

6.4 Deadline for Proposal Receipt

Deadline for receipt of Phase I proposals at NASA is 4:30 P.M. EDT on Wednesday, June 15, 1994. Any proposal received after that date and time will be considered late unless it was sent by the U.S. Postal Service's certified mail not later than June 10, 1994. Since the postmark will be the evidence on which the decision is made, offerors must assure themselves that the postmark is clear and easily legible; hand cancellation is suggested. Postage meter date stamps are not acceptable. Proposals may not be submitted by facsimile. **Late proposals will not be eligible for award and will be rejected without review.**

6.5 Acknowledgement of Proposal Receipt

NASA will acknowledge receipt of proposals by a postal card mailed to the company official who endorsed the proposal cover sheet. If a proposal acknowledgement card is not received from NASA within 30 days following the closing date of this Solicitation, the offeror should call the SBIR Proposal Receiving Station at 202-488-2931. NASA will not respond to such inquiries made prior to July 15, 1994.

6.6 Withdrawal of Proposals

Proposals may be withdrawn by written notice or telegram (including mailgram) received at any time before award. Proposals may be withdrawn in person by an offeror or an authorized representative, if the representative's identity is made known and the representative signs a receipt for the proposal.

7.0 Scientific and Technical Information Sources

7.1 Regional Technology Transfer Centers

NASA's network of **Regional Technology Transfer Centers** (RTTCs) provides access to millions of technical reports in computer data bases, including the Scientific and Technical Information System. Various kinds of searches and assistance, including advice on proposal preparation, can be arranged. User fees are charged for these services. To reach the RTTC in your geographical region, call 800-472-6785.

Northeast:
Center for Technology Commercialization
Massachusetts Technology Park
100 North Drive
Westborough, MA 01581

Mid-Atlantic:
Mid-Atlantic Technology Applications Center
University of Pittsburgh
823 William Pitt Union
Pittsburgh, PA 15260

Southeast:
Southern Technology Applications Center
University of Florida, College of Engineering
One Progress Boulevard, Box 24
Alachua, FL 32615

Mid-West:
Great Lakes Industrial Technology Center
Battelle Memorial Institute
25000 Great Northern Corporate Center, Suite 450
Cleveland, OH 44070-5310

Mid-Continent:
Mid-Continent Technology Transfer Center
Texas Engineering Experiment Station
The Texas A&M University System
237 Wisenbaker Engineering Research Center
College Station, TX 77843-3401

Far-West:
Far-West Regional Technology Transfer Center
University of Southern California
3716 South Hope Street, Suite 200
Los Angeles, CA 90007-4344

The **Technology Application Center** provides services on a nationwide basis to those interested in Earth-observing technologies, including image-processing and geographic information systems.

Technology Application Center
University of New Mexico
2500 Yale, S.E., Suite 100
Albuquerque, NM 87131
505-277-3622

7.2 National Technical Information Services

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
Tel: 703-487-4600
Fax: 703-321-8647

7.3 Technical References

A variety of organizations maintain libraries of scientific and technical documents that offerors may find useful. Some of these are listed below.

American Institute of Aeronautics and Astronautics
Attn: Library
555 West 57th Street, Suite 1200
New York, NY 10019
Tel: 212-247-6500 ext.231

NASA Center for AeroSpace Information
800 Elkridge Landing Road
Linthicum Heights, MD 21090-2934
Tel: 301-621-0100
Fax: 301-621-0134

Defense Technical Information Center
Cameron Station
Alexandria, VA 22304-6145
Tel: 703-274-6800

Engineering Societies Library
345 East 47th Street
New York, NY 10017
Tel: 212-705-8200

IEEE Service Center
PO Box 1331 445 Hoes Lane
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8.0 Technical Topics and Subtopics

8.1 General Information

Section 8 contains the 15 general areas of technology (topics) included in this Solicitation, as follows.

01.00 Aeronautical Propulsion and Power
02.00 Aerodynamics and Acoustics
03.00 Aircraft Systems, Subsystems, and Operations
04.00 Materials and Structures
05.00 Teleoperators and Robotics
06.00 Computer Sciences
07.00 Information Systems
08.00 Instrumentation and Sensors
09.00 Spacecraft and Sensor Platforms
10.00 Space Power
11.00 Space Transportation
12.00 Human Habitability and Biology in Space
13.00 Quality Assurance, Safety, and Reliability
14.00 Satellite and Space Systems Communications
15.00 Micro-Gravity Sciences and Applications

The SBIR topics and subtopics are sufficiently comprehensive to provide a wide range of opportunities for small businesses. Each topic is divided into subtopics that describe certain technical problems and program requirements in which innovative R&D solutions are desired. Subtopics are developed by NASA Installations to include current and foreseen agency program needs and priorities. All subtopics are candidates for project selection and there are no quotas for the selection of Phase I proposals in any subtopic.

This year the number of subtopics has been reduced as a result of merging and combining related needs to broaden scope. Where possible, subtopics have been made less specific or constraining to encourage innovation to meet subtopic intent.

In some instances only one NASA Installation may be concerned with a subtopic, in other instances several. The names of the Installations with the major interests in and responsibility for a subtopic are noted with it, but those indicated may not be the only Installations interested. As in previous years, every Installation is informed of and has access to all proposals received, and each Installation may evaluate and recommend for selection any responsive proposal.

NOTE: Offerors are referred to Section 3.1, Fundamental Considerations, for specific instructions and cautions regarding responsiveness of proposals to the subtopics and for important limitations on proposal submissions. Failure to meet these and other requirements of this Solicitation can lead to rejection of the proposal without evaluation.

8.2 List of Topics and Subtopics

Electronic Distribution: A list of all the topic and subtopic titles follows. A separate electronic file is provided for each topic.

Print Distribution: The Technical Topics and Subtopics section begins with a contents listing.

9.0 Forms

9.1 Electronic Distribution

The three forms needed to complete a proposal--as described in Sections 3.4 and 3.6--are included in a separate file, FORMS. General instructions for completing the forms are provided in Sections 3.4 and 3.6. Information on specific items is included in the instructions following each form.

Offerors must not delete or add any material from the original forms or rewrite them in any way. However, reformatting needed to recover from the transmission process and the choice of fonts is at the offeror's discretion.

Note: Special software to prepare the forms will be available on the NASA SBIR BBS and the Internet FTP server (see Section 1.5.1) as of May 15, 1994. If possible, offerors should use this software to simplify proposal preparation and facilitate proposal processing.

9.2 Printed Distribution

One copy of each of the three forms needed to complete a proposal is included in this Solicitation document:

Form 9.A - Proposal Cover
Form 9.B - Project Summary
Form 9.C - Proposal Summary Budget

Offerors should photocopy them as needed. General instructions for completing the forms are provided in Sections 3.4 and 3.6. Information on specific items is included in the instructions printed after each form.

For assistance in completing your proposal...

FINAL CHECK LIST

☐ 1. The offeror has read all instructions in this Solicitation and understands that proposals not meeting all requirements may be nonresponsive and may not be evaluated.

☐ 2. This proposal and innovation is submitted in only one Subtopic (See Section 3.1.5).

☐ 3. The proposed innovation is described in the first paragraph of the proposal (See Section 3.5.2, Part 1).

☐ 4. All information required by Sections 3.4 through 3.7 is included in order.

☐ 5. Phase II objectives are discussed (see Section 3.5.2., Part 5).

☐ 6. Phase III potential (NASA and commercial applications) and intentions are discussed in Section 3.5.2, Part 6.

☐ 7. Any pages containing proprietary information are labeled "Confidential Proprietary Material." (See Section 5.4.1)

☐ 8. The Certifications in Form 9.A are complete, and Forms 9.A and 9.C are signed.

☐ 9. The period of technical performance does not exceed six months and the funding request does not exceed $70,000.

☐ 10. The proposal (including any supplementary material) contains no more than twenty-five 8½ x 11 inch pages.

☐ 11. The proposal package includes:

A. The original Proposal Cover and a Project Summary (Forms 9.A and 9.B).

B. **Eight** copies of the complete proposal with Proposal Cover and Project Summary as Pages 1 and 2.

☐ 12. The offeror understands that proposals must be received in NASA Headquarters by 4:30 PM EDT on June 15, 1994.

DO NOT INCLUDE THIS PAGE WITH YOUR PROPOSAL

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Technical Topics and Subtopics

01.00 Aeronautical Propulsion and Power

01.01 Internal Fluid Mechanics for Aeropropulsion Systems
Center: LeRC

Innovative concepts are sought for analysis, design, and measurement technology for significantly reducing design cycle time with improved design quality in aeropropulsion systems for low subsonic through hypersonic speeds. Areas of interest include:

Inlets and nozzles: Advanced steady-state and time-dependent flow analyses and benchmark quality data for flow fields including shocks, boundary layers, boundary-layer control, separation, heat transfer, surface cooling, and jet mixing.

Turbomachinery: Advanced flow codes, physical models, and supporting validation data for both steady and unsteady flows including shocks, viscous effects, heat transfer, and tip-clearance effects in fans, compressors, and turbines. Novel concepts for instrumentation and flow visualization.

Combustors and augmentors: Highly efficient flow codes and novel measurement techniques for the flows and physical processes in a combustor, including fuel injection, spray evaporation and mixing; reaction mechanism, and kinetic rates for hydrocarbon oxidation and soot formation; formation of solid and gaseous exhaust emissions.

Computational methods for internal flows: Algorithms utilizing high-order upwind techniques; unstructured and solution-adaptive grid schemes; new methods for surface modeling and grid generation. Software strategies to simplify the parallel implementation of the above methodologies.

Numerical propulsion system simulation: New approaches for coupling multidisciplinary phenomena on different scales. Techniques that efficiently utilize massively parallel computer systems to simulate engine performance rapidly at minimum cost.

01.02 Aeropropulsion Systems and Components
Center: LeRC

This subtopic invites proposals for innovative concepts for new or improved airbreathing propulsion systems or propulsion system components for a wide range of advanced aerospace vehicles. Propulsion system components would include, but not be limited to, inlets, propellers, fans, compressors, combustors, turbines, nozzles, and recuperators and/or regenerators. Improvements may be investigated using multi-disciplinary analysis methods, experimental methods, and/or advanced computational fluid dynamic methods. Objectives include: greater component and cycle efficiency; lower gaseous and particulate emissions; reduced coolant penalties through advanced cooling concepts; reduced noise levels; and reduced weight, volume, and aerodynamic drag. Emphasis is on cycles and component aerodynamics, heat transfer, and acoustics. Concepts that primarily address materials and structures are more appropriate in other subtopics.

01.03 Aeropropulsion System Instrumentation, Sensors, and Controls
Center: LeRC

Instrumentation and Sensors: Propulsion system components are being exposed to increased thermal and aerodynamic loads. This exposure requires that precise measurements of the severe operating environment and engine conditions be made for research, control, safety, and health monitoring considerations. To satisfy these requirements, innovative techniques and instrumentation are sought for accurate, minimally intrusive measurements of pressure, temperature, strain, flow, heat flux, and other parameters. Measurement systems and sensor concepts with significant commercial potential are of interest, especially in the following areas:

- Strain, temperature, and heat flux measurements on both metal and ceramic surfaces up to 1920 K.
- Gas temperature and pressure measurements, both static and dynamic up to 2170 K.
- Silicon carbide high-temperature electronics and integrated sensors.
- Fiber-optic/integrated-optic sensors and control systems.
- Non-intrusive aerodynamic flow and combustion diagnostic systems.

- Image processing techniques for wholefield measurement systems.

Controls: New, powerful, onboard computing capability and new sensor technology will enable achievement of optimum engine performance and life by incorporating artificial intelligence and feedback control. To achieve these objectives, innovations are sought in:

- Advanced dynamics and modelling methods applicable to aerospace systems.
- Integrated propulsion and aerodynamic control concepts.
- Control of distributed systems, including distributed actuation concepts.
- Nonlinear or adaptive real-time controls.
- Redundancy management or fault detection.
- Improved component performance through compressor-stall alleviation, combustor-pattern factor control, or other advanced techniques such as integrated system intelligence and high-speed computation for artificial intelligence applications.

01.04 General Aviation Propulsion Systems

Center: LeRC

Proposals are invited for innovative concepts or integration of technologies in aircraft propulsion that are appropriate for use in general aviation aircraft. Objectives are to improve performance, safety and reliability, simplify operation, reduce maintenance and costs, and improve environmental compatibility (e.g. reduce community noise from aircraft operations). Areas of interest include the following:

- Simplified (single lever) power and/or airspeed controller systems.
- Automated engine performance monitoring systems.
- Innovative, alternative fuel engine concepts (e.g. rotary and diesel concepts).
- Improved propeller performance with reduced propeller noise.
- Reduced interior and exterior engine noise.
- Reduced cooling drag.
- Reduced vibrations.
- Simplified inspection and maintenance.

Anticipated performance and/or cost benefits of introducing or integrating proposed innovative propulsion technologies into general aviation aircraft shall be quantitatively defined in the proposal using appropriate theoretical or experimental data. Proposals must be hardware-oriented for near-term problem solutions and applications; proposals for analyses or system studies are not acceptable.

02.00 Aerodynamics and Acoustics

02.01 Viscous Flow Computation, Modeling, and Control

Center: ARC/LaRC

NASA's interest in computational fluid dynamics encompasses the entire spectrum of aerodynamic and aerothermodynamic phenomena that may be encountered by subsonic-to-hypersonic aircraft and aerospace vehicles. This research would advance the understanding of static and dynamic behavior, transient phenomena, maneuvering, stability and control, aerodynamic performance, real-gas effects, heat transfer, and combustion phenomena. Applications include both external and internal flow fields and multiple body interactions. This subtopic solicits proposals for novel approaches in any of the areas listed.

Flow-physics modeling and control concepts for:

- Modeling and control of transition and/or transitional flows.
- Modeling and control of turbulence and turbulence-related phenomena such as heat transfer, skin friction, acoustics, mixing and combustion.
- Control and/or mitigation of complex flow phenomena such as separation, vortical flows (including drag-due-to-lift) and shock wave drag.

Numerical methods for solving fluid-flow equations that increase computational efficiency, accuracy, speed, and utility. These include construction of new algorithms, improved computer languages, improved boundary condition procedures, efficient grid-algorithm interfacing, applications of automation, and techniques.

Analytical and numerical techniques that enhance understanding of transition and turbulence phenomena and provide improved models for solving the Navier-Stokes equations.

Grid-generation procedures, unstructured grids, solution-adaptive procedures, and grid quality measures.

Scientist's workbenches with integrated, graphical tools for interactive geometry definition, grid-generation, flow visualization, and solution validation.

Scientific visualization including techniques to identify and visualize areas of complex flow physics.

02.02 Hypersonic Vehicle Aerothermodynamics
Center: ARC/LaRC

Innovative applications of computational and experimental aerothermodynamic phenomena are sought that will account for the complex aerothermodynamic phenomena impacting the design and development of future hypersonic aerospace vehicles such as advanced launch systems, aeroassist orbital transfer vehicles, the National Aero-Space Plane, and hypersonic transport aircraft and future planetary probes.

Phenomena of interest include, but are not limited to, equilibrium and finite-rate chemistry; transport properties and multi-component mixing laws; thermal; radiation, gas-surface interactions such as surface catalytic reactions, shockwave/boundary-layer interactions; and laminar, transitional, and turbulent viscous flows.

Technology applications of interest include the extension of computational and experimental methodology to include the above phenomena, grid generation for complex hypersonic and reentry vehicles, diagnostics for high-enthalpy test facilities, new concepts for advanced test facilities, and experiments to validate computational methods, assess nonequilibrium effects about aerospace configurations, and measure physical properties such as phenomenological reaction rates.

02.03 Low-Speed Aerodynamics and Aeroacoustics
Center: ARC

Experimental and computational methods and data analysis procedures are needed to enhance the basic understanding of low-speed aerodynamics, airframe-control-propulsion interaction phenomena, and aeroacoustics. Combined improvements in aircraft performance, stability and control, and noise characteristics for future civil and military aircraft would be a significant benefit. The vortex-dominated flow fields require innovative experimental and analytical techniques to define the interactions between vortices and boundary layers, shear layers, or solid surfaces resulting in aerodynamic forces and noise. Experimental emphasis for this subtopic should be placed on tests in large scale closed-jet and open-jet wind tunnels.

The subtopic solicits proposals for innovative techniques and concepts in the following areas:

- High-light and drag reduction concepts and/or devices to improve low-speed aerodynamic performance.
- Vortex-flow control devices and wing configuration to improve body-wing strake and slender wing performance.
- Integration of airframe, control surfaces, and propulsion systems to enhance the performance of all elements.
- Interactive aerodynamic design, geometry definition, and graphical flow-field and solution visualization.
- Quiet microphones and support struts, acoustic antennas, and signal processing for improved signal-to-noise ratio.
- Control of turbulence-induced sound on models and microphones.
- Simulation and scaling of aeroacoustic noise sources.
- Sound propagation inflow (e.g. propulsion noise) and through shear layers prediction and corrections for flight effects.
- Wind tunnel background noise suppression.
- Simulation and prediction of airframe noise and propulsion/airframe aeroacoustic interactions.
- Integrated design and performance of noise-suppressor mixer ejectors and high-lift wings.

02.04 Unsteady Aerodynamics and Aircraft Dynamics
Center: LaRC

Maneuvering performance improvement in all classes of aircraft emphasizes the flowing dominance of unsteady aerodynamics on aircraft dynamics. Successful design requires an understanding of complex, unsteady aerodynamic phenomena, particularly at conditions involving extensive flow separation. It also requires the development of experimental and analytical methods for reliably predicting these effects and their impact on aircraft flight dynamics, and the development of airframe design approaches for obtaining desired characteristics. Areas for innovation include:

- Aircraft configurational effects on unsteady aerodynamic characteristics.
- Methods for assessing the impact of unsteady effects on aircraft dynamics during early design.
- Flow-control concepts to exploit unsteady phenomena for performance and stability and control benefits.
- Approaches for mathematical modeling of unsteady aerodynamics for accurate simulation of aircraft maneuvering dynamics.
- Analysis of aircraft dynamic phenomena driven by unsteady effects such as wing rock, tumbling, post-stall gyrations, and empennage buffet, and development of methods for predicting such behavior.

02.05 Rotorcraft Aerodynamics and Dynamics
Center: ARC

Many aspects of rotorcraft aerodynamics and dynamics are not thoroughly understood or adequately modeled in proprietary or commercial analysis tools. Areas of

importance include: aerodynamics of rotor-airframe-tail interactions; rotor-blade air-flow loading analyses; improved rotor system performance; analysis of advanced hub designs and their influence on rotor dynamics; rotorcraft vibration and vibration alleviation; aeroelastic stability; rotor noise; and new rotor concepts for high-speed flight.

This subtopic solicits proposals for novel concepts and innovative methods to produce greater understanding of the basic phenomena involved in these areas and greater knowledge of their detailed characteristics. Advances are needed for making verifiable, accurate predictions for current rotorcraft configurations (including tilt-rotors, single main rotor and tandem helicopters, and co-axial helicopters) and for defining next-generation, high-speed rotorcraft--specifically, rotorcraft vehicles with relatively low disk loading and the efficient, low-speed attributes of a helicopter but with a high-speed cruise capability of 300-450 knots.

02.06 Wind Tunnel Instrumentation

Center: ARC/LaRC

Innovative concepts and techniques are needed for the following areas of wind tunnel instrumentation:

- Noninterfering or noninstrusive transition monitors for flow-field visualization in boundary layers in conventional and cryogenic wind tunnels.
- Multidimensional, global measurement of surface and flow-field properties.
- Measurement of combustion efficiency in Scramjet pulse facilities.
- Ultrahigh sensitivity optical sensor and amplifier system capable of resolving laser-induced florescence lines for molecular state characterization.
- Hot wire/hot film calibration techniques for supersonic and hypersonic flows.
- Miniaturized heat flux sensors for high heating rates (up to $5 \times 10^6 J/m^2$-sec).
- Miniaturized pressure sensors for 1-350 kPa range for high-temperature environments (up to 1700 K) and frequencies up to 100 kHz.
- Pressure-sensitive paint/coating systems for applications in conventional and cryogenic wind tunnels.
- A fast model attitude measurement system with an accuracy of 0.005 degrees.
- Skin friction sensors for temperatures in the range of 110 to 810 K.
- Non-intrusive instrumentation systems for determining both mean model attitude and shape as well as amplitude and frequency of modes of model motion. Detection of modal frequencies from 0 to 50 Hz and amplitudes from 0.007 to 2.5cm is required. Test section dimensions of up to 8 meters by 6.5 meters with models spanning up to 6 meters are of interest.

02.07 Aircraft Noise Prediction and Reduction

Center: LaRC

Technology for better controlling noise and associated acoustic loads is needed for developing acceptable aircraft and rotocraft. Advancement of this technology requires understanding fundamental noise, source mechanisms, propogation paths, and response of receivers. Sources of noise and acoustic loads include: jet exhaust plumes, rotors, propellers, boundary layers, turbulent flow, and aerodynamic surface interactions. Propagation paths include inhomogeneous atmosphere and aircraft structures. Receivers can be either people or aircraft structures. In addition to the fundamental understanding of the source, path, and receiver, improved prediction methods and control and reduction concepts are needed. To provide enabling technology for quieter aircraft and rotorcraft, this subtopic solicits innovations in areas noted below.

- Fundamental and applied CFD techniques for aeroacoustic analysis (CAA).
- Reduction concepts and prediction methods for noise radiation and associated acoustic loads of supersonic jet plumes and for high-frequency, fluctuating pressure loads on airframes of supersonic and hypersonic aircraft.
- Prediction of high-frequency dynamic response and sonic fatigue characteristics of advanced lightweight structures to acoustic loads at elevated temperatures.
- Concepts for active or passive interior noise control for aerospace vehicles.
- Reduction concepts and prediction methods for rotorcraft and advanced propeller aerodynamic noise.
- Methods for predicting and assessing the sonic boom impact of supersonic transports.

02.08 Innovative Aerodynamic Concepts

Center: ARC

This subtopic solicits proposals for innovative concepts and techniques for improving aerodynamic performance of aircraft in a broad range of applications from low-speed to supersonic aircraft for aircraft components such as high-lift devices or wingtips or for complete novel configurations. In addition, innovations in methodology to improve aircraft analysis and design are sought. Improved rapid performance prediction methods are needed for incorporation into multidisciplinary design tools. Areas of particular interest, include:

- High-lift systems
- Induced drag reduction

- Supersonic cruise performance
- Prediction of maximum lift for finite wings
- Multidisciplinary design techniques
- Three-dimensional boundary layer separation criteria.

02.09 General Aviation Aircraft Configurations
Center: ARC/LaRC/LeRC

Proposals are invited for innovative concepts for integrating aircraft configuration technologies in ways appropriate to general aviation systems. Objectives include the improvement of performance, safety, utility, and compatibility in the nation's airspace system, together with reduction of manufacturing and operating costs and environmental impact. Anticipated performance and/or cost benefits of proposed concepts and systems shall be quantitatively defined in the proposal. Proposed innovations must emphasize practical, near-term hardware applications; proposals for general studies and systems analyses are not acceptable. Suggested areas of interest and specific technologies for possible integration may include the following:

- Practical drag reduction techniques.
- Natural laminar flow and hybrid laminar flow control.
- Turbulent drag reduction devices (e.g. riblets).
- Improved airfoil and aerodynamic controls designs and methods.
- Sheared wing tips.
- Advanced and unconventional configurations (e.g. free-wing).
- Simplified high-lift systems.
- Stall/spin resistance.
- Improved ride and control quality in gusts and/or turbulence.
- Practical gust load alleviation.
- Active noise control.
- Practical computational methods for aerodynamic or configuration design and analysis (e.g. fluid dynamics, aerodynamics, source noise and noise propagation prediction).

03.00 Aircraft Systems, Subsystems, and Operations

03.01 Aircraft Ice Protection Systems
Center: LaRC/LeRC

Improved aircraft icing protection remains an important aviation safety objective. This subtopics solicits innovative concepts that will lead to highly effective and efficient ice protection systems and techniques for helicopters, general aviation aircraft, commercial transports, and military aircraft. The areas of greatest interest are the sensing, removal, and prevention of in-flight and ground ice on aircraft surfaces; in particular, non-intrusive, flight-worthy sensing systems, in-flight ice protection systems that minimize weight and power consumption, and ground protection techniques that maximize protection time and minimize aerodynamic and environmental impact.

03.02 Environmental Sensing for Aircraft Control, Safety and Hazard Avoidance
Center: LaRC

Innovative improvements are needed in airborne sensors suitable for measuring environmental conditions along the flight path for the purposes of aircraft control, safety, and hazard avoidance. Hazards considered here are heavy rain, winds, wind shear, turbulence, lightning, wake turbulence, hail, and volcanic ash.

Lightning Effects: Determination of the effects of lightning on future advanced composite aircraft employing flight critical digital systems; data for the prediction of lightning-aircraft interactions and direct strike data; techniques for prediction lightning-induced effects on systems in advanced composite aircraft.

Airborne Sensors: Applications in flight attitude control and gust alleviation are intended over a wide range of flight altitudes for both subsonic and supersonic flight. Remote near-field wind measurements ~10m in front of aircraft with high precision (±0.05 m/s) are applicable to planetary boundary layer turbulence research and air data systems. Far field (~1km) are needed for aircraft control, safety and hazard avoidance (precision ±0.5 to ±1.0 m/s). Turbulence and wake/vortex research can benefit from an ability to shift from near-field to far-field distances as well as provide off-axis wind measurements, thus providing the 3-dimensional structure of wake vortices and wind shear along the aircraft's flight path.

Airport Weather Monitoring: Determination of timing for the relaxation of wake vortex separation constraints; determination of the influence of weather on the persis-

tence and decay of wake turbulence; assessment of the hazard presented by weather-reduced strength vortices.

Airborne weather monitoring processing system: Acceptance of data from various sensor units (airborne and ground-based) to provide hazardous weather information to the pilot.

03.03 Control Concepts for Fixed Wing Aircraft
Center: LaRC

Next generation aircraft designs are expected to rely heavily on advanced controls technologies and synergistic impacts with other disciplines to enhance mission performance, reduce pilot workload, and improve safety. Aircraft flight profiles must be carefully tailored and controlled to avoid limits imposed by aerodynamic heating, structural loads, and propulsion system operation. Thus there is a growing need to consider, early in the design process, the dynamic coupling between the various disciplines and to make optimal use of the pilot, the control devices, and the engineering design to achieve desired aircraft performance and stability margins while satisfying mission constraints. These considerations require research investigations into new multidisciplinary approaches to control system design. Also, improved synthesis methods must be developed. Among the key challenges will be a need to provide proper interfaces between airframe, structural and propulsion dynamics, guidance and control systems, pilot, and the exterior situation. In addition, key advances in individual controls disciplines that may contribute to the multidisciplinary design process may be required. Example research areas are:

Guidance and Controls Technologies for Transport Aircraft: Advanced guidance, navigation, and control system methodologies for improving aircraft performance and system capacity.

High Speed Research: Multidisciplinary integration methodologies providing performance benefits from early consideration of controls technology in advanced aircraft design.

High-Performance Aircraft Technology: Design of guidance and control systems maximizing agility and performance.

Guidance and Controls Technology for Hypersonic Aircraft: Provide guidance and controls technologies for design and analysis of highly integrated hypersonic vehicle systems.

Aircraft Modeling and Control Theory: Aircraft modeling and applied control theory methodologies to improve designer productivity and increase the robustness of control system designs.

03.04 Sensing Technologies for Aircraft Low-Altitude Operations
Center: ARC

Nap-of-the Earth (NOE) flight in a conventional helicopter is currently extremely taxing for two pilots under visual flight rule (VFR) conditions. Developing a single-pilot all-weather NOE capability will require significant automation. A major goal is the development of pilot-centered, computer-sensor aiding concepts for enhanced NOE flight-control capability. Many of the sensing technologies for enhancing NOE flight-control capability are also useful in enhancing crew situational awareness for commercial aircraft and emergency helicopters under reduced visibility conditions. A combination of these technologies will be useful during the landing and taxiing of supersonic commercial aircraft. Innovative approaches are sought to advance technologies in the following areas:

- Integration of three-dimensional information from diverse sources such as range estimates from passive and active sensors and stored database of terrain and man-made objects.
- Post-processing of such information for display to pilots or for use by automated flight control systems.
- Enhanced situational awareness during approach, landing, and taxiing.
- Model-based and real-time machine vision.

03.05 Flight Research Sensors and Instrumentation
Center: ARC

Real-time measurement techniques are needed to acquire aerodynamic, structural, and propulsion system performance characteristics in flight and to expand safely the flight envelope of aerospace vehicles. This subtopic solicits proposals for improved airborne sensors and instrument systems in subsonic, supersonic, and hypersonic flight regimes. These sensors and systems are required to have fast response, low power, low volume, minimal intrusion, and high accuracy and reliability. Innovative concepts are solicited in the following areas:

- Temperature, pressure, density, flow angle, and velocity measurements.
- Turbulence measurements up to Mach 0.8.
- Air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach number, and air density).
- Boundary-layer flows using visualization.
- Surface acoustics employing optical technology.

- Off-surface flow fields, including vortical and separated flow, suitable for CFD code validation for regions from the surface to 16m away.
- Strain on advanced structures at 1970 K and above.
- Aerodynamic skin friction on flat and curved surfaces and in the presence of streamwise pressure gradients.
- Structural deflections from Mach 3 to Mach 10 using optical methods.
- Thin-film, pressure-measurement technology to provide static and dynamic measurements for low-speed, transonic, or high-speed applications.

03.06 Aircraft Flight Testing Techniques
Center: ARC

Tools and techniques specifically for aircraft ground and flight testing are being sought. Products resulting from this subtopic are expected to ease the acquisition and assimilation of technical information or increase the rate at which derived knowledge is otherwise transferred.

- On-line monitoring of engine or aerodynamic performance parameters, the vibratory characteristics of flight vehicles, or aerodynamic instability modes affecting boundary-layer transition and separation.

- Applications of smart sensors, sensor arrays, imaging technologies, or multipixel or scanning lasers for automated monitoring of the airframe's structural, aerodynamic, or engine parameters.

- Advanced algorithms to identify impending instabilities in the airframe or propulsion subsystems (e.g. aeroelastic flutter, engine stall, spin/departure).

- Applications involving a distributed computing environment. Examples include automation of data reduction processes, performed either on-board the aircraft or on the ground. These proposals should utilize currently available technologies where possible.

- Signal processing applications involving wavelet transforms.

- Advanced data visualization techniques.

03.07 Hypersonic Vehicle Design and Systems Technology
Center: LaRC

Emerging concepts for air-breathing propulsion systems, combined cycle engines, airframe-engine integration, lightweight structures and tankages, cryogenic insulation and high-temperature insulation and thermal protection systems, and subsystems may produce the necessary dry weight fraction in conjunction with the propulsion and aerodynamic performance needed for hypersonic air-breathing vehicles. Innovative system-oriented research to support, develop, and/or enable the use of advanced hypersonic technologies for vehicle design and optimization is sought.

Design and/or analysis software or algorithms and user interfaces (graphical) to the software to address hypersonic vehicle design needs can include but are not limited to:

- Conceptual and preliminary design.
- Total multi-disciplinary configuration optimization.
- Three-dimensional methods for external and internal vehicle or propulsion flow-path analyses (includes CFD and closed-form methods or a combination thereof).
- Vehicle sizing and scaling.
- Subsystems design database including sizing-integration-networking routines with power balance capabilities.
- Methods for design and analysis of cooled leading edges including heat load predictions.
- Inverse design methods.
- Trajectory design, analysis, and optimization.

Advanced hardware with potential to reduce structural weight fraction and/or increase vehicle performance can include but is not limited to:

- Heat exchangers, reactors, and secondary coolant designs for endothermic fuel systems.
- Propulsion cycles applicable from Mach 0 to 25 and accompanying design and integration techniques.
- Heat-rejection radiators, compact, high-performance convective heat exchangers, and cooling panel designs.
- Lightweight, durable coatings or insulation systems that can significantly reduce the aerothermal heat load to external or internal surfaces.

03.08 Very-High Altitude Aircraft Technology
Center: ARC

NASA currently has no subsonic flight capability above 23 km and is interested in high subsonic speed, atmospheric sampling aircraft capable of at least three hours endurance at altitudes with a 445 kg payload. The physical properties of the atmosphere change quickly with altitude beyond 26 km, and atmospheric flight at such extreme altitudes poses significant challenges in all aerospace technologies.

This subtopic solicits innovative proposals that advance aerospace technologies toward the development of subsonic aircraft for sustained flight above 32 km altitude. The results sought are marketable solutions to specific problems or marketable design tools. Proposals for studies involving the development of specific design configurations are not of interest unless they are to determine the feasibility of innovative concepts that have not been previously reported in the open literature.

Specific areas of interest for this subtopic include: aerodynamics; propulsion; structures and materials; guidance, control, and navigation; aeroelastic and aeroservoelastic flight dynamics; and other technologies related to flight at extreme altitudes.

03.09 Aeronautical Human Factors and Flight Management

Center: ARC

Rapid developments in aerospace and computer technology have made it feasible to automate many crew functions thereby intensifying, not eliminating, the need for careful attention to human performance. Humans do not cease to make errors when interacting with automated systems; they simply tend to make different errors. An important objective in aeronautics human-factors research is to address the interaction of humans with engineered systems. As the crew's role evolves from that of system operator to that of system manager, innovative technological devices, techniques, tools, and models are needed in the following areas that pertain to the automation environment, crew information processing and decision making, and associated cognitive workload:

Operational concepts and crew-system interfaces involving cockpit displays of flight management information to ensure the efficient and safe use of ATC system technology.

Electronic control and display for consolidating and integrating the man-machine interface, including electronic display media, pictorial multimode display generation, and multifunction controls.

Status monitoring systems that inform, advise, or aid the flight crew; other advanced input and output devices and methods for voice synthesis and recognition, pointing, and touch.

Flight path planning, replanning, and communication aids to facilitate safe and efficient flight operations.

- Vision enhancement and integration
- Fatigue and circadian change effects
- Design methods for human-centered automation

Human response measurement for assessment of crew workload and situation awareness.

03.10 Testing and Verification of Flight-Critical Systems

Center: ARC

Accurate and reliable methods for reducing the time required to validate critical systems are needed for design and modification of modern aircraft systems, particularly to enhance a systems engineers ability to understand system interactions, and determine the effect that a component has on the overall system and perform system validation.

This subtopic solicits proposals for innovative projects that will provide the following:

- The capability to observe normal or baseline system behavior and identify instances when system behavior changes because of a system failure or a modification to the system.

- The capability to perform systems sensitivity analysis when using variable performance system/subsystem components. Products that can simulate nominal and off-nominal system performance could be integrated such that decisions on the systems ability to complete the desired functions would be influenced.

- A higher degree of automation in the areas of test definition and analysis of test results. The focus in this area would be on products with the ability to use the same documentation which is used to build the system as opposed to describing the system with a separate test language.

03.11 Multidisciplinary Simulation of Aerospace Vehicles

Center: ARC

Safer and more efficient design of advance aerospace vehicles such as the High Speed Civil Transport 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, 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 understand of the complex interactions between the aforementioned subsystems.

This subtopic solicits proposals for novel, multidisciplinary, linear or nonlinear, dynamic systems simulation techniques. Successful projects are expected to yield a marketable computer code that addresses 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 CFD techniques.

- Effective 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 system 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.

03.12 General Aviation Flight Systems and Operations

Center: ARC/LaRC

Proposals are invited for innovative concepts and integration of technologies for flight systems that are appropriate to general aviation. Objectives are to increase or improve situational awareness and aircraft mission performance in all weather flight conditions, increase systems reliability, ease pilot workloads and improve safety during congested airspace operations. Proposals should address the integration of all navigation, weather, traffic, and aircraft performance information for aircraft operations in all meteorological conditions. Proposals may address integration and testing of innovative concepts that are ready for feasibility testing and evaluation in the flight environment in order to facilitate realistic and practical concept evaluations and verification. Offerors must also address the value of their proposed innovations on utility, safety, performance, cost, manufacturability, certifiability, maintainability, and environmental impact, as appropriate, and should also identify National Airspace System (Air Traffic Control) requirements necessary for these advanced technology aircraft to operate safely and effectively. Areas of interest include:

- Intuitive displays and controls (e.g., moving maps, decoupled controls)
- GPS (and/or LORAN)-based traffic conflict systems, guidance, navigation, and control systems
- Three-dimensional terrain database terminal navigation aids
- Digital and/or optical storage and retrieval of aircraft performance and weight and balance data
- Optical computer memory systems (CD ROM)
- Satellite-based communications systems
- Fiber-optic-based communications and control systems
- Computer-based simulation and training systems
- Cognitive analysis of display and I/O interface requirements

04.00 Materials and Structures

04.01 High-Performance Polymers and Composites for Aircraft Applications

Center: LaRC

This subtopic solicits proposals for innovations in high-performance, high-temperature polymers for aircraft applications. Emphasis should be on synthesis and development of high-performance, high-temperature polymers that display exceptional properties as films, coatings, and adhesives and on composites for structural and functional applications. Materials with an attractive combination of processability, performance, and price would find use in a variety of aerospace applications.

Aircraft Structures: High-performance composites are being developed with high structural efficiency and reduced costs for airframe structural applications on subsonic and supersonic aircraft. Innovations are sought in the following specific areas: textile preforms, low-cost fabrication technology, automated process control for composite fabrication, low-cost tooling for various fabrication methods such as RTM and low-cost fabrication of prepreg and towpreg, rapid methods to fabricate consolidated carbon-fiber reinforced thermoplastic ribbon, thermoforming, lightweight core materials for high-temperature sandwich construction, polymer based matrices, and reinforcement fibers from organic and inorganic precursers.

Adhesives, Films, and Coatings: High-performance polymers are needed for long-term (60,000 to 120,000 hours), high-temperature (>420 K) performance. They should also be easily processed and cost-effective. Innovations are sought for novel materials that can perform on aircraft that experience hostile environments. New/improved chemistry or new formulations of state-of-the-art polymers are needed to meet requirements such as high-temperature performance, toughness, easy processability, environmental durability and low cost. High-performance polymers are required to bond metal-to-metal, metal-to-composite, composite-to-composite, and films to various substrates for use under high-speed aircraft environmental conditions.

04.02 General Aviation Aircraft Structures and Materials

Center: ARC/LaRC

Proposals are invited for innovative improvements in the field of low-cost structures and materials that are appropriate for advanced technology general aviation aircraft. The focus shall be on integrated design and manufacturing methods of airframe and propeller structures and materials. Areas for improvement include manufacturing methods, cost reduction, improved safety. Improved maintainability, increased durability, reduced operating costs, and reduced costs for certification. Example areas of interest include:

- Low-cost manufacturing methods and tooling concepts for airframe and propeller structures.
- Innovative textile preform and RTM/RFI fabrication concepts for near-net shape fabrication of low-cost structural elements.
- Innovative crashworthiness design concepts and analytical methods for improved safety; including energy absorbing seats and substructure, inflatable body and head restraints and airbag technology.
- Low-cost process control, quality assurance and nondestructive inspection methods for skin-stiffened and sandwich structures, including NDE methods for detecting understrength bonds in airframe and propeller structures.

Proposals must be for integrated design and manufacturing concepts to achieve specific, near-term, hardware oriented problem solutions by the offeror; general and systems studies are not acceptable.

04.03 Adaptive, Intelligent or Smart Aerospace Materials, Structural Components, and Mechanisms

Center: LaRC

The development of active structural materials and adaptive, smart or intelligent structural components and mechanisms for aerospace applications offers significant benefit for future missions in increased performance and reduced costs, size, weight, and power. High-performance materials, structural concepts, and mechanisms are sought that produce efficient and predictable changes in geometry, force, mechanical, or thermal properties in response to an input. Concepts for the efficient and compact inclusion of system level functions such as sensing, processing, neural networks, etc. are also needed, including fabrication techniques for integrating geometrical, mechanical, and electronics functions into compact structural concepts. Known active materials include, but are not limited to, electrostrictive materials, piezoelectric ceramics and polymers, magnetostrictive materials, shape-memory alloys and polymers, and high-temperature superconductive ceramics. In selecting materials toughness, load and displacement capability, frequency bandwidth, and simplicity of operation, and operational life are important considerations.

Spacecraft applications include, but are not limited to, concepts for instrument pointing, tracking and/or isolation; component caging, unfolding, latching/unlatching; launch load alleviation; geometry shaping or adjustment; and vibration and jitter suppres-

sion. Operating environments include vacuum, large temperature changes, cosmic radiation, low available power, and dynamic disturbances from attitude control systems, solar arrays, coolers, and/or multiple tracking payloads.

Aircraft applications include, but are not limited to, wing twisting for aircraft control, motion control of winglets and wing leading and trailing edges, control of wing surface for flutter suppression, engine vibration reduction, and interior acoustic noise reduction.

04.04 Testing, Evaluation, and Modeling Techniques

Center: LeRC

Spacecraft materials, subsystems, and systems have been and continue to be designed for increased performance in the space environment. Environmental factors that may significantly degrade performance include vacuum, thermal cycling, solar UV, high-energy particles, plasmas including the ionosphere, precipitating auroral electrons and hot plasma in high altitude (e.g. GEO) orbits, micrometeoroids and, in Low Earth Orbit, debris and atomic oxygen. These environmental factors affect spacecraft singly and in combination. Additionally, system features including operating voltages, grounding schemes and effluents influence the local environment and modify environmental effects.

Methods for testing, evaluating and modeling the performance of materials, subsystems, and systems in space environments are needed as are methods for disseminating state of the art information to spacecraft and payload designers and other interested parties. This subtopic solicits proposals for innovative methods of environmental compatibility testing and evaluation, modeling, and information dissemination. These include:

Novel and innovative software solutions that will allow the linking of rapidly proliferating material databases or significantly improve the availability of data and computer codes for the user community.

Smart tools or similar expert systems that assist designers in making optimum use of material properties information as well as available design codes.

Non-destructive evaluation of materials. Techniques that quantify any of the above effects, singly or in combination, are of interest.

Innovative Design Solutions to environmentally induced effects that can be implemented cost effectively on small spacecraft.

04.05 Spacecraft Structures and Materials Application

Center: JPL/MSFC

Spacecraft materials must be stable when exposed to the combined environmental effects of space for extended periods of time, in some instances exceeding 30 years. The combined environment includes vacuum, thermal cycling, solar ultraviolet radiation, high-energy protons and electrons, micrometeoroids, and in low Earth orbit, neutral atomic oxygen and orbital debris. Planetary landing missions will also require materials, structures, and coatings that can withstand planetary entry, landing shocks, and surface conditions. In addition, novel high-strength, dimensionally stable, rapid prototyping materials for complex, three-dimensional structural component processing and/or direct development of final flight components are required.

- Materials with high-strength properties and high surface accuracy compatible with conventional and unconventional rapid prototyping equipment including material modifications, testing, and characterization instrumentation for rapid prototyping

- Atomic oxygen protective coatings for spacecraft materials are required that are stable in the combined space environment, non-flammable, non-toxic and have low off-gassing characteristics.

- Thermal control coatings with selectable thermal radiative and electrical conductive properties that are stable when exposed to the synergistic effect of the natural space environment.

- Active coatings or materials whose properties can be modified by external electrical, thermal, or mechanical inputs.

- Instrumentation for characterization and verification of material properties, including optical and electrical, that are applicable to factory production, to laboratories, or to spacecraft, both on the ground and in flight.

- Materials and instrumentation for micrometeoroid and/or space debris protection, structural impact detection and location, improved hypervelocity simulation, and impact damage diagnostics.

- An inexpensive, lightweight monitoring instrument to routinely measure and telemeter the integrated atomic oxygen exposure at desired positions on various spacecraft.

04.06 Coating, Bonding, and Joining Technologies

Center: GSFC/LeRC/MSFC

Innovative means for controlling welding, casting, forming, and thermal spray deposition processes are needed to achieve lower cost, lighter weight, and more reliable aerospace components and assemblies. Coatings will be vital in developing advanced high temperature superalloy, intermetallic, and ceramic matrix composites with enhanced structural, environmental and use-temperature capability. The life of composites is strongly influenced by the nature and stability of the fiber, the fiber-matrix interaction and the durability of the composite in high-temperature environments. This solicitation is seeking proposals in advanced coatings, specifically in the areas of:

- Physically-based mathematical models of metal cutting, casting, forming, thermal spraying deposition and welding phenomena.
- Methods to improve formability or weldability without degrading other desired material properties. Materials of interest: High-strength steels, nickel alloys, aluminum-lithium alloys, metal-matrix composites, etc.
- Simulations of metal processing, utilizing graphic displays, correlated to actual process parameters and databases.
- Improved sensors and methods for measuring and controlling metal processing.
- Techniques for on-orbit metals joining, coating, and repairs.
- Improved processing characteristics of normally difficult-to-process materials through innovative techniques such as vacuum or inert gas environment processing.
- Fiber Coating Systems - Innovative approaches in the selection, cost-effective processing, and evaluation of fiber coating systems are of interest, particularly for SiC reinforced Si-base ceramics and oxide/oxide composites, high temperature Ti-based alloys, Ti-intermetallics and Ni-and Fe-base superalloys reinforced with SiC and oxide fibers. Proposals addressing such issues as fiber strength degradation due to processing or interface reaction, CTE mismatch, fiber environmental degradation, and evaluation of coating performance are desired.
- Overlay Coatings - Proposals addressing innovative, cost-effective composite overlay coatings that increase material life in oxidizing environments at high temperature are requested. Coatings are needed to prevent the diffusion of oxygen along the fiber-matrix interface. Composite coatings for superalloy matrices reinforced with continuous Al_2O_3 single-crystal monofilaments and polycrystalline tows, as well as advanced fibers, are of particular interest.

Improved and new materials are desired for many spacecraft applications, including those listed below. All materials must be low outgassing and in all ways compatible with spacecraft applications.

- Thread-locking compound with a range of shear strengths.
- Adhesives for bonding metals and composites for use above 520 K.
- Electrically conductive coatings for electro-static-discharge (ESD) control for use in space in the range 76-373 K.
- Electrically conductive sheets for ESD control in clean rooms and for packaging of parts, components, and assemblies.
- Atomic-oxygen-resistant, flexible coatings for materials, such as wires and composites, exposed to space.
- Coatings that are black from the near UV to the far infrared (at least 500 micrometers) for use in the range 76-373 K.
- Optical cements with refractive indices spanning the ranges of optical glasses.

Devices constructed using a mixture of steel, aluminum, ceramic, and graphite components are envisioned that are mechanically strong, vacuum tight, and able to withstand both high-temperature and chemically reactive environments without leaks or fractures. Innovative techniques are sought that would allow any of the following:

- Bonding of graphite and ceramic parts to stainless steel, aluminum, titanium, or other metals or bonding of ceramic parts to graphite where the joint is capable of sustained high-temperature operation without recourse to active brazes.
- Bonding of very dissimilar metals, such as molybdenum-aluminum, and titanium-aluminum, where the joint is capable of sustained high-and/or low-temperature operation, without active metal brazes.

- Construction of low-resistance, graphite-metal joints capable of operation at temperatures in excess of 1270 K.

04.07 Non-Destructive Evaluation of Material Properties

Center: LaRC

Innovations are solicited for characterizing material properties using non-destructive evaluation (NDE) techniques. Traditionally, NDE has been a final check-out procedure for quality assurance. Quantitative NDE should be applied at development phases of new materials as well as process phases of engineering materials. The desired benefits are improved safety, reliability, and economic advancement for various aerospace systems; reduced development time for introducing new materials and structures; reduced costs in developing and maintaining aerospace systems; and the means to make informed decisions for safe and economic life extension of aging systems.

Proposals should involve novel technology and instrumentation to address the state of health of both space and aircraft systems in practical situations, including aging airfleet evaluation, and must focus on development of non-destructive probing energies to determine aerospace material properties related to their performance requirements. NDE opportunities include the development of measurement science instrumentation for characterizing new, high-temperature materials and aluminum-lithium alloys; detecting and measuring surface contamination as it relates to adhesive bonding; effects of atmospheric and space environment on materials; effects of stress, fatigue, and corrosion; microstructural imaging and characterization; electronic materials NDE; and in situ lifetime monitoring of current and future materials and structures.

04.08 High-Temperature Materials, Processing, and Test Methods

Center: LaRC

Innovations are needed in the area of lightweight carbon-carbon (C-C), ceramic-based refractory composite (RC), light alloy metallic materials, aluminum-lithium alloys, and graphite-based composites for high-temperature airframe and engine aerostructure on advanced aerospace vehicles, including services as actively cooled structure in high-heat flux regions. Service temperatures range as high as 1920 K and pressures range from atmospheric to vacuum. Specific areas in which innovations are needed are:

- Efficient thermal transport in C-C and RC materials by increased through-the-thickness thermal conductivity and enhanced thermal contact between the composite and imbedded coolant tubes. Heat fluxes may be as high as several thousand kW/m^2 or even higher.

- Improved long-life oxidation protection for C-C and RC materials with emphasis on crack-free coatings and oxidation protection systems that are unaffected by high ground-level humidity exposures.

- Processes and techniques to produce new light alloy metallic materials having lower density, improved mechanical properties and thermo-mechanical stability, and higher service temperature capability.

- Low-cost processes to fabricate light alloy metals into useful product forms and structural components for typical airframe applications.

- Process control parameters for thermal spray metal deposition: spray parameters, deposited material temperature, thickness, and substrate temperature.

- High-temperature test methodology: test specimen temperature measurement, non-intrusive techniques for measuring strains, strain rates, and deflections of materials under load at high-temperatures.

- Small supersonic arc-tunnel testing: gas flow-rates, composition, pressure, enthalpy, arc power and current, stagnation test specimen temperature, specimen dimension changes.

04.09 Structures for Propulsion and Power

Center: GSFC/LeRC/MSFC

Proposals are sought for innovative and commercially viable concepts for propulsion and power structural systems. Focus is on problems related to structures that operate at extreme temperatures, hostile aero-thermo-chemical environments, and at high stresses. The objective is to provide structural concepts that enable reliable operation, increased efficiencies, reduced design-to-production time, and reduced life-cycle costs.

Machinery Dynamics: Develop analytical methods and innovative mechanical systems for controlling destructive aeroelastic and rotating structure-induced instabilities and vibrations in rotating machinery; develop dynamic design analysis tools; and extend life of mechanical components. Areas of interest:

- Propulsion Aeroelasticity
- Vibration Control
- Dynamics

- Mechanical Components (e.g. Turbomachinery Seals, Magnetic Bearings)
- Space Mechanisms

Computational Methods: Develop analytical tools for simulating the performance of critical structural components and systems; optimize and tailor their performance; model life cycle performance from material selection to system retirement. Areas of interest:

- Composite Structures
- Computational Simulation
- Optimization/Tailoring
- Process Modeling
- Probabilistic Methods

Life Prediction: Develop life prediction models and failure theories for advanced metals, monolithic ceramics as well as polymer-, intermetallic, metal-, and ceramic-matrix composite materials applied to advanced components operating in extreme environments. Areas of interests:

- Fatigue
- Fracture
- Mechanics of Materials

Test and Evaluation: Develop an understanding of failure modes in critical components that use advanced materials; develop cost-effective test methods for advanced structural materials and components; and validate analytical approaches that predict failure modes and life. Areas of interest:

- Non-destructive evaluation
- Benchmark structural testing

04.10 Processable, Reliable, Low-Cost, High Temperature Polymer Matrix Composites

Center: LeRC

Use of lightweight composite materials, in particular polymer matrix composites, can have a significant impact on improving the operating efficiencies of commercial aircraft engines. To maximize the use these materials in commercial aircraft engines, a number of technical challenges must be overcome. Operating conditions require that these materials be stable for 20,000 hours of continuous use at temperatures up to 590 K. Current polymer matrix composites are only capable of 20,000 hours at 500-530 K. Manufacturing costs for composite engine components are prohibitive due, in part, to the use of labor intensive fabrication techniques. Manufacturing processes such as resin transfer molding, filament winding, and automated tow-preg placement can decrease the amount of hand labor involved in fabrication. While many of these techniques have been demonstrated and used with epoxies and low-use temperature polymers, they have not been widely proven for high-temperature polymeric composites. Successful application of these techniques may require modifications to the polymer and/or process.

This subtopic solicits proposals to develop polymeric materials and processing techniques that enable the low-cost manufacturing of composite aircraft engine components for 20,000 hours use temperatures from 530 K to 590 K. Potential commercial applications for this technology in addition to aeropropulsion include automotive, electrical power generation and distribution, and electronics packaging.

04.11 Epoxy-Based Cryogenic Insulation

Center: SSC

Innovations are desired for alternative epoxy-based thermal insulation systems for use on cryogenic systems. The formation of liquid air on the outside of liquid hydrogen vent lines poses a potential safety hazard on engine test stands, launch pads, and ground support equipment. Traditional foam insulations and other commercially available materials do not stand up to the environment and are costly to install, maintain, and repair. Suitability to each application depends strongly on matching the epoxy thermal contraction to the particular metallic substrate. These cryogenic insulations must be suitable for applications at temperatures between 80 K and 295 K, and capable of withstanding 500 thermal cycles without cracking or peeling.

05.00 Teleoperators and Robotics

05.01 Manipulation, End Effectors and Joint Technology

Center: GSFC/JSC/JPL

Proposals are solicited for innovative concepts that will increase robotic dexterity, manipulation, and reachability. This includes improvements to robotic joints, actuators, grippers, tools, and mechanisms. Specific areas of interest include advanced joints, intelligent links, magnetostrictive motors, intelligent tool interfaces, multi-fingered dexterous end-effectors, robotic grasping and handling systems, actuator controllers, servicing tooling, fluid connectors, and compact driver electronics. Planetary surface exploration with robots will require low-mass and low-power surface and sub-surface sampling devices, e.g., scraping, drilling, and impact or vibratory surface penetration.

05.02 Sensing and Perception

Center: GSFC/JPL/JSC/KSC/LaRC

Proposals are requested for innovative concepts related to real-time vision systems, scene recognition capabilities, autonomous world-model construction systems, stereo correlation technologies, world model anomaly detection and recovery, laser scanners, terrain mapping and surface model generation, structured light sensing, collision detection and avoidance systems, proximity sensors, force-torque sensors, contact and touch sensors, and texture perception systems.

05.03 Planning and Reasoning

Center: JPL/JSC/LaRC

Efficient utilization of robotic systems and human resources for space missions will require intelligent robots that need minimum human attention. These systems must provide both the capability to function under a variety of conditions without human intervention and provide a means for efficient interaction with humans when needed. Innovative approaches to these two requirements are desired in a manner that allows extension of the approach to all space missions and other applications that have similar human-resource efficiency requirements. Proposals are solicited for innovative concepts that will increase robotic system autonomy. Adaptive planning, control execution systems, path and trajectory planners, failure detection and recovery, fault recovery, task level control, environment sensing and modeling, supervisory control, and task decomposition planners are of interest.

Other areas of interest include:

- Situation assessment, response planning, and associated sensing and environment modeling.
- Natural language understanding and language planning as a modality for efficient interaction.
- Plan representation that integrates functionally with language understanding and planning to support instructability.
- Improved safety and reliability of plans and plan execution based on innovative architectures, sensing methods, and plan representation techniques, etc.
- Support of simultaneous deliberative planning and safe, real-time action including reaction to ensure safety.

05.04 Navigation and Mobility

Center: JPL

Proposals are solicited for innovative concepts that will enable robotic system mobility over extremely rugged terrains, including advanced walking machines, unique suspensions for wheeled systems, hybrid locomotion, and adaptive mobility systems. In addition, this subtopic includes requirements for increased robotic navigation capabilities, including autonomous navigation systems, navigation aides, sensors and beacons, and mobility planners.

05.05 Telerobotic Servicing

Center: GSFC/JPL/JSC/LaRC

Proposals are solicited for innovative concepts that will increase the capabilities for robotic systems to perform autonomous and semi-autonomous servicing of on-orbit space systems. This includes elements such as ground-based control technology, servicing tools, task validation, autonomous task execution, on-orbit maneuvering systems and planners, local rendezvous and docking, target identification and acquisition, servicing planners, servicing-compatible design definitions, and servicing aides.

06.00 Computer Sciences

06.01 Reliable and Safety-Critical Software

Center: GSFC/JSC/KSC/LaRC

Safety-critical systems are increasingly dependent on digital computer systems. The software engineering of large-scale computer systems needed for complex aerospace applications places heavy demands on both managers and developers. To ensure that safety-critical systems are reliable and safe, new approaches are needed for developing, validating, and verifying digital computer software and hardware in safety-critical or large-scale applications such as:

- Cost-effective management of the software engineering process.
- Cost and risk reduction in flight software development including software architecture, integrated development environments, testing, and simulations.
- Software safety and risk assessment methods.
- Increased productivity resulting from software engineering paradigms such as software reuse and graphical and/or iconic approaches to programming.
- Formal methods for the specification, design, and analysis of digital systems.
- Improved software performance, reliability, and fault tolerance in critical spacecraft and ground system components.
- Error detection and assessment methods, including testing and verification techniques.
- Requirements analysis and design specification;
- Programming language features to improve software reliability.
- Automated support for software development, such as automatic program generators and systems architecture analysis to assess testing and reusability.

06.02 Mission Operations

Center: ARC/GSFC/JPL/JSC/KSC

The trend in mission operations is toward greater autonomy. Correspondingly, expectations are that there will be fewer personnel per mission having a broader range of responsibilities. New technology will be needed to support these individuals in their work. The emerging commercial software object-oriented technology, which may simplify reprogramming and testing, is a promising candidate. This technology may alleviate the training problem by incorporating self-paced training and by providing operations staff access to documentation reflecting actual system capabilities perhaps by building links to specifications and other documents that reflect spacecraft and ground system changes. Areas of highest priority are:

A comprehensive human-machine interface providing access to all mission operation functions, data, and other team members.

Automated data analysis of both telemetry data from complex and aerospace vehicles and platforms, and science data from the whole range of space science missions. Innovations in machine learning are particularly encouraged.

A computer-based electronic notebook using voice inputs for constructing real-time mission control logs, initiating science and engineering sequence generation, and annotating data.

Artificial intelligence, automated data analysis, and other software technology applications that will reduce mission operations costs, enhance operator ability to handle data, and provide improved data visualization and analysis capabilities.

Software for telemetry processing systems that port easily to different hardware and operating systems, adapt quickly to new mission profiles, require a minimum of staff training, function at low cost, and operate reliably in diverse environments.

Tools for online automatic capture, access and update of spacecraft design, mission design, ground procedures, and analyst experience.

Automated online training.

Model-based reasoning or other approaches for monitoring and diagnosis of problems.

Automated planning and scheduling of missions, hardware development, and organizational tasks.

Automated guidance and targeting algorithms.

06.03 Advanced Processing, Processors and Packaging

Center: ARC/GSFC/JPL/LaRC

Innovations are solicited to meet NASA needs for improved space-borne computers and flight data systems, including advanced processing, networking, and packaging. Novel processing architectures are needed for space applications in which speed, weight, and power consumption are critical issues. Optoelectronic devices have advantages in size, weight, and immunity from electrical interference. Multi-chip modules (MCMs) provide ever increasing interconnection densities that have created a need for improving the interconnection technology used at the next level of assembly.

Improvements are needed in multi-chip interconnection design, and thermal and electrical performance. The connector technology must be mechanically compatible with the other materials used in the system and provide a thermal path for heat rejection. The electrical performance characteristics should be able to accommodate both power and signal interconnection requirements. NASA requires innovations for the following:

Processing and network architecture and topology forms that are performance enhancing and fault tolerance enhancing.

Optical and electro-optical devices including spatial light modulator (SLM) devices and components such as fibers/waveguides, couplers, switches, transmitters, receivers, amplifiers, etc. for optical processing and networking architectures.

Adaptive sensor control systems, possibly using neural networks or fuzzy logic.

On-board data systems including radiation-hard space-qualified 32-bit processors providing high quality data encryption and improved architectures and data compression; neural network hardware and software for analyzing instrument data and selection for transmission; and adaptive processors and algorithms.

Interconnection materials that effectively manage the differential thermal expansion of materials used in packaging MCM systems.

MCM technology that will support high input/output (interconnection densities of 38 connections per square cm of module should be a demonstration goal) and maintain reliable connections over a temperature range of 205 to 400 K. MCMs capable of supporting embedded temperature sensors used to measure substrate and device temperatures during operations.

Fiber-optic data bus components and systems that are space-qualifiable and space-radiation-immune (1-100 Mbps).

Data storage components and devices that provide high data density, and are low-power volatile and non-volatile, space-qualifiable, and space-radiation-immune.

Meteorological radar data processing and displays for airborne observations.

07.00 Information Systems

07.01 Data Storage, Archiving and Retrieval
Center: GSFC/JPL

Traditional libraries have been the agents that provide access, management, and distribution of information. Digital libraries are now being developed to manage and access the ever-growing volumes of data. Innovations are required to provide scientists and commercial users of data sets with tools to locate, browse, access, and acquire complex data sets from large, diverse, and distributed archives. These systems should allow access for commercial and scientific research from multiple, even geographically-separated, data sources within a transparent environment. Specific areas include an expert interface to assist the user in accessing these data sets, knowledge-based and object-oriented data management systems, data access and extraction, data structures and organization, data storage technology, and automated data characterization and labeling. Specific areas that have been identified are as follows:

- User interface systems involving expert systems, voice activation, query processing, and data browsing.
- Common data integration approaches for archiving, accessing, retrieving, and disseminating data.
- Data filtering, abstraction, and reformatting.
- Data structure, organization, and standards.
- Mass storage systems and hierarchical storage management.
- Holographic, neural, and optical data technologies.

07.02 Electronic Review and Evaluation Tools
Center: GSFC/JPL

Wide-band, high-density, electronic communications makes possible highly interactive data management. One product of this emerging technology will be networked, computer-based systems using distributed work groups. This would include joint reviews of software, data, bibiliographies and technology. Automating these processes offers the possibility, for example, of reducing the cost of peer reviews and of obtaining the results rapidly.

This subtopic solicits proposals for developing networked, computer-based tools that would facilitate review and evaluation processes by distributed workgroups for the above mentioned activities. NASA applications include, but are not limited to:

Data reviews involving National Space Science Data Center, Mission To Planet Earth, and Hubble Space Telescope Observations.

Software reviews involving COSMIC, Mission to Planet Earth, and High Performance Computing and Communications.

Bibliographic reviews such as NASA Tech Briefs, ACM Transactions on Mathematical Software, IEEE Transaction on Software Engineering, etc.

Technology application reviews such as Small Business Innovation Research and NASA Research Announcements.

Proposals should describe the proposed innovations and should also include real world NASA-related applications on which the tools will be demonstrated in Phase II.

07.03 Design Analysis Data Sharing
Center: ARC/GSFC/JPL

To improve, facilitate and expedite design of future spacecraft, an engineering design analysis team must be able to share existing system characterization data across the spectrum of high and low fidelity modeling objectives used to validate design and access performance. Automated and semi-automated capabilities are required to enhance and modify existing data files so that they can satisfy a variety of objectives and the different input data formats specified by the CAE software/hardware systems to be employed. This subtopic solicits proposals for innovative software, graphical and intelligent assistant methods that will enhance the efficiency and productivity of spacecraft control, structure, and thermal design analysis teams. Areas of interest include but are not limited to the following:

- Systems for preserving a practical "corporate" memory of multi-site design of complex devices and for using that knowledge for re-design and diagnosis throughout the device lifecycle. Model-based or qualitative reasoning approaches are of considerable interest.

- Interfaces from detailed three-dimensional CAD drawings of large space structures to computationally practical, finite-element models that require complex three-dimensional CAD objects to be lumped into simple one-dimensional and two-dimensional finite elements.

- Interfaces for thermal conduction and radiation analysis.

- Interfaces to information databased in a format consistent with the International Standards Organization STEP standards for product data representation and exchange.

- Interface from model order reduction, environmental disturbance, and finite-element models to attitude control dynamics modeling software used for on-orbit performance analysis.

- Interface between large, mainframe-based, design analysis models and PC-based tools used for follow-on data analysis, reduction, and presentation. For example, determination of structural stress margins for a full spectrum of flight worthiness transient and static loads.

- Interface between structural vibration testing, analysis-based test control, system identification, and model validation methods.

07.04 Data Management for Environmental Monitoring
Center: JPL/KSC

Innovations are required to provide scientists and commercial users of space-derived data sets and in situ measurements with advanced systems and components that increase their efficiency and effectiveness in managing very large and complex data archives. A specific area of NASA's interest is in assuring the environmental effects of operations at the Kennedy Space Center.

- Distributed data management concepts.

- Remotely sensed environmental data collection, transmission, and analysis (e.g., remote water quality monitoring, automated sampling and analyses, radio tracking).

- Software development is needed for Geographic Information Systems to support data analyses and decision making (e.g., spatial analyses, habitat modeling, decision making with artificial intelligence).

- Technology development is needed to support rapid assessment of water and soil contamination (e.g., surface water modeling, ground water modeling).

07.05 Data Visualization and Virtual Reality
Center: GSFC/JPL/JSC/KSC/MSFC

NASA is interested in integrated families of tools, models, and procedures for interactive manipulating and visualizing complex multidimensional and multi-variate data. Virtual reality has been and can be increasingly

useful in scientific data analysis, engineering design, training, robotic telepresence, human factors engineering, operations development, and complete simulations of environments.

Specific interests include but are not limited to:

- Software for interactive three dimensional animation of multidimensional data sets of different origin, resolution, and structure.
- Tools and techniques to interactively build and manipulate complex scientific models and merge these models with data.
- Graphical user interfaces that support data visualization constructs including data navigation, model building and control, data scaling and transformation.
- Software for visually simulating instrument observations including interactive manipulation of instrument and observational parameters.
- Virtual environments that explore and exploit the touring paradigm for data interrogation.
- Novel concepts and technologies are needed for low-cost, large-format display technologies, including investigation of newly observed phenomena such as silicon light emission.
- Determination of feedback requirements and provisions for light and sound simulation.
- Models of user behavior and body tracking devices.
- Utilization of engineering design files in high-fidelity graphical environments.
- Task training, operations development, and viewing analysis for Orbiter and spacecraft missions.

08.00 Instrumentation and Sensors

08.01 Advanced Detectors, Arrays and Readouts

Center: ARC/GSFC/JPL

Innovations are needed in the following areas:

Detectors with sensitivity in a sub-range of 1 keV to 20 MeV operated at or near room temperature. These detectors should have sensitive areas as large as 100 cm^2 and energy resolution ranging from less than 1 keV FWHM at the lowest energies to 5 MeV at the highest energies. The detector efficiency (or fractional absorption) in all cases shall be greater than 50 percent at all energies within the observed energy range. The detectors must be capable of recording up to 100,000 counts per second with minimal spectral distortion, and the background counting rate from detector noise should be less than 10 counts per second in the observed energy range.

High energy detectors, for example, scintillation detectors that have solid-state optical detectors in place of photo-multipliers with comparable or superior energy resolution and sensitivity to the best NaI(Tl)/PMT detectors. Other needs are high purity bulk materials and novel structures for high energy photon detectors; three-dimensional (energy, x, y) detector arrays for ultraviolet and visible; and micro-channel-plate, electron-intensified arrays with no ion feedback, high quantum efficiency, high resolution, low radioactivity, controlled conductivity, and high speed.

High quantum efficiency, near-infrared and ultraviolet photo cathodes.

Charge-coupled devices (CCDs) and active pixel image sensors (APS) from the near infrared to the x-ray including improved short wavelength response, rapid readout, and low noise.

Solar-blind detection of ultraviolet photons with high dynamic range.

Infrared detector arrays operating with high sensitivity and high operating temperature (>200 K) in the 1-3 μm range.

Room temperature thermal detector arrays operating at wavelengths beyond 10 μm and detector arrays for imaging of the sun over very broad wavelength bands.

Discrete infrared detectors (including photon counters) and infrared arrays operating at cryogenic temperatures (<12 K), with low noise, low dark current, high radiometric accuracy, and minimal radiation effects. This includes bolometric arrays operating at

He-3 (sub-Kelvin) temperatures for applications above 50 μm.

Line- and area-array focal planes operating in the 14-20 μm range, with temperatures between 35 and 80 K, incorporating low-noise readout circuitry within the detector array.

Performance models are needed for the simulation of atmospheric temperature and water vapor profilers in the infrared. This should include the ability to compare spectrometer, interferometer, and band-pass filter approaches.

Spectral discrimination, either by detector fabrication or on-chip optical elements, in an infrared focal plane array.

Micron-sized and larger cosmic dust particles detection, location, and analysis (e.g., morphology, molecular, and/or elemental composition), in underdense collection media.

Fast, ultraviolet, slitless spectrometers (FUSSs) covering a wide spatial field are needed to monitor the meteoric flux of metals entering the upper atmosphere.

08.02 Millimeter and Submillimeter Sensing Systems
Center: GSFC/JPL

Millimeter and submillimeter antennas and radiometers operating in the 0.1 to 5.0 mm wavelength range (60 to 3,000 GHz) for space astronomy, astrophysics, atmospheric remote sensing, and satellite altimeters require innovations in the following areas:

Antenna systems with aperture diameters up to 4 meters and root-mean-square (RMS) surface accuracies of less than 1/50th of a wavelength; multiple beams with scan angels of many beam widths.

Room temperature and low-noise radiometers having low power, volume and mass (with T_{REC}<20 hv/k), up to 3,000 GHz, with about five-year lifetimes.

Microantennas that efficiently couple to the submillimeter heterodyne receiver mixer diodes.

Solid-state, phase-locked, submillimeter local oscillators up to 3,000 GHz with output power greater than 100 micro-watts. These local oscillators should have direct current power requirements less than 20 watts, be small and lightweight, and have about five-year lifetimes.

Monolithic microwave integrated circuit (MMIC) technology for low power, low weight remote sensing applications of microwave, millimeter wave, and submillimeter waves.

Stable, non-mechanical, cryogenic (2-4 K) beam chopper or interrupter for use at far-infrared wavelengths (30 to 3,000 GHz).

Multi-channel spectrometers that analyze intermediate frequency signal bandwidths up to 10 GHz with a frequency resolution of ≤1 MHz, are small and lightweight, and use low direct current power (<10 mW per channel). High stability and lifetimes greater than five years are needed.

Spaceborne altimeter systems capable of (~ 2 cm) altimetry over oceans, with significant reductions in power and weight requirements. These should be capable of self-calibrating for ionospheric errors and function at orbital altitudes from 700 to 1500 km.

08.03 Lidar Remote Sensing Technology
Center: GSFC/JPL/LaRC

Active laser sensing applications include: differential absorption lidar measurements of atmospheric gases, aerosols, and clouds; doppler lidar measurements of winds and clear-air turbulence; and laser altimetry measurements of clouds, ice sheets, and land surfaces. High-resolution, high-accuracy measurements of atmospheric aerosols, temperature, pressure, and winds from ground-based, aircraft, and spacecraft platforms require advances in the state-of-the-art in high spectral resolution lasers, narrow band optical filters, holographic optics, and low noise detectors. Emphasis is on compactness, low mass and power, high reliability, and high efficiency. In addition, high-resolution topographic measurement and mapping of Earth, lunar, and planetary surfaces from spacecraft requires major improvements in the laser altimeter sensors including relatively large and ultra-lightweight optical systems, high-speed pulse timing and wave form measurement electronics and high-precision pointing angle sensors.

Specific technology challenges of space-based and airborne lidar remote systems include:

- Laser technology for pumping lasers with laser diode arrays and flashlamps; and for seeding lasers for narrow linewidth, high spectral purity, and high energy per pulse (at 10 Hz and above operation) for measurements of gases such as ozone, water vapor, carbon monoxide, methane, and nitrous oxide.

- Tunable, single-mode lasers, including frequency conversion techniques, with requisite spectral and energy characteristics with emphases on 0.28-0.31, 0.7-1.1, 1.5-2.1, and 3.2-4.7 μm range.

- Lidar receiver technology for large collection apertures; high peak transmission; narrow bandwidth filtering; and high-speed, high-quantum efficiency, and low-noise detectors.

- Lidar components for enabling or improving capability for remote measurements of aerosol characteristics and separating aerosol and molecular spectral components of atmospheric back scatter.

- High detectivity, spectrally diverse lidar receivers are needed that include multi-channel array detection with high spectral resolution capable of resolving visible and near infrared atmospheric spectra.

- Lower mass, compact, electro-optics components and optics for coherent lidar systems in the wavelength range from 1.4 to 12 microns. Specific areas of interest are in novel approaches to beam scanning and beam expansion.

- Micro-joule pulse energy, high repetition rate, narrow line width tunable (e.g., optical parametric oscillator) laser sources are needed in the 920 nm wavelength region for eye-safe lidar measurements of water vapor.

- Geiger-mode, avalanche photo diode detectors with quantum efficiency below 10 percent in the 1.06 μm wavelength region, and high quantum efficiency, low noise detectors for the 1.5 to 2.2 μm wavelength region.

- Eye-safe measurement of the wind field and wind shear in the lower atmosphere using the edge technique, with accuracy better than 1 m/s and range resolution better than 50 m.

- Holographic optical elements for scanning telescopes, having high diffraction efficiency. Airborne applications require 10 to 40 cm diameter apertures, ground-based and space-borne applications require 40 to 150 cm diameter apertures, with diffraction angles of 15 to 45 degrees. Single and multiplexed wavelengths of special interest include 308, 355, 523, 532, 760-770, 1046, and 1064 nm.

- Lidar system models for laser wind sensing (coherent and non-coherent techniques), differential absorption lidar, and altimetry and ranging to include energetics, timing, atmospherics, and detection.

- Room temperature tunable diode lasers for trace-gas detection and wavelength calibration. Application of these lasers require single-mode operation at wavelengths below 0.7 and above 2.5 μm.

- Diode-pumped, solid-state laser innovations including passive Q-switching, self Q-switching, conductivity-cooled AlGaAs diode laser bar packaging, laser optical bench design, and fiber-coupling of diode laser bars.

- A linear array of ~10 pulsed laser transmitter elements with each element independently addressable. Each element should produce a sub-5 nsec pulse of near-infrared radiation with energies ≥ 100 micro-joule within a single spatial mode.

- Integrated pulse timing and pulse waveform digitization electronics capable of nanosecond time-interval resolution and digitization ≥ 250 mega-samples-per-second.

- Lightweight (≤ 15 Kg) optical benches of 1 m^2 area that have angular stability at the 10 arc level in the presence of thermal gradients.

- Lasers and high-speed detectors for measurement of architectural properties of plant canopies.

08.04 Active and Passive Microwave Systems

Center: GSFC/JPL

Active and passive microwave sensing technology will be used for observations of clouds and cloud properties, rainfall observations, soil moisture measurements, biomass assessments, sea surface wind measurements, sea height, ice and snow cover, snowfall rate measurements, and land surface topographic mapping. The technologies needed include radar frequencies from 50 MHz to 200 GHz, large filled and unfilled aperture techniques for passive observations from 1.2 to 300 GHz, and supporting structural and processing technologies. Specific needs that have been identified include:

- Models for developing ideas for passive multiple frequency microwave radiometers. Subjects to be addressed include: antenna, electronics, detection schemes, noise models, and calibration.

- Ground-based variable frequency, airborne low frequency, and satellite-borne low frequency (50-500 MHz quad polarization capable) radar sensor systems for measuring terrestrial vegetative biomass and fresh water hydrology.

- Passive microwave systems, specifically large-aperture antenna systems, low-noise high frequency amplifiers, and multiple feed horn design for atmospheric sounding, sea surface, and precipitation measurements.

08.05 Micro-Instruments
Center: ARC/JPL/JSC/SSC

Innovative research and development of micro sensors and instrument systems are needed to support future exploration of space for both in situ and remote sensing. Micro sensors and instruments offering more than an order of magnitude reduction in overall system dimension and power requirements will be considered. Micro sensors and systems based on novel measurement principles to enhance the science returns are desired. Proposals are also sought in support of technology areas that lie on the critical path for deployment of these micro instruments. Areas of current interest include:

- In situ measurement and mapping of planetary seismology and meteorology.
- Remote and in situ mapping of rocks, minerals, and geological structure and determination of abundance of water, ice, gases, and other useful material.
- Miniature gas chromatograph subsystems including innovative detectors, columns, sampling devices, and sample treatment devices (e.g., pyrolyzers, DTA, DSC) for detection of volatiles and organic compounds at parts-per-billion levels.
- In situ measurement and analysis of atmospheric constituents and planetary soil chemistry, with a goal of sensitivity to parts-per-million levels.
- Miniature infrared diode laser spectrometers and subsystems that operate at temperatures greater than 200 K for molecular spectrometry of gasses at 2 to 5 microns to measure elemental isotopes (e.g., C, O, and N isotopes in CO_2 and NO_x) with precision of 0.1 percent or better.
- Miniature elemental and geochemical analysis devices (e.g., x-ray diffractometer and x-ray fluorescence) with extended range and greater sensitivity for the biogenic elements (C, H, N, O, P, and S).
- Miniature imaging detector arrays for very low energy (0-100 eV) ions and electrons.
- Measurement of magnetic and electric fields; plasma waves; and the nature, density, and energy spectrum of low- and high-energy particles.
- Miniature high voltage power supplies for particle detectors.
- Miniaturized data loggers with very high resolution data conversion and ultra-low power.
- Self-regulating heat switch for autonomous temperature regulation of instrument packages.
- Some in situ analysis systems require low cost, miniature, low-power (< 50 cc, < 1 Kg, < 1 W) vacuum pumps. These should: evacuate a volume ~1 cc from one atmosphere to one milli-torr in a few minutes; maintain a pumping speed of micro-liters per second; and be sufficiently robust for field applications.
- Miniature thermal control modules including Dewars and electronics for housing temperature-sensitive instruments. Temperature control and stability must be better than 1 milli-Kelvins with external variations of up to 100 K. Size, mass, and power requirements are similar to those for the miniature pump.
- Advanced detector, source, pointing and/or tracking, and miniaturization technology as well as improved sensor survival for long periods in harsh environments.
- A compact airborne water vapor instrumentation for harsh and polluted operating conditions (e.g. commercial or research aircraft applications). It must provide repeatable measurements of water vapor concentrations encountered throughout the troposphere and lower stratosphere (0-13.5km) and have a frost/dew point measurement range of 180 K to 315 K with an absolute accuracy better than 5 K.

08.06 Optics Components and Systems
Center: ARC/GSFC/JPL/LARC/MSFC

Innovations in telescopes, interferometers, and optical instrument component technologies and modeling capabilities are needed for ultraviolet, visible, infrared, and submillimeter astrophysics, planetary science, and extra-solar planet detection missions. Active and adaptive optical components will be needed for space applications involving direct and interferometric imaging and for non-imaging systems requiring optimum sensitivity and spatial resolution. Needs include development of components, subsystems, and complete

systems. Work can be directed towards complete corrections, partial corrections, or combinations producing successive levels of correction. Areas of current interest in telescope and instrument technology are as follows:

- High quality, low cost fabrication techniques for thermally stable, large aperture (up to 1 meter diameter), high resolution optical systems and technologies for multi-spectral sensing (ultraviolet through long wavelength infrared).

- Innovative optics for focusing x-rays. The long term goals are to develop fast and inexpensive methods of fabrication for lightweight, high angular resolution x-ray optics for 0.1 to 10 keV spectral imaging and to extend the imaging ability to approximately 100 keV. Developments are needed in surface roughness characterization for x-ray and extreme ultraviolet optics.

- Fabrication and testing techniques for optical materials and components for use in cryogenic environments.

- Technologies for producing low-scatter optics and finishing processes, including contamination characterization and control and stray light characterization and suppression techniques.

- Damage resistant, broad band coatings for optics, band-pass filters, and beam splitters in the thermal infrared.

- Mirror coatings technology developments for the ultraviolet, including multi-layer (for the wavelength range of 100 to 2000 Angstroms) and large-area coating techniques.

- Broad band polarization control elements.

- Novel techniques and ideas for filter design and manufacture, including liquid crystal and acousto-optic tunable filters as well as long-wavelength (>20 μm) infrared filter development and high performance extreme ultraviolet filters.

- Innovative approaches for the development and application of diffractive optics elements to compact, lightweight instrumentation.

- Fabrication of x-ray, gamma-ray, and neutron collimators that have the precision necessary to achieve arcsecond or sub-arcsecond imaging in solar physics and astrophysics when used in stationary multi-grid arrays or as rotating modulation collimators.

- Improvements in diffraction grating technology for ultraviolet instruments.

- Active and adaptive optical components for a variety of applications. The techniques involved include momentum compensated, fast steering mirrors, high speed tip/tilt mirror systems, deformable mirrors, segmented mirrors and membrane mirrors, and optical delay lines. These types of systems can be potentially driven to closed loop frequencies in excess of 1000 Hz to perform atmospheric turbulence correction, optical path alignment and aberration removal. Metrology and control techniques must also be developed along with mass production techniques. Space durable control systems and high speed control processors are needed to control these optical components.

- Wave-front sensors and infrared fine guidance sensors; pupil plane and focal plane wave-front reconstruction algorithms; and innovative approaches and hardware for determining absolute fringe order to ± 0.001. Novel techniques for in situ evaluation of image characteristics.

- Active structural member, precision positioner, and actuator technologies, including piezoelectric, magnetostrictive and electrostrictive devices.

- Multi-wavelength and heterodyne interferometry for absolute length measurements.

- Optical fiducial elements that are stable in optical depth at the sub-nm level against environmental changes and aging. Miniature displacement sensors and edge sensors are also needed.

- Integrated modeling and analysis programs that describe the performance of complex, near diffraction-limited astronomical camera systems. These should be capable of modeling a large area focal plane and simulating the spectrum of on-orbit disturbances while predicting imaging performance. Analysis of the camera with and without active components as a function of structural stiffness is desired.

- Infrared acousto-optic tunable filters (AOTFs) that can provide two-dimensional spectral images with the intrinsic capability of imaging in orthogonal polarizations.

- Cryogenic operation at thermal IR wavelengths beyond 5 μm with high-resolution tuning over one octave is desired.

- A low-focal-ratio, "fast", reflecting-field, optical space flight instrument system capable of focusing onto small pixels of large format infrared arrays in the 1 μm to 30 μm spectral range.

08.07 Sensor Electronics
Center: ARC/GSFC/HQ/JPL

Improvements in sensor electronics will reduce sensor readout noise and simplify instrument interfaces by allowing greater processing on the sensor chip. They will extend the life of cryogenically cooled instruments by reducing the heat loads associated with the readout electronics and enable miniaturization of instruments through "camera on a chip" type concepts. Specific improvements that are needed are as follows:

- High density packaging of sensors and associated electronics to enable instrument miniaturization.
- On-chip optical structures and signal processing circuits.
- Low power, high resolution analog-to-digital converters (ADCs) for use on or near the focal plane.
- Cryogenic multiplexers, amplifiers and associated electronic parts to reduce the heat load in support of cryogenic instruments. Deep cryogenic (2-4 degrees K), low noise, low power readout devices and circuits such as GaAs and Ge junction-field-effect transistors (JFETs) and silicon MOSFETs with low noise at low audio frequencies (10 Hz) and low power dissipation. Superconducting quantum interference devices (SQUIDs) designed for low noise readout of cryogenic detectors.
- Techniques for reducing heat loss (over conventional metal wire connections) while allowing the transmission of data from a cryogenic focal plane to warm signal processing electronics, by such means as optical data transmission or high-temperature superconducting ceramic materials.
- Novel lead-free solders that provide melting temperatures in the range 493-503 K, wetability, high migration resistance, and compliance to stress.
- Materials and strategies to allow electronic components to operate at higher temperature. The target is to achieve performance characteristics for materials operating above 870 K that are comparable to Si or GaAs operating at room temperature.

08.08 Multi- and Hyper-Spectral Remote Sensing
Center: GSFC/JPL/SSC

Novel system approaches and instrument designs are needed to improve performance and miniaturize imaging cameras and imaging spectrometers. Reduced mass, volume, and power, increased system reliability, or new capabilities are critical parameters. Associated technology advancements in spectral selection, calibration, polarization selection, and in-instrument data processing are also sought. Examples include:

- Telescope compatible, simultaneous visible near- and mid-infrared event camera operating in "movie" mode with high speed (approximately 100 frames/second) readout and storage.
- Solid-state false-color hand held video camera for ground based or airborne remote terrestrial sensing.
- Highly miniaturized, rugged scientific charge-coupled device (CCD) camera system.
- Lightweight, rapid scanning, near-infrared imaging spectropolarimeter, operating over the 1.1 to 2.6 micron range, with a spatial resolution of better than 0.2 arc-seconds over at least a 50-arc-second field of view.
- Radiometric math model for imaging spectroradiometers to be used in spectral regions ranging from the ultraviolet through the infrared. Possible modules include sources, atmosphere, optics, platform, detectors.
- Passive fluorescence instrumentation suitable for water and soil pollution assessment, geologic exploration, and vegetation photosynthetic capacity assessment.
- Instrument self-diagnosis techniques that provide a continuous measure of data quality and instrument health. These should support real-time adjustments in sensor operation to compensate for instrument degradation or changes in sensed properties.

08.09 Instrument Support Systems (Coolers, Radiators, Calibration)
Center: ARC/GSFC/JPL

Future robotic facilities will have operational lifetimes of 5 to 15 years, requiring similar total lifetimes for cryogenic cooling systems. Both the lifetime and the reliability of the cryogenic coolers are critical performance concerns. Mechanical coolers, stored cryogens and combinations of these are of interest.

Long-life, low-vibration, high-efficiency cryogenic coolers for cooling telescopes and infrared instruments to temperatures in the 0.1 to 120 K range.

Cooler components such as flexure, magnetic and gas bearings; regenerator technology; vibration control such as low or vibration free vibration coolers, vibration compensation and vibration isolation systems; high reliability thermal switches; and cooler/sensor interface systems.

- Magnetic and solid-state cooler technology.
- Passive radiative coolers for 25-60 K operation in deep space.
- Black-body references for thermal infrared imaging systems. These should be able to track radiating surface temperature changes in the presence of temperature variations, such as that caused by rapid air stream on airborne instruments.
- Low-temperature (60-250 K) heat pipes and capillary pumped loops, including diode and/or flexible capabilities.
- Low thermal conductance structural support systems and support systems with on-orbit release.

09.00 Spacecraft and Sensor Platforms

09.01 Thermal Control for Space Applications

Center: GSFC/JPL

Future robotic spacecraft, space facilities, and planetary landers will require increasingly sophisticated thermal control technology. Heat load centers will be more numerous and at widely dispersed locations, transport distances will be longer, and very tight temperature control will be required. Areas of innovation include the following:

Fluid Systems Technology

- Low-temperature (60-250 K) heat pipes and capillary pumped loops, including diode and/or flexible capabilities.
- Sensor interfaces.
- Modular, self-contained heat pumps (500-1000 W range) to allow equipment to operate at a temperature different from a central thermal bus or in a hot, thermal-sink environment.
- Long-life, no-maintenance thermal components.
- Self-diagnostic repair and correction subsystems.

Special Thermal System Capabilities

- Utilization of low-to-medium-temperature waste heat for auxiliary cooling.
- Integration of thermal and power systems to minimize total weight.
- Innovative and or improved thermal control devices such as thermal switches, louvers, and variable temperature isothermal targets.
- Variable absorptive and emissive thermal control coatings or devices.
- Sprayable, white, electrically conductive, thermal control coatings with low outgassing characteristics.

Spacecraft Multi-Function Structures Technology

New concepts are sought for advanced spacecraft structures in which two or more of the usual functions are integrated. Conceptually these multi-function structures would be a single assembly capable of handling structural loads, thermal control, power management and distribution, data signal transfer (i.e. instead of conventional cabling), sensing of both thermal conditions and external stimulus, and any communications or pointing control functions that can be merged with these other functions.

Advancements in combining structure and thermal functions have been made possible by the recent development of very high thermal conductivity fibers (i.e. K1100) for composite materials. Innovations are sought

for high levels of functional integration that can achieve greater reduction in size and mass over conventional approaches.

09.02 Thermal Control for Crewed Spacecraft
Center: JSC/MSFC

Future thermal control systems to support human space missions will operate at higher loads and in more severe thermal environments than in the past. Therefore, there is a need for advanced hardware and software to provide for lightweight, high-efficiency, and reliable control systems. This subtopic is concerned with the internal and external thermal control functions required to support habitat pressure vessels, human support with food storage for extended durations, human tended laboratory experiments for life sciences experiments (cryogenic storage and freezing), as well as metallurgical and materials processing experiments (high temperature electrical furnaces). Innovative solutions are sought in the following areas:

Advanced heat transport systems, including lightweight, high-effiency heat pumps for moderate-temperature (240 K - 295 K), single-phase and two-phase pumped loops.

Advanced interactive, user-friendly, graphical and computational techniques utilizing state-of-the-art, low-cost workstations for analysis, control, and measurement of thermal and fluid systems, and automated software for locating component failures and performing isolation and recovery operations.

Advanced instrumentation that will allow characterization of single- and two-phase flows, will enhance control, and will monitor the system; provide for detection and isolation of leaks in a vacuum; provide remote and compact temperature sensing and data acquisition; and provide a control device for stable, passive backpressure control of a two-phase flow over a wide quality range.

Low-solar absorptivity and high-infrared emissivity radiator coatings (alpha <1, epsilon >0.8) with a ten-year or greater lifetime in low Earth orbit or other harsh thermal environments.

Lightweight radiator concepts or novel heat rejection devices that have a long life and high reliability to reduce overall thermal control system mass, that can be operated at high temperatures to take advantage of advanced heat pump technologies, and that can operate in the appropriate environment.

Thermal transport fluids development, including environmentally friendly, non-toxic refrigerants and liquid metals developed for use on human missions, and low-temperature refrigerants that freeze at temperatures below 75 K or that do not have a significant volume change upon freezing and thawing.

Thermal storage systems for moderate temperature applications in microgravity or partial gravity.

Lightweight, high-heat-flux contact conductance methods with highly reliable contact that allows repeated breakage and reapplication.

Methods for enhancing thermal control system components such as coating, heaters, and heater controls through electrohydrodynamic technology, advanced materials, and long life insulation for temperatures above 2300 K.

Energy efficient refrigeration and freezing concepts to provide for food storage for long duration missions (greater than 90 days).

Thermal control techniques for materials processing in the appropriate environment.

Advanced insulation materials that are highly efficient, capable of handling extreme temperature (2300 K and above), and have long-life applications.

Long-term thermal control and storage techniques for cryogenic or low-temperature fluids, including vapor-cooled shields, leak detection, systems for cyrogenic storage of laboratory and life sciences specimens, freeze-drying, and quick-snap freezing.

09.03 On-Board Tracking Systems
Center: JPL/JSC/MSFC

Innovations are sought in microwave, photonic, and image-based tracking systems to support autonomous rendezvous and docking, proximity operations, landing, and hazard avoidance. Areas of interest include:

- Tracking techniques and components, with greatly reduced weight, power, and cost, for needed rendezvous target position, attitude and rates or ground-relative altitude, range and velocity for landing.
- Laser beam pointing devices. Critical considerations are low-weight, low-power, agility, accuracy, low-loss, and large field of regard.
- Passive image-based target systems using digital or optical techniques for navigation targeting to locations on mapped and unmapped surfaces.

- Agile, small-target tracking systems capable of on-orbit detection and tracking of meteoroids and orbital debris in the 1 to 10 cm diameter range for orbit determination and collision avoidance. High-gain (greater than 50 dB), narrow scan (± 3° elevation, ± 1° azimuth) phased-array antenna concepts for short-time duration (less than 10 seconds) tracking out to 300 Km range.

- Low-cost primary or backup docking, attitude, and navigation systems for an entirely automated rendezvous mission. Relative accuracies required would be in the 5-10 centimeter range, 0.01 meter per second velocity level, and attitude requirements would be of the milliradian level.

- Architectures and components to support precision formation flying of small spacecraft including attitude and control functions for relative positioning and collision avoidance.

09.04 Space Avionics and Photonics Technology
Center: JPL

Demands for spacecraft autonomy and added performance along with more restrictive mass and power constraints have created a need for innovative technology concepts for high-precision spacecraft guidance and control. Areas of interest are:

- Micro-star and feature trackers, micro-inertial measurement units and micro-reaction wheels with masses on the order of hundreds of grams; high-precision metrology systems for space-based, optical interferometric systems; digital filter algorithms to achieve precision pointing and tracking with dithered ring laser gyros.

- New concepts, architectures, and algorithms for miniature spacecraft control, providing capability for monitoring spacecraft functions and environmental conditions, assessing health status and optimizing performance through in-flight identification, fault detection, stabilization and reconfigurable control, utilizing fuzzy logic, neural network and robust control techniques.

- Space photonic innovations including, solid-state 1300 nm laser with two distinct and stable wavelengths; compact fiber-optic isolator that provides access to the "rejected" return light; compact high-power integrated optics switch array implemented in multimode channel waveguide for 800 nm, 1000 nm, or 1300 nm; compact, solid-state optical frequency shifter; micro-optic lens array for use with active pixel sensors; 2-2.5 μm wavelength semiconductor diode lasers based on ternary InAsP substrates and short-period superlattice structures; and intelligent fiber-optic sensor arrays.

- Autonomous optical navigation architectures, algorithms and parallel processing schemes, processors, and hardware components for near-Earth-orbital and planetary space systems.

09.05 Space System Guidance, Navigation, and Control
Center: JPL/LaRC

Space systems include expendable launch vehicles, transatmospheric vehicles, interplanetary spacecraft, flexible space platforms and small satellites, with attendant subsystems such as sensors, flexible appendages and remote manipulators. Advanced techniques for guidance, navigation, and both rigid-and flexible-body control, that are robust to parametric uncertainty and modeling errors, must be developed. These advances will be needed to improve system reliability, availability, and operational capability, and to reduce life-cycle costs. Innovations **not** based on conventional design or existing systems are solicited:

- On-demand GN&C techniques that can enhance the flexibility and economic performance of aerospace systems.

- GN&C methods that can adapt to environmental uncertainties encountered by a vehicle during atmospheric flight and navigational uncertainties associated with on-orbit proximity operations.

- Algorithmic or computational advances that can significantly improve the ability to solve complex optimization problems for space vehicles.

- Methods for integrated controls-structure design and analysis.

- Advanced techniques for robust control, multivariable analysis and synthesis.

- System identification, model order reduction, fault identification, isolation and reconfiguration, and adaptive control strategies for systems with appreciable structural dynamics and changing mass/inertia characteristics.

- Sensors and control devices for flexible structures.

- Autonomous inflight-calibration of GN&C systems and sensors to allow rapid, optimized, and reduced cost of operations.

09.06 Communications and RF Systems for Crewed Space Vehicles

Center: JSC

Multiple, simultaneous, efficient links will be required for low-rate and high-rate communications and RF system components for space transportation systems, future spacecraft, and extravehicular astronauts.

Areas for innovation include:

- Multiple beam antennas with near-hemispherical coverage at Ku, Ka, W-band, and optical frequencies for supporting up to six simultaneous multiple access users. Techniques for minimizing grating lobes, achieving high-efficiency front-end (power amplifier and low-noise amplifier) performance, minimizing electronic components by using monolithic microwave integrated circuits (MMIC) technology, and utilizing conformal array antennas for near-range (less than 1 km).

- Ultra-small, active, integrated microwave sensors to allow embedded measurement and relay of spacecraft parameters to centralized instrumentation data terminals.

- Innovative schemes for highly efficient microwave beam power transfer. Support technology includes beam steering accuracy, photonics for phase reference distribution, minimizing electromagnetic interference (EMI) noise outside the transmission frequency band, and high conversion efficiencies for DC to RF and RF to DC.

- Lightweight, low-power spaceflight encoders to allow highly bandwidth-efficient space-to-ground transmission of HDTV.

- Highly automated communications control, monitoring, and test systems to allow ultra-rapid, fault detection, isolation, and recovery.

09.07 Spacecraft Contamination Monitoring and Control

Center: GSFC

This subtopic addresses the need for advanced understanding of spacecraft contamination management. Innovative approaches are sought for measurement, prediction, and verification of spacecraft molecular and particulate contaminations. New concepts and approaches are required in following areas:

- Reliable, molecular monitoring systems to measure the concentration of contaminant species, the velocity distribution, and the resulting effects such as column density, surface deposition, spectral background, and glow phenomena.

- Compact particulate monitoring systems to determine the particle size, density, velocity, trajectory, and the resulting effects in space environment.

- Mass transport models to predict molecular direct transfer, backscattering, particle transport, and surface effects. Implementation on mini-computer and PC-based computer systems should be improved.

09.08 Deployable Stuctures and Devices

Center: GSFC/JPL/MSFC

Deployable structures (solar arrays, antenna, etc.) are critical to the success of virtually every spacecraft. Failures can be catastrophic (the Galileo high-gain antenna, for example). Planetary landers may use deployable devices for deceleration. As spacecraft complexity increases, deployable structure requirements (reliability, mass, stiffness, accurate and repeatable positioning, testability) become more stringent, but development costs must decrease. To meet these demands, innovations are required in the following areas:

Computer tools for modeling and analyzing the dynamics of deployable structures. Accurate, three-dimensional capability. Run on desktop computers, account for test conditions, and have graphical input and output for iteration of design and analysis.

Rotary dampers. Light, non-magnetic, with no leakage, non-outgassing in vacuum, and able to withstand temperatures of 230-330 K. Damping rates nearly constant with temperature and applied torque, adjustable up to 100 Nms/radian, torque capacity of up to 25 Nm, and at least a 4.7-radian range of travel.

Passive damping devices. For constant deployment rate of spacecraft appendages requiring a single on-orbit deployment such as solar arrays and antennas when simultaneous deployment is critical. Insensitive to a wide temperature range, continuous operation in either direction, adjustable, manual disengagement for quick reset, minimal space to operate, and withstand launch and landing loads.

Vibration actuator/sensor. Space flight capable, low-profile, self-contained. Can convert electrical signals to a force output, impulsive or sinusoidal, on the order of 4.5N. Must sense the response of the appendage to which it is attached. Frequency response of 0 to 1000 Hz.

Planetary landers. Parachutes, ballutes, and autorotators.

09.09 Space Tether Technology

Center: HQ/MSFC

NASA and other sponsors are interested in flying a number of low cost tether applications using the Small Expendable Deployer System (SEDS). SEDS has demonstrated the capability to provide the transportation to re-enter small payloads from low Earth orbit, to boost payloads to higher orbits, and to stabilize science platforms along local vertical. SEDS also has capability to deploy science instruments downward to measure atmospheric parameters on a global scale, to measure aerothermodynamics of spacecraft traversing Earth's lower thermosphere, and to measure the interaction of conducting tethers in the Earth's ionosphere. Specific examples of space transportation applications are the deorbit of waste from Space Station and the re-entry and recovery of COMET payloads. Innovations are sought for new approaches to developing, fabricating, and packaging low cost universal instrumentation for SEDS missions; and for developing SEDS-type tether systems as an element of infrastructure for space operations.

09.10 Microactuation Technology

Center: JPL

Advances in microactuation technology are sought in high-performance active structural members and tubular polymorph piezoelectric actuators.

High-performance active members must be lightweight, have a static stiffness of approximately 1750N/cm, travel under no load of not less than 0.025cm, withstand a dynamic loading of approximately 1300N, and a wideband, random-input vibration level of 20 g rms. The active members must have built-in sensors to measure relative deflection of the unit to within a few microns. A design goal is to have the active member maintain a particular state of force or displacement once the excitation voltage is removed.

Innovative concepts of tubular polymorph piezoelectric actuator to bio-mimic a "muscle" are solicited. The actuator is to be employed in the control of deployable structures, specifically tethers and umbilicals, preferably by intercepting and/or accurately accommodating perturbations propagating along such structures.

09.11 Control of Flexible Space Systems

Center: LaRC

Flexible spacecraft require control systems and components that are more reliable and efficient than current systems and are robust with respect to parameter variations such as modeling errors, component failures, and disturbances. In particular, methods are needed that integrate control and structure systems design and embody advanced control system analysis and synthesis techniques, including system identification and model order reduction; fault identification, isolation, and reconfiguration; microprecision control and adaptive control strategies for systems with appreciable structural dynamics. The focus should be on both robust multivariable control systems design and control devices for flexible structures and may involve ground validation of advanced system concepts and attendant breadboard hardware in Phase II or subsequent R&D activities.

09.12 Microspacecraft Technology

Center: JPL

*(This subtopic identifies applications that are covered more generally under other subtopics, for example in Topics 7, 8, 9, 10, 11, and 14. **Wherever possible, proposals must be addressed to the appropriate subtopics in those Topics.** Note that each proposal must be unique and may be submitted under just one subtopic.)*

Innovative concepts are sought to advance technology for microspacecraft (10 to 100 kg, <0.05 m^3) for NASA's solar system exploration program and other space science programs. Concepts to provide maximum capability and efficiency with minimum cost, mass, power and volume, and that can be reused in 3-5 years could include:

Miniaturization of all subsystems, for example:

- Methods for incorporating advanced high-density packaged electronics.
- Spacecraft control including status monitoring and performance optimizing.
- Precision pointing capabilities to support science instrument needs.
- Deep-space telecommunications.
- High-energy-density batteries.
- High-power-density, high-efficiency solar arrays.
- Low-mass, low-leakage propulsion (dry gas and liquid).

Reduced life-cycle mission costs based on hardware concepts related to the spacecraft and mission development, launch, or operations phases, or any combinations of these. Interest includes means for incorporating advanced spacecraft autonomy and improving spacecraft performance and operations margins. Multidisciplinary system design and optimization tools capable of supporting current and advanced CAD software are also desired for analysis of life-cycle costs.

09.13 Planetary Atmospheric Buoyant Vehicles

Center: JPL

Constant altitude balloons have been flown in the upper atmosphere of Venus during the 1985 U.S./French/Russian mission. NASA is interested in using variable altitude balloons to explore the Venus atmosphere and surface. These balloons must traverse the region between

the Venus surface (93 bar pressure, 730 K) and the higher, cooler altitudes up to 60 km (0.15 bar pressure, 260 K). A key challenge to operation of these balloon systems is the need for repeated, short excursions to the surface. Innovations are solicited with the following suggested areas of emphasis:

Balloon altitude control concepts that require little or no consumable spacecraft energy (<10 W), are lightweight (<25 kg total mass), and can provide at least one round-trip altitude excursion per day for at least one month. Proposers can take advantage of energy available due to temperature variations within the Venus atmosphere, but should not utilize consumable ballast nor the release of buoyancy gases.

Nonmetallic balloon materials that can withstand the rigors of the Venus environment without significant degradation. Requirements include high tensile strength, tear and impact resistance, high strength-to-weight ratio, maintenance of mechanical and physical properties during temperature cycling, resistance to flexural fatigue, and compact storability for approximately one year.

09.14 Earth Atmospheric Balloon Systems
Center: GSFC

The NASA Balloon Program provides scientific balloon flight operations support from a large number of locations around the world. The balloon sizes range from a few thousand cubic meters to 1.1 million cubic meters. Payloads range from a few kilograms to approximately 3600 kilograms. The scientific missions would benefit tremendously from longer, high-altitude exposure of the scientific sensors that could provide improved resolution and sensitivity to both global and astronomical events. Flight missions are limited to just a few days except in specific areas on our globe, such as the polar regions. To provide increased duration, NASA is investigating the feasibility, development, and use of fiber reinforced films in the fabrication of a new generation of balloon vehicles. One of the primary challenges is the development of a structural seal or seam that provides a gas tight joint and allows load transfer between the individual fibers and base film to the individual fibers and base film of the adjoining gore.

New innovative method(s) are sought for developing a seam that maintains the integrity of the structural system and load transfer capabilities. The required seam shall have, but not be limited to, the following characteristics:

- Capable of supporting the design loads (which encompasses uniaxial and biaxial stress states induced by tensile and pressure loading conditions) under the service environment for the duration of the flight.
- A strength equal to the parent scrim film it joins.
- Free of voids and/or defects that deteriorate structural integrity.
- Suitable for industrial production of large balloons with particular attention given to application technique, cure conditions, shelf life, handling, and cost.

Innovations are needed in pointing-control and aspect-determination subsystems for balloon-borne payloads. Low-cost, modular subsystems using state-of-the-art, low-power, digital electronics are required for high-altitude, scientific ballooning. Particularly desirable are low-cost, high-precision gyro systems that can be re-calibrated frequently during flight or that have inherently low drift rates. The capabilities required of the subsystems for actual balloon applications are as follows:

- Pointing control in azimuth and elevation to within 0.002 rad rms, of the desired cosmic source, and with motions constrained to be smaller than an arcsecond per millisecond.
- Pre-programmed control algorithms with parameters adjustable in real time to enable investigators to vary subsystem performance characteristics such as speed of acquisition, amplitude of swing in acquisition mode, and fundamental frequencies that might otherwise excite payload resonances.
- Absolute aspect determination with respect to right ascension and declination to within 0.2 arcsecond rms, or better.
- Measurement of absolute roll angle about the pointing direction, on millisecond time scales, to within 0.002 rad rms, or better.
- Measurement of relative roll angle about the pointing direction, on millisecond time scales, to within 1 arcminute rms, or better for time intervals as long as 30 minutes.

09.15 Spacecraft Attitude Determination and Control
Center: GSFC

NASA is involved in ground-based determination of spacecraft attitude, in-flight calibration and alignment of attitude sensors, and studies of spacecraft attitude dynamics and control. Innovations are sought that address the following:

- Near-real-time multi-star identification and other methods for improved attitude sensor measurement processing.

- Generalized attitude determination techniques and filters.
- Flight-dynamics analysis and spacecraft support.
- In-flight sensor alignment and calibration.
- Environmental models to enhance attitude sensor measurements and spacecraft dynamic simulation.
- Infrared horizon sensors that minimize power usage, cost, and weight.

10.00 Space Power

10.01 Photovoltaic Cells, Arrays, and Components

Center: LeRC/MSFC

Future NASA missions will require high efficiency and lightweight photovoltaic systems for LEO, GEO and deep space and planetary surfaces to support orbiting platforms, space science missions and robotic exploration of the solar system. Current technology targets include cell efficiencies over 25 percent, and array performance parameters of up to 800 W/kg and 300 W/m^2. Potential concepts consistent with mission requirements can include rigid arrays, thin film arrays, deployable arrays, and various concentrator configurations. Some missions may require highly radiation resistant arrays to survive protracted time in the Van Allen radiation belts where high efficiency is still a driver but combined with low radiation loss. Concepts that can provide tens of watts of power to support outer planet missions, or similar low intensity conditions, such as the poles of Mars, are also needed as low-cost alternatives to radioisotope power systems.

10.02 Thermal to Electric Energy Conversion

Center: JPL/LeRC

This area covers both static and dynamic thermal energy conversion methods, including thermoelectric, thermo-photovoltaic, alkalai-metal thermoelectric-conversion, solar-dynamic, and other innovative approaches that may include thermodynamic conversion cycles such as Brayton and Stirling. Currently, NASA needs systems that are lightweight, low-cost alternatives to radioisotope power sources for missions where photovoltaics are not practical, as well as more cost effective options to photovoltaics. NASA is also interested in innovative approaches to low power, highly distributed and localized power sources that can significantly reduce the size and weight of spacecraft for purposes such as supplying power to various instruments at the point of need rather than through a central power system. Future missions may also require advanced concepts to support high power systems in Earth orbit. Possible power levels range from tens of watts to many kilowatts for an advanced space platform/station power source. Practical systems must have distinct advantages in overall life-cycle cost to the spacecraft.

10.03 Energy Storage and Electrochemical Power Systems

Center: JPL/JSC/LeRC/MSFC

NASA programs require energy storage systems having high energy density and cycle life. This includes rechargeable batteries, fuel-cell-electrolyzer energy storage (or fuel-cell primary power systems) and

competing alternatives with high power density such as lightweight flywheels and ultracapacitors.

The current focus in spacecraft/space system battery research is on nickel-hydrogen (IPV, CPV and bipolar configurations) and nickel-metal hydride systems with goals of at least 100 Watt-hour per kilogram and 10-year life in LEO and GEO. There is also strong interest in lithium and lithium-polymer batteries for planetary spacecraft and probes with goals of 125-150 Watt-hour per kilogram. Other longer term options include sodium-sulfur and lithium-CO_2. Current space applications include Space Station, EOS, small spacecraft, advanced communications spacecraft, deep space planetary spacecraft and planetary surface power (e.g. Mars) for science operations.

In fuel cell and fuel-cell-electrolyzer systems, NASA is actively pursuing the PEM system but is interested in other systems such as solid oxide. Possible applications include the Space Station, space vehicle, and advanced spacecraft.

Spacecraft/space system battery and fuel cell innovations should emphasize increased power/energy density and longer operational life while reducing the cost, weight and simplifying manufacture and checkout operations prior to use in space. A general requirement for batteries is very high cycle life with certain application-specific requirements for rapid charging and high discharge rates. For deep space and planetary applications operation over wide temperature ranges (e.g. Mars day-night cycle) is desirable. Fuel flexibility (including direct fuel oxidation) is important for fuel cells.

NASA also solicits innovations for portable, rechargeable energy storage concepts that yield significant increases in the energy density over Ni-Cd and Ni-H_2 batteries. These are needed to power such applications as cameras, tools, scientific instruments, life support backpacks, robotic devices, and mobile transporters. Much of this equipment is used on Extravehicular Activities (EVAs). Long replacement intervals are needed to minimize the overall weight-to-orbit requirements. Safety is also of prime consideration since many of these systems are handled directly by the space flight crews and used either inside or outside habitable modules.

10.04 Power Management and Distribution
Center: JPL/LeRC/MSFC

Creative concepts are desired in power management and distribution (PMAD) technologies for the control of space power systems with increased autonomous operations. Included are hardware, software, and overall electrical system concepts that are fault- and radiation-tolerant. New concepts are sought in the following:

- Advanced materials for power electronics, devices, thermal management, and EMI shielding.
- Electronic devices (including transformers, transistors, electro-optical devices, and sensors for high-temperature and high-efficiency) for use in dc or high-frequency ac PMAD systems, motor drives, electrical actuation, electro-mechanical systems.
- Power system fault detection and isolation and system reconfiguration, including "smart component", built-in-test, and vehicle health management concepts.
- Management, control, and autonomous operation of space electrical power systems.
- Space and planetary environmental interactions such as plasmas, atomic oxygen, particulates, and gases that affect electrical/power systems or surface materials.
- Thermal control of space power management systems using high-emittance radiator surfaces and advanced, lightweight heat pipes for low and high operating temperatures.

11.00 Space Transportation

11.01 Advanced Space Transportation Systems
Center: MSFC/SSC

Innovative concepts and approaches are solicited in areas relating to low cost booster, upper stage, and orbital transfer vehicles. Interest encompasses all sizes of commercially applicable launch and spacecraft systems up to 2.9 MN thrust.

Innovative developments are sought in technologies and systems such as test methods and sensors, solar thermal collectors, design techniques, plume characterization, various advanced concepts, and other related issues. Proposals should emphasize cost reductions (as compared to existing systems) as the primary objective in relation to improvement in recurring costs, reliability and performance. More specifically, innovations are sought in:

Test methods and diagnostic sensors for characterizing space transportation systems readiness for flight and performance. Innovative test equipment (hardware and software), techniques and strategies are essential for low cost and responsive test services for future space transportation systems. New methods for multipoint strain measurement in rocket motors are required.

Liquid, solid, and hybrid rocket motor test technologies for use in ground test systems including (but not limited to) use of electromagnetic actuators, characterization of propulsion system component interactions, use of built in test equipment in ground test environment, development of test article simulators or emulators, development of new diagnostic and data acquisition equipment.

Non-intrusive sensors to measure rocket performance, combustion stability and efficiency, fuel regression or burn rate (for solid or hybrid motors) and to evaluate engine modifications, and to quantify any potential environmental effects; and to conduct exhaust plume diagnostic measurement. These sensors may be active or passive, but must not require physical modification to the test article in question.

Soot formation mechanisms: Specific areas of interest include LOX-RP, tri-propellant and hybrid boosters.

Trace species definition: quantitative measurements of trace atomic species in engine exhausts are needed for UV plume signatures, engine health monitors, chemical kinetics code development, environmental impact studies, stratospheric ozone depletion studies, and gas diagnostic measurements. Species of interest include metal atoms, H, OH, CH, NO_x, SO_x, CO, N_2, C_2H_2, CH_2, hydrocarbons and PCAH.

Aluminum oxide optical properties for the prediction of radiative heating rates from boosters and orbital insertion motors and the prediction of UV-Visible-IR signatures of aluminized solid rocket exhaust plumes. Specific areas of interest include: determination of the emissivity of liquid alumina in ambient rocket gases, suppression or augmentation of emission using additives, and the formation and properties of the gamma phase.

Deployable solar thermal collector designs for use in a transfer-orbit, upper-stage booster. Collector designs are expected to incorporate reflective surface and/or lense type concentrators and lightweight structures, and be able to withstand launch and orbit environments (including meteoroid and debris hazards).

Thermal design: analytical techniques and advanced concepts for designing nozzles, combustion chambers, and insulation systems.

Design and installation of minimally intrusive thermal instrumentation in rocket nozzle and throat regions, and turbine sections.

Analysis and design of components that generate frictional effects within high-speed cryogenic turbomachinery, including bearings and seals.

Highly reliable heat exchanger concepts for advanced vehicle and engine systems.

Analytical techniques for simulation of advanced manufacturing processes.

Miniaturized flight instrumentation systems for recording thermal data on reusable space transport systems and spacecraft with high response and accuracy.

Estimation of remaining component life.

Extension of the stable operating envelope of high-head pumps.

High-speed fluid film bearing and seal concepts.

Probabilistic fluid/thermal analysis methodologies for structural interactions.

Simplified construction of combustion chambers or nozzle extensions.

11.02 Space Propulsion System and Subsystem Technology

Center: LeRC

Cyrogenic Propellant Systems: Component and instrumentation concepts to improve the reliability, operating efficiency, safety, and performance of cryogenic fluid systems are solicited for both ground and low gravity environments. There is an emphasis on:

- Low cost insulation concepts for propellant tanks. Bonding techniques to enable cryogenic fluid ground hold and repeated launches.
- Low gravity mass gages with high accuracy and response.
- Small reliable pressure transducers (<690 kPa) for cryogenic liquids capable of withstanding launch loads.
- Devices for vapor free acquisition of cryogenic liquids during complex launch and reentry maneuvers.
- Lightweight tanks, lines, and valves using composite materials.

On-Board Propulsion: Propulsion is often a driver for more cost-effective satellites. Innovative, on-board propulsion system technologies are sought that are characterized as lightweight; compact; very low power (if electric); and low cost. Proposed propulsion systems are to significantly outperform, on a mission basis, state-of-the-art storable chemical propulsion systems. Proposals may consider innovations in combustion systems, propellant management, power management, and other developments germane to propulsion systems.

11.03 Computational Fluid Dynamics (CFD) Methods and Unsteady Flows in Rocket Propulsion Systems

Center: MSFC/SSC

Innovative concepts are sought for improving numerical computational capabilities to predict fluid flow phenomena in liquid and solid rocket propulsion systems, and for launch vehicles including multi-phase and multi-species considerations. Emphasis should be placed on methodologies and models that will enhance the efficiency and use of CFD for launch vehicle and propulsion environment definition. Design and flow environment assessment tools should address issues that are unique to commercial and government launch systems, and should lead to advanced and/or low-cost rocket hardware design concepts and design methodologies.

New concepts are being solicited that will provide a more direct measure and interpretation of the complex nature of unsteady flow characteristics that is routinely observed in the feedlines and pumps during operations of liquid rocket engines. These innovations should be able to provide a more complete and detailed interpretation of these phenomena for cryogenic and hot gas flow sections so that new systems designs can be incorporated that will eliminate these anomalous unwanted flow conditions. Phenomena of interest include surface fluctuating pressures, wandering frequencies of unknown origin, vortex shedding, edge tones, cavitation, dynamic gains of the pressure fluctuating across pumps and the effect of modulation of these flows with other pump components. These techniques can be a model, a diagnostic or analysis tool, a new type measurement system, or a new type of data acquisition system.

NASA is also interested in innovative methods for extending the knowledge of flow instabilities in supercritical gas flows. Determination of the acoustic modes (axial, radial or tangential) and the strength of flow instabilities that result from excitation at the convergent regions of gas flows is of primary interest. NASA operates high-pressure gas systems that often have supercritical flows and is in need of extending both the theoretical and empirical databases for these types of flows.

11.04 Thermal Protection Materials, Systems, and Analyses

Center: ARC

Future atmospheric launch and entry vehicles, planetary entry probes, and aerobraking orbital transfer vehicles require new thermal protection materials (both reusable and ablative) and novel thermal protection systems that are lightweight and durable with lower fabrication and operational costs than those currently available. Design and optimization of these systems requires innovative applications of computational and experimental technologies to account for the complex high-temperature, multiphase phenomena that occur in the vehicle external shock layer and on the surface and within heat shield materials.

This subtopic solicits innovative concepts for novel light weight, rigid and flexible materials and systems having extremely good thermal-shock resistance and temperature capability in the range from 770 K to 2770 K. Mass efficient ablative materials using novel technologies are also sought. Possible forms are fiber-fiber composites, fiber-matrix composites, foams, and various woven systems. New minimum-weight, load-bearing, and non-structural thermal protection systems using new components and processing methods are of interest. Potential for reduced operational costs compared to

current systems (resulting from reduced fabrication costs, and/or improved robustness to adverse environmental conditions such as handling, impact, rain/humidity, corrosion, etc.) will be an important consideration for selection.

New analytic and computational technologies are needed to design and develop these probes and vehicles, including equilibrium and finite rate chemistry; transport properties and multi-component mixing laws; thermal radiation; gas-surface interaction such as surface catalytic reactions, shock-wave/boundary-layer interactions; and laminar, transitional, and turbulent viscous flows. Proposals should also address the important issues of computationally coupling the external shock layer flow and transport to the hot surface and material response phenomena.

Proposals are also solicited for innovative thermal protection systems for launch pad and static test stand flame buckets to reduce operating and maintenance costs.

11.05 Small Chemical Space Propulsion Systems
Center: JSC

Improvements are needed in components and systems for small chemical space propulsion for reusable Earth-to-orbit and return vehicle reaction control, orbit insertion and deorbit systems. Propellants of interest include oxygen-hydrogen, oxygen-hydrocarbon, and alternative combinations that can ultimately reduce reusable vehicle processing time.

Figures of merit for improvements include lower weight, reduced cost, and higher reliability. Innovations sought include:

- Materials to withstand high-temperature, high-pressure oxidizing combustion environments.
- High-response, low-power valve designs.
- Techniques for precise metering, injection and ignition of fluids in combustion devices.
- Valves, seal, and bellows for high-pressure gaseous and liquid isolation, regulation, relief, quick connect/disconnect and directional flow-control.
- Gaseous storage and pressurization systems.
- Non-intrusive component and system diagnostics for health monitoring, including pressure measurement, and fluid leak detection.
- Systems for liquid-free gas venting, gas-free liquid propellant delivery and quantity mass gauging in a reduced gravity environment.

Proposed concept feasibility to be demonstrated in Phase I should lead to hardware R&D in Phase II. Proposals limited to system studies are not acceptable.

11.06 High Specific Impulse Propulsion Technology
Center: JPL

High specific impulse in-space propulsion systems offer significant advantages over chemical propulsion systems for solar system exploration, as well as commercial satellite applications such as stationkeeping, repositioning, and orbit raising. Advanced propulsion topics of interest include electric propulsion, advanced chemical rockets, beamed energy concepts, and other advanced types. Electric propulsion thrusters of interest include electrothermal arcjets, electrostatic ion engines, stationary plasma thrusters, anode layer thrusters, and magnetoplasmadynamic (MPD) engines. Innovative approaches for significant improvements are sought in these areas:

- Electric thrusters with improved total impulse capability.
- Inert gas-fed, pulsed-plasma thruster concepts (scalable to small physical sizes, for spacecraft attitude control).
- Power processing concepts (very high efficiency, innovative packaging approaches).
- Sputter resistant materials, high-temperature insulators, high-current cathode materials and/or configuration and high-emissivity coatings.
- High-speed vacuum chamber pumping systems.
- Gaseous pressure regulation, flow rate control and measurement.
- Modeling of thruster exhaust plumes.
- Storable liquid chemical propulsion systems using exotic propellants.
- New advanced propulsion concepts.

12.00 Human Habitability and Biology in Space

12.01 Human and Environmental Health Maintenance and Monitoring

Center: ARC/JPL/JSC

Human presence in space requires understanding of the effects of microgravity and other components of the space environment on the physiological systems of the body and on the psychology of the crew. Countermeasures must be developed to oppose deleterious changes in space or on return to Earth. Health care and medical intervention must be provided over extended duration missions.

Space missions generate requirements for a variety of environmental and biomedical activities to protect crew health and to counter the effects of space on human physiology. As launch costs are extremely sensitive to mass and volume, sensors and instruments must be small and light with a premium on multi-functional aspects. Low power consumption is a major consideration, as are design enhancements to improve operation in microgravity and enhance design reliability and maintainability. As the efficient utilization of time is extremely important, innovative instrumentation setup, ease of usage, improved astronaut (patient) comfort, non-invasive sensors, and easy to read information displays are all important human factors considerations.

Health Monitoring and Countermeasures

- Methods and equipment to maintain and assess levels of aerobic and anaerobic physical capability.
- Methods to monitor physical activity and loads placed on different segments of the human body.
- Exercise equipment to load the musculoskeletal and cardiovascular systems with the capability to monitor, record, and provide feedback about performance.
- Approaches to sustain, maximize, assess, and model individual and team performance.
- Countermeasures against deleterious changes in body systems in flight or on return to the ground. Changes include space adaptation syndrome including space motion sickness, in-flight loss of muscle and bone mass, postflight orthostatic intolerance, and postflight reduction in neuromuscular coordination.
- Approaches to assess gas bubble formation or growth in the body after in-flight or ground-based decompression and to prevent or minimize associated decompression sickness.
- Innovative means to apply artificial gravity and to reduce deleterious effects associated with short-arm centrifuges.
- Approaches to achieve health care and intervention within the operational constraints of space flight. These approaches include extended shelf-life pharmaceuticals, diagnostic methods and procedures, medical imaging systems, non-invasive medical monitoring, dental care and surgery, and blood replacement technology.
- In-flight procedures and techniques for assessing the human metabolism of protein, carbohydrate, lipids, vitamins, and minerals.
- In-flight specimen collection and analysis to evaluate physiological, and metabolic and pharmacological responses of astronauts. Non-invasive methods to measure crew performance and related factors.
- Novel software methods for documentation, storage, retrieval, analysis and diagnosis of crew health, and environmental quality information.

Environmental Monitoring

- In-flight monitoring techniques including fiber optics (IR, UV, visual sensors) and bio-sensors for chemical, microbial, and physical quality of recycled water and atmosphere, spacesuit atmosphere, food and surfaces. Of particular interest is the detection, measurement, removal, and health-effects assessment of organic contaminants.

- Instruments for assessing the overall acceptability of the environment for human habitation and methods of assessing associated risks.

- Methods for maintaining microbial and toxicological quality of the atmosphere, water and surfaces during extended missions and means of assessing their effectiveness.

- Techniques for monitoring non-ionizing and ionizing radiation and for determining organ doses. Quantitative measurement of the cytogenic and carcinogenic effect of protons and heavy ions, especially at low doses. Methods for measuring cellular and tissue levels mechanisms and effectiveness of radio protectants.

Sensors and Instrumentation

- Instrumentation to be used in flight and ground-based studies for reliable and accurate noninvasive monitoring of human physiological function such as the cardiovascular, musculoskeletal, neurologic, gastrointestinal, pulmonary, immunohematological, and hematological systems.

- Noninvasive instruments to provide quantitative data to establish the effectiveness of an exercise regimen in ground-based research.

- Improved, non-invasive methods to evaluate the function of the cardiovascular, neurological, bone, muscle, and pulmonary systems.

- Smart sensors (on-sensor data processing and sensor reconfiguration).

- Ultrasonic Doppler systems for blood flow.

- Virtual medical instrumentation.

- Automated biomedical analysis.

- Microgravity blood, urine, and respiratory gas analyzers.

- Microgravity refrigeration systems for the storage of biological samples and incorporating refrigerants acceptable for use in a sealed environment.

12.02 Regenerative Life Support
Center: ARC/JPL/JSC/KSC/MSFC

Closure of regenerative life support systems is essential for the success of future human planetary exploration. The requirements include micro- and partial-gravity operation, high reliability, elimination of expendables, and low system weight and power. Innovative, efficient, practical concepts are desired in all areas of regenerative physical, chemical, and biological processes, associated hardware, sensors, and instrumentation for basic life support system functions including air revitalization, water reclamation, and waste management.

Air Revitalization

- O_2, CO_2, and H_2O vapor concentration, separation, and control techniques including regenerative physical-chemical, and biological approaches.

- Gas-phase separation of CO_2 from a mixture primarily of N_2, O_2, and water vapor to maintain concentrations of CO_2 below 0.3 percent by volume.

- Highly efficient gas-separation of N_2 and O_2 from CO_2 to reduce concentrations of N_2 and O_2 to less than 0.2 percent by volume.

- Trace contaminant removal.

- Regenerative sorbent beds.

- Improved oxidation techniques (physical-chemical and/or biological).

Water Reclamation

- Efficient, direct treatment of waste water (e.g., urine, wash water, and condensates) without requiring expendables to produce potable and hygiene water. This includes removal of effluent gases and stabilization of waste water prior to storage and processing or overboard venting.

- Potability maintenance techniques.

- Recovery of water from waste water concentrates (e.g., reverse osmosis brine).

- In situ cleaning and sterilization of potable water systems.

Waste Management

- Stabilization of wastes (metabolic and inedible biomass) and recovery of useful products (e.g., N_2, H_2, CO_2) from organic waste materials.

- Treatment of laboratory, metabolic and other wastes for storage.

- Physical-chemical/biological techniques for waste treatment in micro- or partial-gravity.

Sensors and Controls

- Micro-miniaturized sensors capable of real-time multiple measurement functions and self-calibration.

- Specific measurements of chemical and biological species concentrations with temperature, pressure and mass flow rate on micro-miniaturized sensors for gas and aqueous media.

- Pre-training artificial neural net controllers to provide rapid real-time control using mathematical models of degradation.

12.03 Regenerative Production of Food
Center: ARC/JPL/JSC/KSC/SSC

NASA's future long-duration missions mandate extensive regeneration of life support consumables and utilization of local planetary resources. Regenerable life support systems with higher plants, microorganisms, and physicochemical processes for recycling air and water, processing wastes, and producing food are required. Components must minimize mass, volume, power, and thermal requirements, as well as crew-time requirements.

Sensing and Monitoring Devices

- O_2, CO_2, humidity, dissolved and volatile organics, and microbial flora.
- Volatile and soluble organics in air, transpired water, nutrient solutions, and soils.
- Control of pH, water levels, flow, salinity, turbidity, electrical conductivity, and nutrient composition within hydroponic solutions and soils.
- Plant photosynthetic and respiratory gas exchange.
- Automated biological tissue sampling.
- Non-invasive monitoring of plant health.

Plant Growth

- Alternative plant lighting methods.
- Utilization of waste heat and transpired water.
- Recovering resources from wastes and inedible biomass.
- Automated robotic computer-vision systems for crop propagation, planting, cultivation, harvesting, and food processing.
- Techniques for growing or propagating plants such as tissue culture; techniques for improving plant materials.
- Production of food products from inedible cellulytic and lignolytic matter through the use of edible fungi.

Other

- Oxygen gas storage.
- Integrated systems.

12.04 Plant Space Biology Support Equipment
Center: ARC/KSC

Current facilities for growing plants on the Space Shuttle are primitive for many types of investigations of plant responses to the space environment. Methods of lighting, control and measurement of atmospheric and nutrient solution constituents, and methods and devices for delivering water and nutrients to plants in microgravity all contribute to the fidelity of the experimental results and are critical to the interpretation of plant responses to the other variables (radiation, microgravity and launch) on Space Shuttle flights. Areas in which innovations are solicited include the following:

A mid-deck locker-sized plant experiment container that is flexible as to the size of plant chambers it can facilitate and modular as to containing appropriate hardware for different plant species and investigations.

Lightweight, miniature, low power devices designed to monitor and control chamber air flow rate, trace gases, and nutrient solution delivery to plant roots.

A plant lighting system that is lightweight, has high power efficiency, and provides adequate light at the appropriate wavelengths for plant growth and development.

A computer control and data logging system for the plant container such that data from the monitoring and control devices can be used to calculate photosynthesis, respiration (whole plant, shoot, root), evapotranspiration, water utilization, and nutrient uptake.

Centrifuge capabilities with the same monitoring and control devices to sustain and monitor plant growth as in the mid-deck plant container. This will provide 1-g and hyper-g environments concurrently with the micro-g environment of the Space Shuttle mid-deck on-orbit.

LED lighting systems are needed as an alternate light source in plant chambers on board Space Station.

12.05 Human Factors for Space Crews
Center: JSC

Space human factors relate to improving crew performance and productivity. Innovative devices and techniques are required to enhance crew operations under all space flight conditions and to facilitate the design of crew habitats and human-to-systems interfaces for both zero-g and reduced-g environments.

- Anthropometric and biomechanics inflight measuring systems which can be used to determine acute and long-term performance responses in zero-g and partial-g.

- Computer modeling tool kits supporting dynamic computer models of humans and environments for purposes of visualizing and simulating lighting, sound, motion, strength, tasks, and behavior to be used for designing and planning activities and tools.

- Techniques for providing data and models of human perceptual and cognitive processes for use in the development of cooperative intelligent systems and optimization of human cognitive workload for the control of space systems.

- Enhanced human interfaces with telerobotic and automated systems.

- Layout, arrangement, and decor of spacecraft interiors to promote effective use of both the zero-g and partial-g environments in carrying out living and working tasks.

- Means to temporarily stow items of loose equipment aboard a spacecraft with some type of zero-g effective retention system that is non-flammable, does not contaminate the atmosphere, is reusable, and is cleanable.

- Provide a data base or procedure for methodologies, techniques, and evaluation criteria for evaluating Intravehicular Activity (IVA)/Extravehicular Activity (EVA) crew performance and productivity.

- Lightweight means to control the spacecraft acoustic environment.

12.06 On-Board Systems and Support for Space Crews

Center: JSC

Innovative concepts in crew accommodations, equipment, and procedures are required to support complex future space missions. Areas of interest include safety, comfort, performance, and productivity of crew members:

Improved personal hygiene systems and procedures in a zero- or partial-gravity environment to enhance crew living accommodations while minimizing required resources. Examples of interest include: total body cleaning methods and hardware, hair grooming methods and hardware, and personal cleansing agents compatible with both open- and closed-loop life support systems.

Flame retardants for crew clothing with emphasis on launder-in treatment for off-the-shelf knits and woven fabrics.

Housekeeping solutions to problems encountered in both zero- and partial-gravity environments including: crew habitat cleaning, trash management systems and techniques, apparel cleaning, noise abatement and control, particulate reduction and control, and cleansing agents compatible with both open and closed loop life support systems.

Food management systems and procedures in both zero- and partial-gravity environments, such as extending shelf life including packaging and preservation technologies, improvements in acceptability and palatability, and improvements in food waste management systems.

Inventory management with emphasis on consumables and crew equipment tracking systems.

Stowage system and/or software with emphasis on efficiency and stowage of loose items. Examples of interest include: lightweight, nonflammable, non-contaminating, high-efficiency packaging material; computer software systems; and innovative stowage hardware.

12.07 Extra-Vehicular Activity (EVA)

Center: ARC/JSC

Extensive new requirements for extra-vehicular activities to support complex future human space missions will require innovative approaches to maximize crew productivity and capability to perform useful work tasks while reducing ground launch-to-space resupply weight and volume penalties for EVA support systems expendables. EVA system design approaches that minimize crew member fatigue and the time spent servicing and checkout and that minimize EVA system volume, weight, and energy and power consumption. Areas of interest include:

- Low-venting or non-venting regenerable individual life support subsystem(s) concepts for crew member cooling, heat rejection, and removal of expired water vapor and carbon dioxide.

- Long-life chemical oxygen storage systems for an emergency breathing oxygen supply.

- Light weight, high-strength composite materials and related manufacturing processes.

- Materials for space suit thermal control having variable insulation and infra-red emissivity properties that are capable of either rejecting or preserving heat (when facing the sun or when facing deep space).

- Space-suit gloves made with size-reproducible manufacturing processes and techniques that provide highly dexterous hand, fingers, and thumb mobility and fingers and thumb tactile sensitivity.

- Hardware and software for objective evaluation of pressure suit glove performance including mobility characteristics and crew member hand fatigue.

- Techniques for analyzing laminate and stitched fabric pressure structures, pressure suit fabric integrity, structural joints and attachment methods.

12.08 On-Orbit Environmental Noise Control Measures

Center: MSFC

Permanent human presence in space requires that the habitable environment be suitable for human operations. One concern is the on-orbit internal noise environment. Long term exposure to excessive noise will effect crew performance and productivity. New concepts and innovations are being solicited to develop new noise

control measures and/or techniques to reduce the source of the noise, increase the attenuation during propagation of the noise, and/or to increase the absorption of the noise during reflections. In this application, weight, size, and volume are limited. Improved methods and/or techniques for predicting the acoustic environment in the habitat are also being sought. Specific areas in which innovations are requested include:

- Aerodynamically designed, low noise source fans.
- Improved low noise design of pumps, compressors, and water separators used in environmental control and life support systems.
- Active noise cancellation devices and techniques.
- Improved enclosures, silencers, absorbers and tuned resonators designs.
- High acoustically absorbent materials suitable for on-orbit applications.
- Light weight, high-transmission loss materials for use in racks and enclosures.
- Improved, efficient analytical modeling techniques for predicting the internal sound (audible) field in a highly three-dimensional enclosure.

12.09 Optical Imaging Systems and High-Resolution Electronic Still Photography

Center: JSC

Extended-duration spaceflight and exploration missions will require innovative techniques to solve unique optical and photography problems, particularly for storage and near-real-time, high-resolution image return. Innovations are desired in both optical systems and components and megapixel high-resolution electronic still-photography systems and components. Emphasis in the proposal evaluation will focus on a concept's potential to provide greater utility, efficiency, resolution, image compression, and value to the flight crew on long duration missions. Technical thrusts and improvements for electronic still photography involve the following:

- Electronic still-camera systems with operation and performance similar to a 35mm film camera.
- Devices for small, removable, high-density, digital image storage media.
- High-resolution image sensors for electronic photography systems.
- Manipulation and processing of megapixel image data.
- Image data compression schemes adaptable to electronic still-photography systems.
- Low-noise, high-efficiency, battery-power conversion.
- Methods for archiving uplink, downlink, and display of images and data.
- Error detection and error correction, versatile transmission systems, and image data compression during transmission.
- Color splitting in a small system utilizing a minimum of three sensors.
- Anti-reflective coatings for image sensors and optical components.
- Image depth perspective and dimension measurement.
- Obtaining ultra-thin optical low pass filters for single color sensors.

13.00 Quality Assurance, Safety, and Reliability

13.01 Devices

Center: JSC/KSC/SSC

Proposals are solicited for innovative devices to enhance safety and provide assurance that mission objectives will be met. Examples of areas of concern include, but are not limited to, personnel and equipment safety such as detection of toxic vapors, fire, static charge; and impending failures of pressure relief valves, pyrotechnics, life support systems and other electronic, photonic, and micromechanical devices and systems. Other interests include life extension tools for use beyond certifications; weather displays; means to reduce or eliminate maintenance requirements; and prediction techniques for environmental hazards and plasma arc effects in space, and vehicle charging.

In addition to the general requirements, specific needs are for:

- A new material to replace palladium-oxide as a hydrogen getter in vacuum jackets of cryogenic fluid lines.
- A new, portable device to detect toxic propellant vapors (e.g., hydrazines, nitrogen tetroxide) as low as 0.01 ppm for personnel protection.
- A rapid sensor to detect leaks in the 1-1000 ppm range during fueling operations.
- A self-contained portable induction welder for welding tubing and pipe that also performs the weld verification without the use of off-line shops or labs.
- Novel approaches for detectors of hydrogen fires.
- A low cost hydrogen fire imaging and detection system to replace wider field-of-view optical sensors and minimize the need for in situ heat sensing wires.

13.02 Measurement Methods

Center: KSC/SSC

Innovations are solicited for measurement techniques that enhance safety and mission assurance. This includes vehicle and subsystem health monitoring systems, advanced strain measurement technology, non-intrusive pressure and temperature measurements, and remote and in situ measurement of weather hazards; for example:

- Determination of the three-dimensional structure of the electric field in clouds not producing lightning.
- Measuring wind speed and direction from the surface to 30 m without the use of towers.
- Determination of the distribution of soil moisture to improve performance of existing numerical prediction models.

13.03 Operations Research

Center: KSC

Innovations are solicited leading to improving mission operations including, but not limited to:

- Systems to verify models for the transport of hazardous materials.
- Hierarchical network simulation and modeling to support resource allocation in hazardous environments.
- Software program that models a hydrogen gas leak for various environmental conditions and determines the optimum location and number for point sensor gas detectors.

13.04 Non-Destructive Test and Evaluation Methods

Center: KSC

Proposals are solicited for innovative nondestructive means for determining hardware quality and capability to meet specification performance. Examples include: nondestructive inspection of ceramic components, spacecraft window/optics lenses, surface inspection techniques, turbine blade-life determination, corrosion detection, leak detection of SRB joints, NDE of spacecraft structure, pressure vessel and ground systems for high pressure and hazardous materials. Welding and bonding integrity of solid rocket motors are also of interest.

13.05 Bioremediation of Contaminated Groundwater, Soils, and Sediments

Center: KSC

Environmental policies over the past three decades have changed dramatically, leaving industries and government installations squandering in efforts to comply with new regulations. NASA's past operational and disposal practices, although acceptable at the time, have lead to groundwater, soils, and sediment contamination. An emerging technology, referred to as bioremediation, involves the use of microorganisms to treat some forms of contaminated groundwater, soil and sediments. Innovative form of bioremediation for solvent and petroleum based clean-up programs are solicited for cost-effective remediation on the Kennedy Space Center. Regulatory agencies such as the Florida Department of Environmental Protection require a prototype form of bioremediation to be set up for pilot scale activation prior to its approval as a remedial technology.

14.00 Satellite and Space Systems Communications

14.01 RF Components and Systems
Center: LeRC

Innovations are being sought for devices, components, and subsystems for new applications and increased capabilities for a broad spectrum of civil-space communications applications. Commercial communications satellite applications include both fixed and mobile services at geostationary and nongeostationary altitudes. Specific NASA communications satellite applications include data-relay satellites and miniature spacecraft for lunar and planetary missions. Specific innovations sought include:

MMIC, hybrid, discrete, semiconductor and/or superconductor- based electronics concepts for components and subsystems that stress improvement in power, efficiency, bandwidth, noise figure, gain, reliability, manufacturability, size or cost at frequencies from L-band to W-band. Advanced power efficient and/or linear power amplifiers are of particular interest.

Vacuum electron and hybrid devices and/or electronic power conditioning subsystems that stress improvement in bandwidth, power efficiency, gain, reliability, size, mass, or cost. Power conditioners utilizing new architectures or recent state-of-the-art components are of particular interest. Hybrid devices combining solid state and vacuum devices are also included.

Cryogenic electronic concepts for components and subsystems with improved RF performance at temperatures as low as 77 K. Components and subsystems of interest are active devices, filters, high-Q resonators, receivers, amplifiers and phase shifters. Packaging and integration issues including digital-RF or semiconductor-superconductor integrations are also included.

Advanced materials, structures, and devices (FETs, MODFETs, HBTs, SIS, or FFTs) for improved power, efficiency, frequency response or noise that will enhance the performance of communications systems components or subsystems. Material and device characterization technologies and advanced substrate-active device material structures are also of interest.

14.02 Optical and Photonic Devices and Systems for Space Communications
Center: GSFC/JPL

Future space-borne communications systems require advanced concepts, techniques, and components in photonic technology to provide improved performance and small size at low cost. The applications include commercial satellites; tracking and data relay satellite systems (TDRSS); and NASA deep space and Earth observing missions. Optical and electro-optic technologies for lightweight telescopes, high-power and efficient lasers, electronics for high-speed modulators and detectors, and precise, low-mass beam pointing, tracking and acquisition systems, as well as combining techniques that integrate these ingredients into reliable and producible low-mass optical terminals are needed. Photonics technologies to implement optical/RF communications and phased array systems include optical-to-RF down-converters/up-converters, optical RF signal distribution systems, optically controlled transmit/receive modules, optical beam forming networks, optical samplers, modulators, demodulators, detectors, mixers, and radio frequency locked semiconductor lasers. System hardware development and flight experiments are needed to demonstrate performance advantages of photonic technology applied to space communications applications.

14.03 Array Antennas for Satellites Communications
Center: LeRC

Innovations are being sought for devices, components, and subsystems that will enable new applications, increased capabilities, and lower costs for space communication phased array antenna systems. Commercial communications satellite applications include reconfigurable arrays for fixed satellite services at geostationary orbit and electronically scanning arrays for cross and gateway links at low Earth orbit and other non-geostationary orbits. NASA mission applications include geostationary data relay satellites and small spacecraft for lunar and planetary missions.

Innovations are sought relating to the integration technologies required for active MMIC arrays at C-band and higher frequencies. Technologies and techniques having the potential for enabling the eventual manufacturing of arrays at affordable cost are of interest. Innovations leading to a reduction in total satellite system cost by increasing array efficiency or reducing array weight are also of interest. Areas for which innovations are sought include the following:

- Analog or digital beamforming approaches for producing multiple, scanned beams from a single array in direct radiating array or array feed configurations.
- Packaging and integration of MMIC, digital and/or photonic devices; radiating elements; and beam formers/combiners in phased arrays.

- System-level circuit development. Methods, processes, and techniques wherein power-processing, interface support, and control circuitry are co-located with MMICs to improve array performance, reliability, and stability.

- Advanced concepts, structures, and materials that relate to the thermal and mechanical operation of MMIC transmit arrays in a flight environment.

14.04 Mobile and Personal Satellite Communications
Center: JPL/LeRC

New satellite system concepts and technology are needed to enable low power, highly sophisticated terminals offering multiple services and supporting interconnection with dissimilar networks. Modulation, coding, and multiple access schemes must be refined to work in a satellite channel having substantial frequency offsets, multipath, shadowing, and phase noise (due to the use of high frequencies, non-geostationary satellites, or operation in aircraft). Innovations are sought for the following:

Satellite network designs supporting a variety of applications (from digital voice and data to compressed video) with handheld and mobile (land, air, and sea) terminals. Topics such as appropriate orbit determination and constellation, efficient Earth coverage concepts, frequency and timing synchronization between space and ground segments, inter-satellite beam power allocation and uplink/downlink power control are needed to efficiently allocate satellite resources among a large user base.

Interconnection of satellite and terrestrial networks require the definition and simulation of various interconnection schemes supporting intersystem call-delivery and call-handoff, the development and simulation of adaptive routing algorithms, and the examination of protocols supporting satellite implementation of Intelligent Network features.

Modulation, coding, and multiple access schemes for the satellite uplink and downlink must be refined to reduce power and bandwidth requirements of satellite payload and user terminals, and to increase satellite system capacity. These schemes need to be simulated and implemented for operation in the envisaged satellite channel, i.e., with expected frequency offsets; multipath; shadowing; phase noise and so forth.

Satellite hardware such as low-mass, high-gain, high G/T spacecraft and terminal antennas, multiple data rate robust modems, and compact RF and IF conversion equipment must be developed to support new satellite systems.

14.05 Digital Systems for Satellite Communications
Center: LeRC

Innovative and high leverage technologies are invited that offer significant potential application to NASA's program in support of commercial satellite communications. Advanced digital, optical, and superconductor-based products are invited that support commercial LEO and/or GEO satellite networks, hybrid satellite/terrestrial/wireless networks, autonomous network control, practical, high-performance modulation and coding, and video data compression. Innovative products are sought in the following areas:

Low cost digital components for space or ground segment of LEO and/or GEO satellite networks for integrated fixed/transportable, broadcast and/or wireless communications and information services.

Autonomous network management and control including hardware and software development that would provide decision support and high level interfaces for running test protocols, provide fault diagnostics, test evaluation and data analysis for the space and ground segment.

Burst modulators and demodulators at up to 50 Mbps throughput implemented in either single chip or multi-chip modules.

Low complexity, high-performance, high-speed error corrective codes for bandwidth and power efficient data transmission.

Video data compression techniques, both lossless and lossy, that achieve significant bit rate reductions while preserving high image quality. Particular interest is in low complexity encoder implementations and Pyramid transforms.

Strategic use of superconducting technology for high-speed digital signal processing systems enabling the realization of future system architectures, or targeting critical performance bottlenecks of existing systems. Emphasis should be placed on developing products beyond the component level and include the overhead associated with maintaining the cryogenic environment.

14.06 Deep Space Communications

Center: JPL

NASA deep space planetary, orbiter, and lander communication systems have a number of unique requirements that require technical innovations to meet future performance, mass, and cost objectives for small spacecraft missions. Specifically:

Low-voltage and high-efficiency integrated circuits including MMICs, MMIC filters, and signal processing circuits to implement high-performance space communication receivers to provide carrier tracing, command, and ranging capabilities. Low voltage multifunction MMIC designs with integrated filters are required to provide low noise down-conversion, automatic gain control function, up-conversion and transceiver functions at Ka-band. MMIC modulators to provide large linear phase (+ 2.5 radians) modulation, and high data rate BPSK/QPSK modulation at Ka-band. High-efficiency and high-power (3-10W) solid-state amplifiers for X-band and Ka-band applications.

Miniature ultra-stable oscillator for deep space communication and GPS applications.

Low-mass, high-gain, high G/T antennas that can be integrated into spacecraft surface and that have reconfigurable pattern capabilities for small spacecraft applications.

Microwave and millimeter wave high-temperature superconductor (HTS) technology for steerable antenna concepts, beam-forming networks, and HTS digital and analog data processing subsystems.

Modulation, coding, and network designs for deep space communications to reduce power, bandwidth, and operations requirements.

14.07 Technology for Search and Rescue

Center: GSFC

Distress detection markers. Crash-activated emergency locator transmitters, which must be carried by general aviation aircraft, do not operate in a large percentage of airplane crashes. Visual searches, which must be carried out in such cases, are laborious, often unsuccessful, and must wait for good weather and daylight. Similar problems limit the effectiveness of searches for marine survival craft. NASA's Search and Rescue Mission Office is developing ways to aid in these searches by applying air and spaceborne active and passive remote sensing instruments, including radars operating at UHF through microwave frequencies, and imaging sensors at visible and infrared wavelengths.

As part of this effort, innovative concepts and designs are being sought for passively and inexpensively marking aircraft, vehicles, and boats to greatly enhance target recognition during searches using such sensors. The marking means must be crash-resistant and suitable for widespread application. Proposals must describe the capabilities required of the remote sensing instrument necessary to detect the marking, and the method of applying the marker to aircraft and marine survival craft.

Earthquake survivor detection, location and removal techniques. One of the greatest challenges associated with earthquakes is saving survivors in collapsed structures, especially those constructed using reinforced concrete. Innovative techniques are sought for detecting the presence of live victims under collapsed structures, locating and gaining access to them, providing them with aid and sustenance, and removing them to safety.

15.00 Micro-Gravity Science and Applications

15.01 Materials Science
Center: HQ/LeRC/MSFC

Materials research and development has always been hindered by gravity-induced disturbances and convection currents. In advance of potential space flight demonstrations, NASA provides access and assistance to outside investigators for materials studies and applications to exploit the advantages of microgravity. Innovations are sought for the following areas:

Materials:

- Electronic materials, semiconductors, and solid-state detectors with improved, controlled crystal growth for scientific and commercial applications.
- Metallic alloys with improved grain structures by directional solidification and processing involving supercooling and undercooling states.
- Glasses, ceramics, and optical fibers made by containerless processing to eliminate impurities, to control nucleation sites, and to process reactive melts.
- Ceramic-ceramic composites with innovations in dispersion to decrease tendency to agglomerate in a dry environment.

Equipment, Instrumentation, and Techniques:

- Experimental methods for thermodynamic and transport property measurements in microgravity, including multiphase and complex regimes in crystallization, solute-solvent separation, phase-change and glass-transition separation.
- Processing techniques, including acoustic, electromagnetic, and electrostatic levitation; chemical vapor transport; physical vapor transport; directional solidification; float zone, edge-defined growth.
- Furnace and combustion processing for materials processing.
- Characterization of materials.

Computational Techniques:

- Simulation capabilities that will elucidate the interaction of transport phenomena during processing leading to microstructure and materials properties.
- Experimental design methodologies combining advanced process models, optimization techniques, and advanced controls.
- Models that could be incorporated into standard available transport codes.

15.02 Combustion and Fluid Physics Sciences and Applications
Center: LeRC

The removal of gravity-induced disturbances and convection currents by the low-gravity (microgravity) environment of orbiting spacecraft offers new opportunities for research and technology in fluid and energy transfer. For studies and applications in low gravity, NASA can provide assistance to outside investigators and access to its unique Government facilities, such as the NASA Lewis Research Center Microgravity Materials Research Laboratory, the 27-meter (2.2 sec of low gravity) and 145-meter (5.2 sec) drop towers, and parabolic trajectory airplanes (up to 20 sec) as large as a DC-9. Innovations are sought that exploit the advantages of the microgravity environment including, but are not limited to, the following designs, computational methods, experiments, experimental equipment, technology, and products:

- Combustion science for fundamental studies and for applications to spacecraft energy conversion, power systems, fluid and thermal management, fire safety, and environmental control.
- Fluid physics for fundamental studies and applications to flow systems, droplet dynamics, and interfacial phenomena.
- Instrumentation, sensors, and diagnostics for non-disturbing thermal and flow measurements in microgravity.
- Experiment-related techniques, such as sample preparation, automated processing, high-rate data recording and storage, optimization methodologies, product characterization, and waste-product disposal.
- Techniques to lower the cost or shorten the lead time to develop flight experiments.

15.03 Biotechnology: Molecular Biology and Medical Applications
Center: HQ/JSC

Microgravity provides a unique environment for new methods of processing biological materials that have medical applications or will lead to spinoffs in medicine and biotechnology. Current space research includes new

methods for free-fluid, electric-field purification of living cells or proteins, culture of fragile cells that have applications in biomedical and cancer research, growth of large protein crystals and analysis of the 3-D structure to aid drug designs, and methods for measuring the specific cell and immune functions of persons under environmental or physiological stress. A biotechnology research facility is being planned for future spacecraft. Innovations are sought in biotechnology, cell culture or protein crystal growth systems, such as:

- New methods for culturing live human cells in bioreactors, including miniature flight sensors for measurement of pH, O_2, CO_2, glucose, and process controllers. Methods for purification of living cells or proteins, especially using electric or magnetic fields that avoid thermal convection and sedimentation.

- Advanced protein crystal growth, techniques for: macro-molecular assembly of biological membranes, biopolymers, and molecular bioprocessing systems; microencapsulation of drugs and novel delivery systems; development of biocompatible materials, devices, and sensors for implantable medical applications.

- Quantitative applications of molecular biology, image and flow cytometry, and micro-assays for measurement of cell metabolism, immune cell functions, DNA, intracellular proteins, secretory products, and cytokine or other receptors on the surface of mammalian cells.

- Instrumentation and technology to non-invasively measure the growth, metabolism and bioproduct secretion of a variety of plant and mammalian cell cultures. Specific areas of interest are development of fiber optics or other systems for measuring cellular growth parameters including the pH, glucose, nitrogen, oxygen, and carbon dioxide content and other specific components such as protein secretions from the cells into the culture medium.

- A vapor diffusion/temperature protein crystal growth system that will provide investigators with the ability to increase the size and quality of protein crystals by analyzing the crystal growth rate via dynamically controlled systems for vapor diffusion and temperature-induced crystal growth processes.

- An automated system that can examine crystal growth in each crystal growth chamber and make intelligent decisions regarding the usefulness of these crystals based on size and quality.

15.04 General Microgravity Science Support Technologies

Center: HQ/LeRC/MSFC

Microgravity science experiments conducted in space require general technology support that can apply to more than one type of experiment. Some particular types of innovations required are vibration control for microgravity experiments; automated fluids dispensing, metering and monitoring; and methods for diffusing fluids and gases in microgravity. These are described in more detail below:

Vibrations and transient disturbances from crew motions, thruster firings, umbilicals, and rotating machinery, gravity gradients, and aerodynamic drag cannot be avoided. An isolation system that will successfully function in the range of 1 micro-g at 0.1 Hz will be required along with capabilities to measure low accelerations at low frequency for verification and testing purposes.

Processes and devices are sought that will permit the accurate dispensing, metering and monitoring of fluids in microgravity. Consideration should also be given to incorporating advanced sensors, data logging capability, and computer-based experimental routines so that technical capabilities can be maximized.

Processes and devices are solicited for techniques that will permit the management of two-phase fluids on scales of <10 liters. Examples of such applications include storage and transfer of two-phase liquids, elimination of gases from fluids, and the appropriate mixing of gases and fluids. Concern should be given to the development of robust, lightweight, cost-effective systems that can be adapted to a wide variety of technical applications. Offerors should address the issues of reliability, maintainability, quality, and ease of manufacture. Offerors should also consider the demand for ground-based devices that mirror those used in space laboratories and that are candidates for commercial markets.

FORM 9.A - PROPOSAL COVER

	Subtopic Number	Last 4 digits of Firm's Phone #	Change Letter	
PROPOSAL NUMBER	94-1 _ _._ _	_ _ _ _	_	(Instructions on Reverse Side)

SUBTOPIC TITLE _____

PROJECT TITLE _____

_____

FIRM NAME _____

MAIL ADDRESS _____

CITY/STATE/ZIP _____

PHONE _____

PHASE I AMOUNT REQUESTED: $_____ DURATION: _____ MONTHS

OFFEROR CERTIFIES THAT:

As defined in Section 2 of the Solicitation, this firm qualifies as a:	YES	NO
(a) Small business concern	☐	☐
(b) Socially and economically disadvantaged small business concern	☐	☐
(c) Women-owned small business	☐	☐
The requirements described in Section 3.4.1 are met :		
(d) Limits on subcontracting	☐	☐
(e) Eligibility of the Principal Investigator	☐	☐
(f) Prior federal funding	☐	☐
(g) Proposals to other agencies	☐	☐
(h) Subcontracts and agreements	☐	☐

ENDORSEMENTS:

	Principal Investigator:	Corporate/Business Official:
Typed Name	_____	_____
Title	_____	_____
Signature	_____	_____
Date	_____	_____

PROPRIETARY NOTICE (If Applicable, See Sections 5.4.1 & 5.5)

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.

INSTRUCTIONS FOR COMPLETING PROPOSAL COVER

General--Complete Form 9.A and sign it in ink. Make eight photocopies to use as the cover sheet for each copy of your proposal. Submit the original copy separately. (See Sections 3.2, 3.3, 3.4 and 6.1 for further instructions)

1. **Proposal Number**--This number does not change even if the firm gets a new phone number. Complete the proposal number as follows:

   a. Enter the four-digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

   Example I: A company with telephone number 273-8126 submits one proposal to subtopic 06.03. The proposal number is **06.03-8126.**

   Example II: A company with telephone number 392-4826 submits three different proposals to subtopic 11.03. The proposal numbers are: **11.03-4826, 11.03-4826A, and 11.03-4826B**

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

3. **Project 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. **Firm Name:** 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.

5. **Address:** Enter address where mail is received.
   State: Enter 2-letter designation (example Maine: ME)
   Zip Code: Enter 5- or 9-digit code
   Phone: Enter general phone number of the firm.

6. **Phase I: Amount Requested:** Enter proposal amount from Budget Summary. The amount requested should not exceed $70,000. Round to nearest dollar. **Do not** enter cents. **Duration:** Enter the proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss the reason in the text of the proposal.

7. **Certifications:** Review Section 3.4. Put a check in the appropriate boxes.

8. **Endorsements:** The proposal should be signed by the proposed **Principal Investigator and an official of the firm** qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person. The copy of the cover sheet submitted as the single original should have original signatures.

FORM 9.B - PROJECT SUMMARY

	Subtopic Number	Last 4 digits of Firm's Phone #	Change Letter	
PROPOSAL NUMBER **94-1**	__ __ . __ __	__ __ __ __	__	**(Instructions on Reverse Side)**

PROJECT TITLE

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

NAME AND ADDRESS OF OFFEROR (Firm Name, Mail Address, City/State/Zip)

INSTRUCTIONS FOR PROJECT SUMMARY

1. **Proposal Number**: (See instruction for Form 9.A, Cover Sheet).

2. **Project Title**: Enter the same title as shown on your Proposal Cover.

3. **Technical Abstract**: Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information and must describe the proposed innovation. (See Section 3.4.2.) how it addresses the stated subtopic requirement, the project objectives, the effort proposed, the results anticipated, and the expected NASA applications and benefits.

4. **Potential Commercial Applications**: Summarize the direct or indirect commercial potential of the project, assuming the goals of the proposed research or R&D are achieved.

5. **Name and Address of Offeror**: Enter firm name and mailing address as shown on the Proposal Cover sheet.

FORM 9.C - SBIR PROPOSAL SUMMARY BUDGET

FIRM: PROPOSAL NUMBER:

DIRECT LABOR:

Category	Hours	Rate	Cost $

TOTAL DIRECT LABOR: (1) $

OVERHEAD RATE _____% of Total Direct Labor

OVERHEAD COST: (2) $

OTHER DIRECT COSTS:

Category	Cost $

TOTAL OTHER DIRECT COSTS: (3) $

(1)+(2)+(3)=(4)

SUBTOTAL: (4) $

G&A RATE ____% of Subtotal

G&A COSTS: (5) $

(4)+(5)=(6)

TOTAL COSTS: (6) $

ADD PROFIT or SUBTRACT COST SHARING

PROFIT/COST SHARING: (7) $

(6)+(7)=(8)

AMOUNT REQUESTED: (8) $

This proposal is submitted in response to NASA SBIR Program Solicitation 94-1 and reflects our best estimates as of this date:

NAME AND TITLE (Typed):

SIGNATURE:

DATE:

INSTRUCTIONS FOR SBIR SUMMARY BUDGET

By using this form, the offeror 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. (See Section 3.6 for further information). 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 budget in the proposal. (See below for discussion on various categories)

(1) **Direct Labor**--Enter labor categories (e.g., principal investigator, laboratory assistant, administrative staff), rates of pay and the hours for each labor category.

(2) **Overhead**--Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant federal negotiating agency, if available. If no rate(s) has(have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I that will be subject to approval by NASA. If a current negotiated rate(s) is(are) not available for Phase II, NASA will negotiate an approved rate(s) with the offeror. The offeror may use whatever number and types of overhead rates that are in accordance with the firm's accounting system and approved by the cognizant federal negotiating agency, if available. Multiply Direct Labor by the Overhead Rate to determine the Overhead Cost.

(3) **Other Direct Costs**

a. Materials and Supplies: Indicate types required and estimate costs.
b. Documentation Costs or Page Charges: Estimate cost of preparing and publishing project results.
c. Subcontracts: Include a completed budget--including hours and rates--and justify details. (See Sections 3.5, Part 9 and 5.12 for further information)
d. Consultant Services: Indicate name, daily compensation, and estimated days of service. (See Section 3.5, Part 9 for further information.)
e. Computer Services: Computer equipment leasing is included here.

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

(5) **General and Administrative (G&A)**--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 (overhead) rate may be requested for Phase I that will be subject to approval by NASA. If a current negotiated rate is not available for Phase II, NASA will negotiate an approved rate with the offeror. Multiply (4) Total Direct Cost by the G&A Rate to determine G&A Cost.

(7) **Profit or Cost Sharing**--See Sections 3.6.4, 5.8, and 5.9.

(8) **Amount Requested**--This should exclude any cost-sharing and not exceed $70,000.