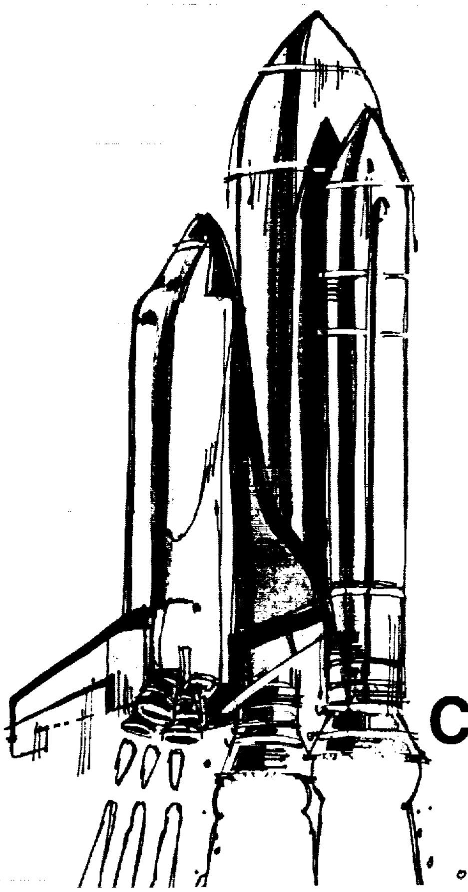
SBIR 89-1

OMB Approval No. 2700-0042

Small Business Innovation Research



Program Solicitation

Closing Date: June 28, 1989

(NASA-TM-101869) SMALL BUSINESS INNOVATION RESEARCH: PROGRAM SOLICITATION (NASA) 108 p CSCL 05A

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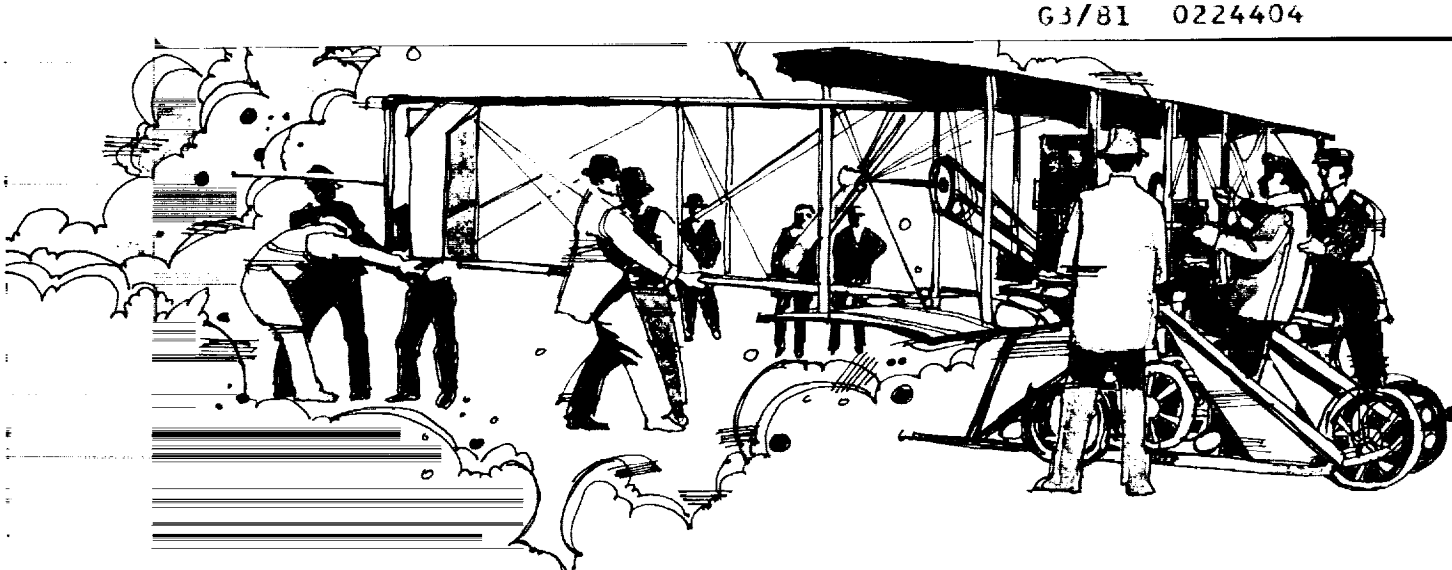

NASA

SBIR PROGRAM
WASHINGTON, D.C.
20546

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) plans, directs, and conducts civil research and development in space and aeronautics.

NASA's goals in space are to develop technology to make operations more effective, to enlarge the range of practical applications of space technology and data, and to investigate the Earth and its immediate surroundings, the natural bodies in our solar system, and the origins and physical processes of the universe. In aeronautics, NASA seeks to improve aerodynamics, structures, engines, and overall performance of aircraft, to make them more efficient, more compatible with the environment, and safer.

NASA SBIR PROGRAM SOLICITATION 89-1

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****** OFFERORS PLEASE READ THESE IMPORTANT NOTICES ******

1. SBIR SOLICITATION REQUIREMENTS VARY AMONG FEDERAL AGENCIES

Offerors are advised that proposals developed for another agency may not be fully responsive to all requirements of this NASA Solicitation.

2. PROPOSALS MUST MEET SOLICITATION REQUIREMENTS

Offerors are advised to read this Solicitation carefully before developing a Phase I proposal and to verify that each proposal conforms to the requirements specified herein, particularly those for which additional emphasis **(bolding)** is indicated. Offerors are also advised that certain requirements in the NASA 1989 Solicitation differ from those in 1988. A check list is provided as Appendix E. Proposals that do not meet all of the requirements of this Solicitation may not be evaluated.

3. INFORMATION REQUESTS MUST BE LIMITED DURING SOLICITATION PERIOD

To insure competitive fairness to all, inquiries for interpretations of the intent or content of Technical Subtopics or for advice on the approach to or content of specific proposals cannot be accepted by NASA Field Installations or Headquarters Offices during the Phase I solicitation period.

4. THERE ARE CONSTRAINTS ON SUBMITTING PROPRIETARY INFORMATION

Information that is included in the Technical Objectives and Work Plan Sections of proposals will NOT be treated as proprietary information to be protected from public disclosure by NASA. Provisions for including proprietary information in SBIR proposals are described in Section 5.4 of this Solicitation.

5. MANDATORY ELIGIBILITY REQUIREMENTS APPLY

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

6. NEW EMPHASIS IS PLACED ON PHASE III POTENTIAL

Two of the major goals of the SBIR legislation are (1) to strengthen the role of small business in meeting Federal R&D needs and (2) to increase the commercialization of innovations developed under or derived from Federally supported research and development programs. It is expected that SBIR offerors will direct their proposed activities toward the achievement of both these goals.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
1989 PROGRAM SOLICITATION
SMALL BUSINESS INNOVATION RESEARCH

1.0 PROGRAM DESCRIPTION

1.1 Summary

The National Aeronautics and Space Administration (NASA) invites small business firms to submit Phase I proposals under its Small Business Innovation Research (SBIR) Program Solicitation 89-1. Firms with research or research and development capabilities in science or engineering in any of the areas listed are encouraged to participate.

This, the seventh annual SBIR solicitation by NASA, describes the program, identifies eligibility requirements, outlines the required proposal format and content, states proposal preparation and submission requirements, describes the proposal evaluation and award selection process, and provides other information to assist those interested in participating in NASA's SBIR program. It also identifies, in Section 8.0 and Appendix D, the Technical Topics and Subtopics in which SBIR Phase I proposals are solicited in 1989. These Topics and Subtopics cover a broad range of current NASA interests, but do not necessarily include all areas in which NASA plans or currently conducts research. High-risk high pay-off innovations are desired.

For planning purposes, NASA expects to select approximately 225 high-quality research or research and development (R/R&D) proposals for Phase I contract awards based on this Solicitation. Phase I contracts are for six months duration and may be funded up to $50,000, including profit. Selections will be based on the competitive merits of the offering and on NASA needs and priorities.

For planning purposes, NASA anticipates that approximately 50 percent of the Phase I projects – those deemed to have highest feasibility and greatest value to NASA – will be selected competitively for further development under Phase II continuations. The Phase II period of performance and funding will depend on the project scope, but will normally not exceed 24 months and $500,000. Phase II competition is limited to Phase I contractors.

1.2 Program Features

Legislative Basis. The "Small Business Innovation Development Act of 1982," 15 U.S.C. 638, P.L. 97-219 was enacted July 22, 1982 and was re-authorized by P.L. 99-443 on October 6, 1986. SBIR Program Guidelines are provided by the Small Business Administration Policy Directive for SBIR whose current revision became effective on June 28, 1988.

Objectives. SBIR program objectives include stimulating technological innovation in the private sector, strengthening the role of small business in meeting Federal research and development needs, increasing the commercial application of Federally supported research results, and fostering and encouraging participation by minority and disadvantaged persons in technological innovation.

Program Conduct. Participating agencies conduct SBIR programs by reserving 1.25 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 below. Each agency, at its sole discretion, selects the Technical Topics and Subtopics included in its Solicitation, chooses its SBIR awardees, and may decide to make several awards or no awards under any subtopic.

Funding Agreements. The funding agreements used by NASA in both Phase I and Phase II programs are contracts rather than grants or cooperative agreements. All contract awards are subject to the availability of Federal Government funds.

1.3 Three-Phase SBIR Program

Phase I. Project objectives in Phase I are to establish the feasibility and merit of an innovative scientific or technical concept proposed in response to an opportunity or agency need stated in a subtopic of this Solicitation. Projects may be experimental or theoretical in nature. Concepts proposed must be useful to NASA and should also suggest either direct or indirect commercial applications of end results (potential Phase III pursuits).

To reduce the time and cost for small firms in preparing a responsive proposal under this Solicitation, **the entire Phase I proposal is limited to 25 – 8½ x 11 inch pages, including all forms and any attachments or enclosures.**

The proposal should concentrate on means to establish or demonstrate the scientific or technical feasibility of the proposed innovation to justify further NASA support in Phase II.

Evaluation and selection criteria, which are described in Section 4.1 of this Solicitation, concentrate on technical merit and innovativeness, value to NASA and to the economy, and the ability of the proposer to conduct the research.

Phase I funding agreements with NASA are fixed-price contract awards. Simplified contract documentation is employed. Price competition is not usually a factor in Phase I within the $50,000 funding limitation, since the basis of selection among the best proposals will be value to the Government in terms of the stated evaluation criteria and NASA priorities. NASA alone is responsible for those determinations.

Successful offerors will have up to six months to complete their Phase I research and 30 days in which to submit their Phase I final reports. Phase I contractors competing for Phase II must meet the Phase II proposal schedule provided by the NASA Installation requesting their Phase II proposals. The Phase I final report is required to accompany the Phase II proposal because of its importance in Phase II evaluations.

Phase II. This SBIR phase is the principal research effort. Its purpose is to continue the development of the most promising innovations among the Phase I projects in an effort to achieve results most useful to NASA at their completion and which, it is hoped, may have even more far reaching values to the economy. Competition for Phase II continuations is limited to Phase I performers satisfactorily completing Phase I projects who meet all SBIR eligibility requirements and from whom NASA Installations have requested Phase II proposals. Phase II awards are expected to be made during 1990 to continue projects whose Phase I results suggest highest technical feasibility, merit, and NASA priority. Phase II award funding may be for as much as $500,000. Phase II periods of performance do not usually exceed 24 months.

Phase II proposals are more comprehensive than those required for Phase I and are not page-limited. They are prepared in accordance with instructions provided by the contracting NASA Field Installations after the Phase I contracts are awarded.

Selection for Phase II awards is based on criteria similar to those for Phase I and are outlined in Section 4.2 of this Solicitation, but in addition include evaluations of the results of the Phase I project and contractor performance. Proposed Phase II cost is an unscored selection factor based on NASA's judgments of cost-value and effectiveness. Selections also depend on NASA program priorities and availability of funds.

For Phase II proposals determined to be suitable for award and to have essentially equal merit, NASA will give special consideration to those which have obtained valid non-Federal funding commitments for Phase III activities. The Phase III commitment is described in Section 4.2-c of this Solicitation.

Phase III. This activity consists of (1) the pursuit of commercial applications of the results of SBIR Phase I and Phase II research by the small business, using non-Federal capital, or (2) continued Federal Government support of the research or acquisition of end products for government use, or both activities, where appropriate. SBIR set-aside funds will not be used to support Phase III activities. Offerors are encouraged to seek non-Federal funding commitments and to secure them prior to NASA's completion of Phase II proposal evaluations, since such commitments can be key considerations in Phase II selections for award. Further details on the Phase III commitment will be provided to those selected for Phase I awards.

1.4 Eligibility To Participate in SBIR

Small Business. Only firms qualifying as Small Businesses as stated 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 Minority and Disadvantaged Small Business (see Section 2.3) or as a Women-Owned Small Business (see Section 2.6).

Place of Performance. For both Phase I and II, the R/R&D must be performed in the United States (see Section 2.5), unless specifically approved by NASA.

Principal Investigator. The Principal Investigator (PI) is always presumed to be key to the success of an SBIR project. Due to the central role of the PI in a project, Co-Principal Investigators are not acceptable to NASA. The PI must possess the requisite technical competence and authority to plan and guide the proposed research, must make a substantial contribution to its conduct if the project is selected for award and in fact perform the activities specified and provide the time committed in the proposal for that effort. After an award is made, any substitution of an approved Principal Investigator may be made only with NASA's consent.

The primary employment of the principal investigator must be with the small business firm at the time of contract award and during the conduct of the proposed research. Primary employment means that more than one-half of the principal investigator's time is spent in the employ of the small business. Primary employment with the small business precludes full-time employment or full-time student status in an academic institution during the conduct of the SBIR project. If a principal investigator is employed by an academic institution in a tenured position or on a tenure track, he or she is considered a fulltime employee of that institution regardless of consulting, part-time or summer employment. Leaves of absence, sabbaticals, or other release time from an academic institution will not influence the determination of primary employment unless the periods of such release are for the full Phase I and Phase II periods of performance.

If the primary employment of a principal investigator is not clear, NASA may require verification by the current employing institution before a proposal is accepted for evaluation and/or before an award is made. Should appropriate verification not be provided, such a proposal would become nonresponsive to this solicitation and would be returned to the proposer without evaluation or award.

1.5 General Information

Relevance of the Proposed Innovation. Each proposal must be based on an innovative, original concept relevant to a NASA program need or opportunity identified in a subtopic listed in Appendix D of this Solicitation, and it may be submitted under only one subtopic (see Section 5.14-d). Proposals must conform to the format and requirements described under Section 3 of this Solicitation.

Questions about this Solicitation. For competitive fairness to all offerors, all communications regarding this Solicitation during the Phase I proposal preparation period are restricted to requests for clarification of solicitation instructions. Inquiries must be submitted in writing to the address below:

Mr. John A. Glaab
SBIR Program Manager
Code CR
National Aeronautics and
Space Administration
Washington, DC 20546

Attn: 89-1 Question

Additional Copies of this Solicitation may be ordered by writing the SBIR Program Manager at the address listed above. No telephone requests will be accepted.

Questions Regarding Proposal Status. Evaluation and selection of proposals for contract award will require approximately four to six months. No information on proposal status will be available until the final selection is made, except for NASA's postal confirmation of receipt of proposal as noted in Section 6.5 of this Solicitation.

General Questions about the SBIR Program. Questions about NASA's SBIR Program which do not pertain to this Solicitation or for copies of the Solicitation may be submitted to either Harry W. Johnson, SBIR Director, or John A. Glaab, SBIR Program Manager, at the above address or the offerer should telephone the SBIR Program Inquiry telephone number, 202-453-2649, giving 1) company name; 2) full 1989 proposal number (example: NASA 89-1-04.06-9876A); 3) company address and telephone number; 4) whom to contact; 5) date and time the call placed to NASA; and 6) the specific inquiry. Please note that unintelligible or incomplete information cannot be handled.

Scientific and Technical Information. Information sources on NASA R/R&D programsinclude NASA Industrial Application Centers and the National Technical Information Ser-vice. Their addresses are included in Section 7.0 of this Solicitation. **NASA assumes no responsibility for any information these organizations may provide in response to requests for their interpretations of the content or intent of technical subtopics in this Solicitation, or for assistance on proposals.**

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, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

2.2 Small Business - A concern that, at the time of award of Phase I and Phase II -

- 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, 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 defined in 13 CFR 121.2(b). Business concerns include, but are not limited to, a sole proprietorship, partnership, corporation, joint venture, association or cooperative.

2.3 Minority and Disadvantaged Small Business Concerns - A small business concern that (1) is at least 51 percent owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business having at least 51 percent of its stock owned by one or more socially and economically disadvantaged individuals, and (2) has its management and daily business controlled by one or more such individuals.

Minority and disadvantaged individuals include members of any of the following groups: Black Americans; Hispanic Americans; Native Americans (American Indians, Eskimos, Aleuts, and native Hawaiians); Asian-Pacific Americans; and subcontinent Asian Americans.

2.4 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 day-to-day management.

2.5 United States – The 50 states, the District of Columbia, the Territories and possessions of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands, and the Trust Territory of the Pacific Islands.

2.6 Subcontract – Any agreement, other than one involving an employer-employee relationship, entered into by a Federal Government contractor calling for supplies or services required solely for the performance of the original contract. See also Sections 3.3.D-9 and 5.12 of this Solicitation.

2.7 Innovation – Innovation in the context of the NASA SBIR program includes, but is not limited to, invention. It encompasses new, original and imaginative approaches to the solution of new and old problems, evolutionary and revolutionary improvements or advances to existing technology, exploitation of new technological opportunities, and some limited aspects of basic research when such objectives are stated in the technical subtopics.

Proposals for surveys, studies, and conventional applications of engineering design, development or testing of products which do not meet these innovation criteria will not be evaluated in the SBIR program. NASA would expect to procure such activities and products through other means.

3.0 PHASE I PROPOSAL CONTENT AND PREPARATION REQUIREMENTS

3.1 Proposal Objectives and Considerations

The purpose of a Phase I proposal under the SBIR Program is to provide sufficient information to persuade NASA that the proposed work represents a sound approach to the investigation of an important scientific or engineering innovation of interest to NASA and is worthy of support under the stated selection criteria. A proposal should be self-contained and written with the care and thoroughness accorded papers for publication.

Important considerations include the following:

- SBIR proposals must be limited to activities requiring significant scientific or technical innovation R/R&D, either experimental or theoretical. They may or may not involve construction and evaluation of a laboratory prototype, but each project must develop specific end products or results for delivery at the conclusion of the project which may include data, reports, hardware and software programs.
- Scientific or technical merit of the proposed innovation and its value to the NASA program are primary factors without which no award would be made.
- An SBIR proposal may respond to only one of the subtopics in Appendix D, (see Section 5.14-d) and must address a NASA program objective or opportunity described therein. Desirably, the proposed innovation should also serve as the basis, directly or indirectly, for new commercial products, processes, or services which may benefit the general economy.
- Proposals directed toward market research or the commercial development of existing products or concepts, whether new or proven – proprietary, patented or otherwise – should not be submitted for SBIR support. Such activities are considered responsibilities of the private sector and may not be funded by SBIR.

3.2 General Requirements

Page Limitation. Phase I SBIR proposals shall not exceed a total of 25 standard 8-1/2" x 11" pages consisting of the cover page (Appendix A form in this Solicitation), project summary (Appendix C form in this Solicitation), the technical proposal, the proposed budget (Appendix B form in this Solicitation), and any other enclosures, attachments or addendum the offeror provides. Each page shall be numbered consecutively at the center, bottom. All material supplied will be included in the page count except the check list (Appendix E in this Solicitation). **Proposals exceeding the 25 page limitation will be returned without consideration.**

Type Size. No type size is to be smaller than elite except as legends on reduced drawings, but not tables. Pages are to be printed on one side only, single or double spaced.

Brevity is Desired. The proposal should be direct, concise, and informative. Promotional and non-project-related material should not be included. **Offerors are requested not to use the entire 25 page allowance unless that is actually necessary. Appropriate brevity facilitates proposal evaluations.**

Content and Format. All required items of information are to be covered fully and in the order set forth in Section 3.3 of this Solicitation, but the space allocated to each will depend on the project chosen and the Principal Investigator's approach.

NASA Use of Optical Character Readers. To facilitate proposal processing, NASA intends to employ optical character readers to record proposal cover sheet and project summary information wherever possible. Therefore it is required that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed very carefully on the indicated lines using one of the following type styles:

COURIER 12 10 or 12 PITCH
COURIER 72 10 PITCH
ELITE 72
LETTER GOTHIC 10 or 12 PITCH
OCR-B 10 or 12 PITCH
PICA 72 10 PITCH
PRESTIGE ELITE 10 or 12 PITCH
PRESTIGE PICA 10 PITCH

IMPORTANT: Do Not Use Proportional Spacing on Appendixes A and B

Check List. A check list (Appendix E in this Solicitation) is provided to assist the offeror. One copy of Appendix E is to be completed and included with the original signed copies of Appendixes A and B as noted in Section 6.1 of this Solicitation. The Check List is not counted as a proposal page.

3.3 Required Phase I Proposal Format

The format required for all Phase I proposals is provided herewith. **Proposals will consist of Parts (A) through (E)**, below, but may also include supplementary information (included in the total page count) at the option of the offeror. **Part D** is further subdivided into Sections. All Parts and Sections must follow in the stated order. **All proposal Parts and Sections must be addressed.**

Part A. Cover Sheet. The offeror shall include a photocopy of the signed original cover sheet (Appendix A in this Solicitation) as page 1 of each copy of the proposal. No other cover sheet is permitted. The proposal title must be concise and descriptive, but must not be stated as an acronym.

Part B. Project Summary. The offeror shall include a photocopy of the signed original project summary (Appendix B in this Solicitation) as page 2 of each copy of the proposal. The technical abstract section should include a brief description of the proposed innovation and how it addresses the stated subtopic problem or opportunity, the project objectives, and a description of the effort proposed and results anticipated. In summarizing anticipated results, the expected NASA applications and benefits and any potential commercial applications shall be identified. **The project summary of successful proposals will be published by NASA, therefore NO information provided on Appendix B will be treated as proprietary information by NASA.**

Part C. Table of Contents. Page 3 of the proposal shall begin with a brief Table of Contents indicating the presence and page numbers of each of the Parts and Sections of the proposal.

Part D. Technical Proposal. The Technical Proposal shall consist of the following **eleven Sections** and may begin immediately after the Table of Contents. **Entries are required in each of these Sections.**

1. Identification and Significance of the Innovation. The first paragraph shall contain a clear and succinct statement of the specific **innovation** proposed, why it is an innovation, and how it is relevant and important to meeting the need or opportunity described in the subtopic. The paragraph shall contain no more than 150 words. **NASA reserves the right to refuse proposals which lack this introductory paragraph.**

This Section of the proposal may also include appropriate background and elaboration to explain the proposed innovation and its value to NASA.

2. Phase I Technical Objectives. This Section shall include the specific objectives of the Phase I effort and state the technical questions the offeror will try to answer to determine the feasibility of the proposed approach and outcome.

This Section will also explain why the expected Phase I results should warrant Phase II continuation, and state very briefly the anticipated Phase II objectives and accomplishments which are to be amplified within Section 3.3.D.5, below: Relationship to Phase II or other Future R/R&D.

3. Phase I Work Plan. This Section should be comprehensive and explanatory, normally constituting approximately one-third of the total proposal. It shall include a detailed description of the proposed Phase I activities indicating what will be done and where the work will be carried out in addressing the stated objectives and questions cited in Section 3.3.D.2. 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.

In every proposal, the Phase I Work Plan must be a complete, stand-alone document. **NASA must treat all information included in this Section as public information if the proposal is selected for contract award.** See Section 5.4-a of this Solicitation for instructions on including Proprietary Information in an SBIR proposal as a separate Section entitled "Proprietary Addendum," and what must be done to protect such information from public disclosure.

4. Related R/R&D and Bibliography of Related Work. The purpose of this Section is to persuade reviewers of the offeror's awareness of key recent developments by others in the specific subject area. It should describe any significant R/R&D that is directly related to the proposal (noting any conducted by the Principal Investigator or by the offeror's firm) and how it relates to the proposed effort, also indicating any planned coordination with outside sources during the course of the proposed research.

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.**

5. Relationship with Phase II or other Future R/R&D. This Section shall elaborate the Phase II Technical Objectives and expected results previously summarized under Section 2 (Phase I Work Plan), and discuss the significance of the Phase I effort to further justify the expected scope, results and NASA applications of a Phase II continuation. Any other planned R/R&D related to this proposal should also be noted.

6. Potential Commercial Applications. Commercialization of the results of research innovations supported by Federal R&D is an important SBIR goal. Offerors shall discuss whether the results or products of their proposed innovation research have potential direct or indirect commercial applications, and include their intentions and/or plans, if any, to pursue commercialization if the research effort through Phase II is successful. Applications of the results or products for use by the Federal Government shall have been described in Section 5, above.

7. Company Information. This section will provide information needed by evaluators to assess the ability of the firm to carry out the proposed Phase I and projected Phase II activities. While extensive background or experience is not a prerequisite for an SBIR award, the ability of the offeror to perform the proposed activities must be established before an award would be made.

A description of the firm's business organization, operations, R/R&D capabilities and experience is to be provided if it has such a history. All firms, including start-up firms are requested to outline their business objectives or plans in which this SBIR project would fit.

This Section must also provide a description of the firm's physical facilities, instrumentation and equipment pertinent to the proposed research. If facilities, equipment and instrumentation needed for the proposed research are not presently available, the offeror must explain how they are to be obtained.

As a general rule, NASA will not fund the purchase of equipment or instrumentation (or acquisition of facilities) under SBIR Phase I contracts. If such purchases are authorized, ownership is vested in the US Government. Refer also to Part E, below.

8. Key Company Personnel. This Section shall identify the key company employees to be committed to Phase I activities, including the Principal Investigator and other individuals whose expertise is essential to the success of the research. Their directly related education, experience and bibliographic information is required. Offerors are requested to avoid extensive vitae and publication lists not pertinent to the proposed research.

This Section shall also establish the Principal Investigator's eligibility (see Section 1.4 of this Solicitation) and indicate the extent to which (1) other proposals recently submitted or planned to be submitted in 1989, and (2) existing projects for which he/she is identified as PI commit his/her time concurrently with this proposed activity.

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, non-profit organizations and individual consultants (see Section 5.12 of this Solicitation). Subcontracting is encouraged when it enhances the ability of the firm to write a better proposal, conduct more valuable research, and improve its prospects for commercial success.

This section must describe any subcontracting requirements and identify the organizations and individuals with whom subcontracts are planned. Generally, these arrangements will be viewed as key to the success of the work, so the expertise to be subcontracted must be described in detail as well as descriptions of the functions, services, time intervals and extent of effort to be provided.

The proposal must include an agreement by each subcontracting organization and individual consultant that they will be available at the times required for the purposes and extent of effort described in the proposal.

10. Related Proposals to and Awards from Other Agencies. Whenever the offeror (a) has received Federal Government awards for related work, or (b) has submitted proposals for essentially equivalent or similar work under other Federal Government program solicitations, or (c) intends to submit proposals for such work to other agencies during 1989, those awards, proposals and intentions shall be identified. A statement must be included indicating:

(1) The agencies to which proposals were submitted or from which awards were received.

(2) Date of proposal submission or date of award.

(3) Solicitations under which proposals were submitted or awards received.

(4) The specific research topic for each proposal submitted or awards received.

(5) Titles of research projects.

(6) Name and title of principal investigator for each proposal submitted or award received.

(7) Intended proposal submissions in 1989.

NOTE: If no such awards have been received, or proposals submitted or intended, the offeror shall so state.

11. Previous NASA SBIR Awards Received. Offerors who have received previous NASA SBIR awards shall include a list of contract numbers, indicating for each the year of award, and the NASA installation making the award. If no NASA awards have been received, the offeror shall so state.

Part E. Proposed Budget. Offerors shall complete Appendix C, SBIR Summary Budget, and include it (and any budget explanation sheets if needed) as the last page(s) of the proposal. Items on Appendix C that may not apply to the proposed project may be omitted. What matters is that enough information is available to allow NASA to understand how the offeror plans to use the requested funds and business-like evidence that the proposed budget is realistic and cost-effective. Special attention is directed to the following items:

- **Title to all property.** Because NASA will not normally fund instrumentation, equipment or facility acquisition under Phase I, the inclusion of such items should be avoided in proposed budgets, and must be fully justified if included. Any inclusion of property will be carefully reviewed relative to need and appropriateness for the research proposed.

Equipment is defined as an article of non-expendable, tangible, personal property having a useful life of more than one year and an acquisition cost of $1,000 or more per unit. Title to all property (including equipment) acquired under an SBIR contract will be vested with NASA unless it is determined that transfer of title to the contractor would be more cost effective than recovery of the property by NASA.

It should be noted that prototypes, working models and devices, measurement instrumentation and test apparatus built under NASA SBIR contracts and which cost more than $1000 per unit to develop are normally considered to be equipment owned and deliverable to NASA. Proposals should clarify the Offeror's expectations or plans, if any, for future use and possible ownership of such items to avoid possible future misunderstandings.

- **Travel.** Budgets for travel funds are not normally acceptable, but if proposed must be justified as essential to the conduct of the project.

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

NOTE: Detailed instructions for completing Appendixes A, B and C are printed on their reverse sides.

4.0 PROPOSAL EVALUATION AND AWARD SELECTION

4.1 Phase I

a. Evaluation and Selection. The initial step is screening for compliance with administrative requirements of the Solicitation. Proposals which pass that screening are then reviewed to determine whether they respond to the subtopic chosen by the offeror. Those found to be responsive are evaluated in greater depth by two or more scientists and engineers at the NASA Installation responsible for the research, using the criteria listed below.

Evaluators base their conclusions only on information contained in the proposal. Offerors should not assume that evaluators are acquainted with the firm or key individuals or with any experiments or other information referred to but not described in referenced professional journals. To be of any value in this process, relevant information must be identified in proposal Section D-4.

Each proposal is judged and scored on its own merits using a uniform scoring procedure, then ranked relative to all others evaluated under the same subtopic. Those considered suitable for award selection are recommended for further consideration by the Installation SBIR Committee, who prepare final recommendations for awards in rank order, based on proposal merit, program balance and Installation priorities, which are then forwarded to NASA Headquarters for final selection decisions which take into consideration the recommendations from all Installations and overall NASA priorities and program balance. Proposals judged to have the highest merit and value to NASA will be selected for award.

Proposals are evaluated at the NASA Installation cited in the Solicitation subtopic, but other NASA Installations may also conduct evaluations and make recommendations for award selections of any proposals received by NASA in this Solicitation.

In the evaluation and handling of proposals, NASA will make every effort to protect the confidentiality of the proposals and their evaluations. NASA reserves the right to use outside evaluators at its discretion (refer to Solicitation Section 5.4-b).

b. Phase I Evaluation Criteria. NASA plans to select proposals for award which offer the best value to the Government, giving approximately equal consideration to each of the following four criteria except for the first, which has twice the weight of each other item:

1. **Scientific/technical merit** of (a) the proposed innovation and its relevance to the needs stated in the selected subtopic, and (b) the proposal's statement of objectives and approach for addressing questions of feasibility. Special emphasis is given to innovativeness and originality.

2. **Qualifications** of the principal investigator, other key staff, and consultants, if any, and the adequacy of available or obtainable instrumentation and facilities.

3. **Anticipated benefits** (technical and/or economic) to the NASA mission through applications subsequent to Phase II, and the potential for direct or derived commercial applications of the expected results or products if the research is successful.

4. **Soundness and technical merit of the proposed work plan** including its likelihood of meeting the Phase I objective of establishing the feasibility and merit of the proposed innovation as a basis for Phase II continuation.

4.2 Phase II

The NASA Installations awarding the Phase I contracts will provide to the Phase I contractors from whom Phase II proposals are to be solicited; instructions regarding Phase II proposal submission, the relative importance of the evaluation factors to be employed, the date when Phase II proposals must be submitted (usually, one month after the end of the Phase I performance period), and other information to facilitate their compliance with Phase II requirements.

a. Evaluation and Selection. Phase II proposals undergo a technical review and competitive selection process in greater depth than Phase I proposals. As in Phase I, the Phase II proposals are evaluated by the NASA Installations responsible for the research using uniform evaluation procedures and the criteria noted below. Proposals are then ranked by the Installation SBIR Committee taking into consideration overall quality, value to NASA, and Installation program balance. Recommendations are forwarded to NASA Headquarters for final consideration with the recommendations made by all Installations.

Final selections take into consideration overall NASA programmatic or schedule requirements and availability of funds. Special consideration is also given to acceptable proposals of essentially equivalent merit which are accompanied by valid non-Federal funding commitments for Phase III activities.

At its discretion NASA may initiate early negotiations for a Phase II award at any time after the proposal has been received.

b. Phase II Evaluation Criteria. Evaluation criteria for Phase II proposals include:

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

2. **Results of Phase I,** including feasibility of the innovation and how well the results support current NASA program priorities.

3. **Future Importance and Eventual Value** of the product, process or technology results to the mission of NASA after completion of Phase II. The potential for commercial applications of the expected research results or products if the research is successful, as described in the proposal, will also be considered.

4. **Ability of the Small Firm.** NASA will assess the ability of the firm 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.

c. Non-Federal Commitments for Phase III Funding. Valid non-Federal capital commitments for Phase III follow-on activities may be contingent on the outcome of Phase II and on other stated circumstances, but must provide that a specific, substantial amount (usually at least half the Phase II funding request) will be made available to the firm for Phase III and indicate the source and date or conditions under which the funds will be made available. Realistic, substantial self-commitments by the firm can also qualify.

Valid commitments must be provided as brief letters to the proposing firms from the organization making the commitments. Preferably, they should accompany the Phase II proposal but they may be considered up until final Phase II award decisions have been made by NASA. It should be noted that mere expressions of technical interest in the outcome of the Phase II research, or of potential future financial interest by a third party do not constitute valid Phase III commitments and will not be accepted as such by NASA.

4.3 Debriefing of Unsuccessful Proposals

After final Phase I and Phase II award decisions have been announced, a debriefing of an unsuccessful offeror's proposal may be provided – to the offeror only – upon written request. No telephonic requests for debriefings will be accepted. Debriefings are not opportunities to re-open award decisions. They are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal and perhaps to provide suggestions for constructive future action by the offeror.

Debriefings will not disclose the identity of the proposal evaluators and NASA will provide the evaluators' verbatim comments in the course of debriefings only at its option. Such information is exempt from Freedom of Information disclosure, as are proposal scores, proposal rankings in the competition, and the content of and comparisons with other proposals with which they were in competition.

Phase I. For Phase I proposals, all requests for debriefing must be directed in writing to the SBIR Program Manager, NASA Headquarters, within 45 days after notification has been mailed to the Offeror that the proposal was not selected for award. When feasible to do so, oral (telephonic) debriefings will be provided; otherwise written debriefing comments will be mailed.

Phase II. To request debriefings on Phase II proposals, proposers must contact the SBIR Procurement Officer at the NASA Installation responsible for their Phase I contract.

5.0 CONSIDERATIONS

5.1 Awards

In October 1989, NASA expects to announce the selection of approximately 225 proposals for negotiation of profit-bearing, fixed-price Phase I contracts with values ranging up to $50,000. Following contract negotiations and awards, Phase I contractors will usually have six months to carry out their proposed Phase I programs.

For planning purposes only, NASA anticipates that during 1990 approximately 50 percent of the Phase I projects may 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 may be either fixed-price or cost-plus-fixed fee contracts. Phase II performance periods normally will not exceed 24 months with funding not exceeding $500,000.

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.

5.2 Reports

Six (original plus five (5)) copies of a final report on the Phase I project must be submitted to NASA within 30 days after completion of the Phase I research effort. The final report shall include a single-page project summary as the first page, on a form to be 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 results through Phase II both for NASA purposes and for commercial potential will also be included. The project summary is to be submitted without restriction for NASA publication. The balance of the report shall elaborate the project objectives, work carried out, results obtained, and estimates of technical feasibility. Rights to this data shall be in accordance with the policies set forth in Section 5.5.

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

5.3 Payment Schedule

Payments on Phase I contracts may be invoiced 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. Payments will be made 30 days after receipt of valid invoices.

5.4 Treatment and Protection of Proposal Information

a. Proprietary Information. It is NASA policy to use information (data) included in proposals for evaluation purposes only and to protect such information from unauthorized use or disclosure. While this policy does not require that the proposal bear a notice, protection can be assured only to the extent that an appropriate "Notice" set forth in the clause of the NASA FAR Supplement at 18-52.215-72, Restriction on Use and Disclosure of Proposal and Quotation Information (Data) is applied to the data which constitute trade secrets or other information that is commercial or financial and confidential or privileged, as follows:

"NOTICE: No proprietary information is included except in a Proprietary Addendum. The information (data) on pages ________ in the Proprietary Addendum Section of this proposal constitute a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, in the event a contract is awarded on this proposal, the Government may obtain additional rights to use and disclose this information (data)."

Other information will be afforded protection to the extent permitted by law, but NASA assumes no liability for use and disclosure of information to which the "Notice" has not been appropriately applied.

The offerer should also note that the above notice is printed on the proposal cover page to alert NASA to the presence of a "Proprietary Addendum" if one is included. **Proposals indicating that other Sections contain proprietary information will not be evaluated.**

b. 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 scientists and engineers 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 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.

c. Release of Proposal Information. It is NASA's practice to notify the offeror of the proposal before releasing any information (data) contained therein pursuant to a request under the Freedom of Information Act (5 U.S.C. 552) and, time permitting, to consult with the offeror to obtain assistance in determining the eligibility of the information (data) in question as an exemption under the Act.

d. Final Disposition of Proposals. The Government retains ownership of the physical copies of proposals accepted for evaluation while considering proposal information (data) ownership to be the offeror's (subject to any content that would be available to the public under the Freedom of Information Act, as noted above).

Phase I proposals found during initial screening to be unacceptable for review will be returned to the offeror.

NASA will retain copies of all proposals evaluated for one year after the announcement of Phase I awards, after which time those which were not selected for award will be destroyed. Copies of proposals selected for award will be retained for the duration of Phase I and any subsequent Phase II activities, and will then be archived (normally on microfiche cards) and the original documents destroyed.

e. Nominal Disclosure. By submission of a proposal, the offeror agrees to permit the Government to disclose publicly only the title of its proposed project and the name, address and telephone number of the designated official of the proposing firm.

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. Such clause provides for rights consistent with the following:

a. 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.

b. In keeping with NASA's policy, data that constitute trade secrets or other information that is commercial or financial and confidential or privileged **and 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 reprocurement purposes.

c. Other than as required by (a) above, rights in technical data including software developed under the terms of any funding agreement resulting from proposals submitted in response to this Solicitation shall remain with the contractor, except that the Government shall have the limited right to use such data for Government purposes and shall not release such data outside the Government without permission of the contractor for a period of two years from completion of the project from which the data were generated, i.e., after completion of Phase II if the Phase I project receives Phase II funding. However, effective at the conclusion of the two-year period, the Government shall retain a royalty-free license for Government use of any technical data delivered under an SBIR contract whether patented or not, but (except per (b) above) is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of the data by third parties.

5.6 Copyrights

Contractors will be permitted (in accordance with paragraph (c) of the clause at FAR 52.227-20) to assert or establish claim to copyright data first produced under a Phase I or Phase II contract, subject to a paid-up, nonexclusive, irrevocable, worldwide license for Governmental purposes. The contractor is required to include an appropriate credit line acknowledging Government support for any works published under copyrights.

5.7 Patents

The contractor will, as provided in the clause at FAR 52.227-11, Patent Rights--Retention by Contractor (Short Form), have first option to retain title to inventions made in the performance of any Phase I or Phase II contract in accordance with P.L. 96-517 (35 U.S.C.

200, et. seq.). This option is subject to the reservations and limitations, including a non-exclusive, royalty-free, irrevocable license in the Government and certain march-in rights to assure commercialization, as required by 35 U.S.C. 203 and implementing regulations thereunder.

Whenever an invention is made and reported under any NASA contract, it is NASA policy to withhold such report from disclosure to the public and to use reasonable efforts to withhold other information which may disclose the invention (provided that NASA is notified of the information and the invention to which it relates) for a reasonable time to allow the contractor to obtain patent protection as authorized by 35 U.S.C. 205.

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.

5.9 Profit or Fee

Both Phase I and Phase II SBIR contracts may include a reasonable profit or fee in the total contract award.

5.10 Joint Ventures and Limited Partnerships

Both joint ventures and limited partnerships are permitted, provided the entity created qualifies as a small business in accordance with the definition in Section 2.2.

5.11 Similar Proposals and Prior Work

Submission of related proposals to and receipt of related awards from other agencies, intentions to submit related proposals during to 1989 to other agencies, and prior NASA SBIR awards received by the offeror must be identified in the Technical Proposal Sections D-10 and D-11 as noted in Section 3.3 of this Solicitation.

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, nor is currently being, paid for essentially equivalent work by any agency of the Federal Government.

5.12 Limits on Subcontracting Research and Analytical Work

Subcontracts (defined in Section 2.6 of this Solicitation) may be placed with other firms, universities and other non-profit organizations, and with individual consultants, but there are cost limits on subcontracting the research and analytical portions of both Phase I and Phase II contracts:

- For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the proposing firm unless otherwise approved in writing by the contracting officer.
- For Phase II, a minimum of one-half of the research and/or analytical effort must be performed by the proposing firm unless approved in writing by the contracting officer.

The costs of research and analytical effort do not include the SBIR contractor's costs for overhead, general and administrative costs, and profit or fee.

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 general provisions will be made available prior to award.

a. 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.

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

c. 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.

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

e. Termination for Convenience. The contract may be terminated at any time by the Government 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.

f. Disputes. Any dispute concerning the contract that cannot be resolved by mutual agreement shall be decided by the contracting officer with right of appeal.

g. Contract Work Hours. The contractor may not require an employee to work more than 40 hours a week unless the employee is compensated accordingly (that is, receives overtime pay).

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

i. 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.

j. 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.

k. Officials Not to Benefit. No member of or delegate to Congress shall benefit from the contract.

l. 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.

m. 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.

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

5.14 Additional Information

a. Precedence of Contract over Solicitation. This Program Solicitation is intended for informational purposes and 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.

b. 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 assure responsibility of the offeror.

c. 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 89-1 are contingent upon the availability of funds.

d. Multiple Proposal Submissions. An offeror may submit any number of different Phase I proposals on different subtopics, or different proposals on the same subtopic. However, every proposal must be limited to one subtopic. Should the offeror consider a proposal to have relevance to more than one subtopic, the offeror must choose the one under which to submit the proposal. Within that proposal, the discussion of the innovation may identify other subtopics for which the concept is believed relevant; **however, such identification will not insure that the proposal will be evaluated within any subtopic other than the one to which the proposal is addressed, or at NASA installations other than those identified in the subtopic addressed.**

Offerors should be aware that none of any identical or substantially similar proposals submitted in response to this Solicitation, whether to one or to several subtopics, will be evaluated.

e. Classified Proposals. NASA will not accept classified proposals.

f. Unsolicited Proposals. The SBIR Program is not a substitute for existing unsolicited-proposal mechanisms. Unsolicited proposals will not be accepted under the SBIR program in either Phase I or Phase II.

6.0 SUBMISSION OF PROPOSALS

6.1 What to Send

For each Phase I proposal submitted, offerors must submit the following:

a. The **original Cover Sheet** (Appendix A, printed in red ink), bearing the original signatures of the Principal Investigator and an official of the company empowered to commit the offeror. Those pages attached to each of the five proposal copies should be black and white photocopies;

b. The **original Project Summary Sheet** (Appendix B, printed in red ink). Those pages attached to each of the five proposal copies should be black and white photocopies;

c. One (1) **completed Check List** (Appendix E) to be included with the original copies of the cover sheet and Project Summary.

NOTE: DO NOT Staple Items (a), (b) and (c) together!

d. Five (5) photocopies of the entire proposal, complete with cover sheet, project summary and proposed budget (Appendices A, B and C, respectively) and any optional enclosures, attachments and addendum;

6.2 Physical Packaging Requirements

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

Packaging - All items (6.1 a through d) 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 whenever possible.

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

6.3 Where to Send Proposals

Proposals shall be addressed as below:

SBIR Program Manager
Code CR
National Aeronautics and
Space Administration
Washington, DC 20546

Note: No street address is required

Handcarried proposals or proposals delivered by messenger should be delivered to the NASA Headquarters Mailroom, which address is Room A16, Federal Office Building 10B, NASA Headquarters, 600 Independence Avenue, SW, Washington, DC, 20546. Secure packaging is mandatory. NASA cannot be responsible for the processing of proposals damaged in transit.

NOTE: 1. Send packages only to NASA Headquarters.

2. Proposals cannot be received by NASA on Saturdays or Sundays.

6.4 Deadline for Proposal Receipt

Deadline for receipt of Phase I proposals at NASA is 4:00 p.m., EDT, June 28, 1989. NASA assumes no responsibility for evaluating proposals received after the stated deadline or that do not adhere to other requirements of this Solicitation. Offerors are cautioned to be careful of unforseen delays that can cause late arrival of proposals at NASA with the result that they may not be included in the evaluation process. Nevertheless, should actions be deemed to be in the best interests of the Government, NASA reserves the right to accept late proposals or modifications to otherwise acceptable proposals received before the stated deadline. Any such acceptances would be made only under unusual and justifiable circumstances and when such acceptances would not provide unfair competitive advantages to such offerers.

6.5 Acknowledgement of Proposal Receipt

NASA will acknowledge receipt of proposals by a special card mailed to the company official endorsing the proposal cover sheet. If a proposal acknowledgement card is not received from NASA within four weeks following the closing date of this Solicitation, the offeror should telephone 202-453-8702. **NASA will not accept telephone inquiries of acknowledgement of receipt of proposals prior to July 24, 1989.**

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 before award.

7.0 SCIENTIFIC AND TECHNICAL INFORMATION SOURCES

The following organizations can provide technology search and/or document services and can be contacted directly for service and cost information. These include:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600

Aerospace Research Applications Center
Indianapolis Center for Advanced Research
611 N. Capitol Avenue
Indianapolis, IN 46204
(317) 262-5003

Central Industrial Applications Center
Rural Enterprises, Inc.
P.O. Box 1335
Durant, OK 74702
(405) 924-6822

NASA/Southern Technology Applications Center
One Progress Boulevard
P.O. Box 24
Progress Center
Alachua, FL 32615
(904) 462-3913

NASA Industrial Applications Center
823 William Pitt Union
University of Pittsburgh
Pittsburgh, PA 15260
(412) 648-7010

NASA/UK Technology Applications Program
University of Kentucky
109 Kinkead Hall
Lexington, KY 40506-0057
(606) 257-6322

NERAC, Inc.
One Technology Drive
Tolland, CT 06084
(203) 872-7000

NASA Industrial Applications Center
University of Southern California
Research Annex
3716 S. Hope Street Rm 200
Los Angeles, CA 90007-4344
(213) 743-8988

Technology Applications Center
2808 Central, S.E.
University of New Mexico
Albuquerque, NM 87131
(505) 277-3622

Computer Software Management and Information Center
University of Georgia
382 East Broad Street
Athens, GA 30602
(404) 542-3265

North Carolina Science and Technology Research Center
P.O. Box 12235
Research Triangle Park, NC 27709
(919) 549-0671

NASA/SU Industrial Applications Center
Southern University
P.O. Box 9737
Baton Rouge, LA 70813-9737
(504) 771-6272

8.0 TECHNICAL TOPICS

Proposals shall address Subtopics in Appendix D under the following Technical Topics:

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 and Applications
07.00 Information Systems and Data Handling
08.00 Instrumentation and Sensors
09.00 Spacecraft Systems and Subsystems
10.00 Space Power
11.00 Space Propulsion
12.00 Human Habitability and Biology in Space
13.00 Quality Assurance, Safety, and Check-Out for Ground and Space Operations
14.00 Satellite and Space Systems Communications
15.00 Materials Processing, Micro-Gravity, and Commercial Applications in Space

APPENDIX A - PROPOSAL COVER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 89-1 SOLICITATION PROPOSAL COVER
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

		4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
<T>	89-1 <*>	___ . ___	_______	_____

ENTER PROPOSAL NUMBER ON APPENDICES B & C

PROJECT TITLE <*> ____

____

FIRM NAME <*> ____

MAIL ADDRESS <*> ____

CITY <*> ____________________ STATE <*> ______ ZIP CODE <*> ____________

AMOUNT REQUESTED <*> $ __________ (PHASE I) DURATION <*> ______ MONTHS (PHASE I)

OFFEROR CERTIFIES THAT:

	YES	NO
1. As defined in Section 2 of the Solicitation, this firm qualifies as a:		
1.1 Small business	☐	☐
1.2 Minority and disadvantaged small business	☐	☐
1.3 Women-owned small business	☐	☐
NOTE: 1.2 and 1.3 are not eligibility requirements for SBIR and the offeror may decline to indicate status by stating "Decline" across boxes.		
2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made.	☐	☐
3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research.	☐	☐
4 Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency and the details required by Section 5.10 of the Solication are included in the proposal.	☐	☐

ENDORSEMENTS

	Principal Investigator	Corporate/Business Official
Typed Name	<*> ____________________	<*> ____________________
Title	<*> ____________________	<*> ____________________
Telephone No.	<*> ____________________	<*> ____________________

Signature of Principal Investigator ____________________ Date __________

Signature of Corporate/Business Official ____________________ Date __________

PROPRIETARY NOTICE (IF APPLICABLE, SEE SECTION 5.4a, 5.5)

NOTICE: No proprietary information is included except in a Proprietary Addendum. The information (data) on pages __________ in the Proprietary Addendum section of this proposal constitute a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, in the event a contract is awarded on this proposal, the Government may obtain additional rights to use and disclose this information (data).

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

To facilitate proposal processing, NASA intends to employ automated optical devices to record proposal information wherever possible. Towards this end, it is desirable, but not required, that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed without proportional spacing using one of the following typestyles:

Courier 12 10 or 12 pitch
Courier 72 10 pitch
Elite 72
Letter Gothic 10 or 12 pitch
OCR-B 10 or 12 pitch
Pica 72 10 pitch
Prestige Elite 10 or 12 pitch
Prestige Pica 10 pitch

Please complete and ***submit the original red forms*** bound in this solicitation (not photocopies). The completed forms can then be copied for use as pages 1 and 2 of your proposal. The original red forms should be submitted in addition to the five copies of your total proposal (see section 6.2 "Physical Packaging Requirements").

Carefully align the forms in the typewriter using the underlines as a guide. The forms are printed to accommodate standard typewriting spacing.

Appendix A:

1. ***Proposal Number:*** Complete the proposal number as follows:
   a. Enter 4 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: 1. Firm, telephone 273-8126, submits one proposal to subtopic 06.03. Proposal number is: ***06.03 8126.***

Example: 2. Firm, telephone 392-4826, submits three different proposals to subtopic 11.03. Proposal numbers are:

11.03 4826
11.03 4826A
11.03 4826B

2. ***Project Title:*** Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title.
3. ***Firm Name:*** Enter full name of company submitting the proposal. If a joint venture, list company chosen to negotiate and receive contracts. If name exceeds 30 keystrokes, please abbreviate.
4. ***Address:*** Enter mail address.
   State: Enter 2 letter designation (example Maine—ME)
   Zip-Code: Enter 5 or 9 digit code
5. ***Amount Requested:*** Enter proposal amount from budget summary. Round to nearest dollar. ***Do not*** enter cents.
6. ***Duration:*** Enter proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss reason in the text of the proposal.
7. ***Certifications:*** Enter Y for yes or N for no in the appropriate boxes in response to statements or questions.
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.

Appendix B:

1. ***Proposal Number:*** Enter the same proposal number as shown on your Proposal Cover Sheet.
2. ***Project Title:*** Enter the same title as shown on your Proposal Cover Sheet.
3. ***Technical Abstract:*** Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information.
4. ***Potential Commercial Applications of the Research:*** Summarize the commercial potential of the project assuming the results of the proposed research or R&D are achieved.
5. ***Key Words:*** Provide no more than 8 key words descriptive of the project and useful in identifying the technology, research thrust or application of the proposed effort
6. ***Name and Address of Firm:*** Enter firm name and mail address as shown on the Proposal Cover Sheet.
7. ***Principal Investigator:*** Enter name of the Principal Investigator as shown on the Proposal Cover Sheet.

APPENDIX B - PROJECT SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 89-1 SOLICITATION
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
89-1	___ . ___	______	_____

AMOUNT REQUESTED: $

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS OF THE RESEARCH

KEY WORDS
(LIMIT 8)

NAME AND ADDRESS OF OFFEROR

PRINCIPAL INVESTIGATOR

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

To facilitate proposal processing, NASA intends to employ automated optical devices to record proposal information wherever possible. Towards this end, it is desirable, but not required, that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed without proportional spacing using one of the following typestyles:

Courier 12 10 or 12 pitch
Courier 72 10 pitch
Elite 72
Letter Gothic 10 or 12 pitch
OCR-B 10 or 12 pitch
Pica 72 10 pitch
Prestige Elite 10 or 12 pitch
Prestige Pica 10 pitch

Please complete and ***submit the original red forms*** bound in this solicitation (not photocopies). The completed forms can then be copied for use as pages 1 and 2 of your proposal. The original red forms should be submitted in addition to the five copies of your total proposal (see section 6.2 "Physical Packaging Requirements").

Carefully align the forms in the typewriter using the underlines as a guide. The forms are printed to accommodate standard typewriting spacing.

Appendix A:

1. ***Proposal Number:*** Complete the proposal number as follows:
   a. Enter 4 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: 1. Firm, telephone 273-8126, submits one proposal to subtopic 06.03. Proposal number is: ***06.03 8126.***

Example: 2. Firm, telephone 392-4826, submits three different proposals to subtopic 11.03. Proposal numbers are:

11.03 4826
11.03 4826A
11.03 4826B

2. ***Project Title:*** Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). Do not use the subtopic title.
3. ***Firm Name:*** Enter full name of company submitting the proposal. If a joint venture, list company chosen to negotiate and receive contracts. If name exceeds 30 keystrokes, please abbreviate.
4. ***Address:*** Enter mail address.
   State: Enter 2 letter designation (example Maine—ME)
   Zip-Code: Enter 5 or 9 digit code
5. ***Amount Requested:*** Enter proposal amount from budget summary. Round to nearest dollar. ***Do not*** enter cents.
6. ***Duration:*** Enter proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss reason in the text of the proposal.
7. ***Certifications:*** Enter Y for yes or N for no in the appropriate boxes in response to statements or questions.
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.

Appendix B:

1. ***Proposal Number:*** Enter the same proposal number as shown on your Proposal Cover Sheet.
2. ***Project Title:*** Enter the same title as shown on your Proposal Cover Sheet.
3. ***Technical Abstract:*** Provide a summary of 200 words or less of your proposed project. The abstract must not contain proprietary information.
4. ***Potential Commercial Applications of the Research:*** Summarize the commercial potential of the project assuming the results of the proposed research or R&D are achieved.
5. ***Key Words:*** Provide no more than 8 key words descriptive of the project and useful in identifying the technology, research thrust or application of the proposed effort
6. ***Name and Address of Firm:*** Enter firm name and mail address as shown on the Proposal Cover Sheet.
7. ***Principal Investigator:*** Enter name of the Principal Investigator as shown on the Proposal Cover Sheet.

APPENDIX C - SBIR PROPOSAL SUMMARY BUDGET
(INSTRUCTIONS OR REVERSE SIDE)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 89-1 SOLICITATION

FIRM: PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

(See Instructions on Back of Form)

	TOTAL PRICE
MATERIAL:	$
PERSONNEL:	$
OTHER DIRECT COSTS:	$
OVERHEAD:	$
GENERAL AND ADMINISTRATIVE (G&A):	$
PROFIT:	$
TOTAL PRICE PROPOSED	$

TYPED NAME AND TITLE: SIGNATURE:

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 89-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE.

DATE SUBMITTED

PROPOSAL PAGE NO.

INSTRUCTIONS

The purpose of this form is to provide a vehicle whereby 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.

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. **MATERIALS —**
   a. *Materials and Supplies.* Indicate types required and estimate costs.
   b. *Publication Costs/Page Charges.* Estimate cost of preparing and publishing project results.
   c. *Consultant Services.* Indicate name, daily compensation, and estimated days of service.
   d. *Computer Services.* Include justification. Computer equipment leasing is included here. Purchase of equipment is included under OTHER DIRECT COSTS.
   e. *Subcontracts.* Include a completed budget and justify details.
   f. *Other.* Itemize and justify.
2. **PERSONNEL** — On the budget explanation page, list individually all personnel included, the requested person-months to be funded, and rates of pay (salary, wages, and fringe benefits).
3. **OTHER DIRECT COSTS** — List all other direct costs which are not otherwise included in the categories described above. For travel, address the type and extent of travel and its relation to the project. List each item of permanent equipment to be purchased, its price, and explain its relation to the project.
4. **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 which 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.
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 which 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.

APPENDIX D
SUBTOPICS

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									01.00 AERONAUTICAL PROPULSION AND POWER
						•			01.01 INTERNAL FLUID MECHANICS FOR AERONAUTICAL PROPULSION SYSTEMS
						•			01.02 AERONAUTICAL PROPULSION SYSTEM COMPONENTS
						•			01.03 AERONAUTICAL PROPULSION SYSTEM INSTRUMENTATION, SENSORS AND CONTROLS
						•			01.04 NOVEL PROPULSION CONCEPTS

Field Centers[1]

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									02.00 AERODYNAMICS AND ACOUSTICS
•									02.01 COMPUTATIONAL FLUID DYNAMICS
					•				02.02 EXPERIMENTAL FLUID DYNAMICS
					•				02.03 THEORETICAL DYNAMICS AND VISCOUS FLOW
					•				02.04 HYPERSONIC AEROTHERMODYNAMICS
							•		02.05 RAREFIED GAS DYNAMICS
•									02.06 CONFIGURATIONAL AERODYNAMICS INCLUDING VORTICES
•									02.07 ROTOR AERODYNAMICS AND DYNAMICS
					•				02.08 WIND TUNNEL INSTRUMENTATION
					•				02.09 AIRCRAFT NOISE REDUCTION
						•			02.10 AERONAUTICAL PROPULSION NOISE REDUCTION

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									03.00 AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS
						•			03.01 AIRCRAFT ICE PROTECTION SYSTEMS
					•				03.02 AIRCRAFT FLIGHT ENVIRONMENT
					•				03.03 CONTROL CONCEPTS FOR FIXED WING AIRCRAFT
•									03.04 FULLY AUTOMATIC GUIDANCE FOR ROTORCRAFT
•									03.05 AIRCRAFT FLIGHT TESTING TECHNIQUES
•									03.06 FLIGHT RESEARCH SENSORS AND INSTRUMENTATION
					•				03.07 HYPERSONIC FLIGHT SYSTEMS TECHNOLOGY
•									03.08 VERY HIGH ALTITUDE AIRCRAFT TECHNOLOGY
•									03.09 AERONAUTICAL HUMAN FACTORS AND FLIGHT MANAGEMENT SYSTEMS
•									03.10 COMPUTER-AIDED DEVELOPMENT, TESTING AND VERIFICATION OF FLIGHT CRITICAL SYSTEMS

[1] Legend appears on page 24

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									04.00 MATERIALS AND STRUCTURES
						•			04.01 STRUCTURAL COMPOSITE MATERIALS FOR PROPULSION SYSTEMS
						•			04.02 HIGH TEMPERATURE STRUCTURAL COMPOSITES
					•				04.03 COMPOSITE MATERIALS FOR AEROSTRUCTURE AND SPACE APPLICATIONS
						•			04.04 ADVANCED ALLOYS, INTERMETALLICS AND METAL MATRIX PROCESSES
						•			04.05 COMPUTATIONAL STRUCTURAL METHODS
					•				04.06 NONDESTRUCTIVE EVALUATION TO CHARACTERIZE MATERIAL PROPERTIES
				•					04.07 BOND STRENGTH OF THERMAL SPRAYED COATINGS
							•		04.08 SPACE ENVIRONMENTAL EFFECTS AND SURFACE DEGRADATION
					•				04.09 LIGHT ALLOY METALLICS FOR AIRFRAME STRUCTURES
							•		04.10 WELDING TECHNOLOGY
	•								04.11 SPECIAL-PURPOSE MATERIALS FOR SPACE FLIGHT APPLICATIONS
		•							04.12 CONDUCTIVE COATING SYSTEMS FOR SCANNING ELECTRON MICROSCOPE IMAGING
			•						04.13 SPACECRAFT STRUCTURES AND MECHANISMS
		•							04.14 ACTIVE STRUCTURAL ELEMENTS FOR SPACE APPLICATIONS
			•						04.15 MATERIALS FOR SPACE TRANSPORTATION SYSTEM AND SPACE STATION
		•							04.16 HIGH TEMPERATURE SUPERCONDUCTING MATERIALS FABRICATION AND CHARACTERIZATION
						•			04.17 HIGH TEMPERATURE SUPERCONDUCTORS FOR AEROSPACE PROPULSION, POWER, AND COMMUNICATIONS
			•						04.18 LUNAR MATERIALS UTILIZATION

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									05.00 TELEOPERATORS AND ROBOTICS
					•				05.01 TELEROBOTIC SYSTEMS TECHNOLOGY
	•								05.02 TELEROBOTIC AND BIOMECHANICAL SYSTEM SOFTWARE DEVELOPMENT
	•								05.03 TELEROBOTIC ELECTRO/MECHANICAL SYSTEMS
			•						05.04 ROBOTIC ADAPTIVE GRASPING SYSTEMS
			•						05.05 ARTIFICIAL INTELLIGENCE FOR SPACE STATION APPLICATIONS
		•							05.06 TELEOPERATION AND ROBOTICS
						•			05.07 SPACE MECHANISMS
				•					05.08 SERPENTINE ROBOTIC ARM
							•		05.09 MISSION EXPERIMENT SUPPORT TELEROBOTICS

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									06.00 COMPUTER SCIENCES AND APPLICATIONS
					•				06.01 ENGINEERING COMPUTER SCIENCE
	•								06.02 ADVANCED SOFTWARE DEVELOPMENT AND MAINTENANCE

	TOPIC AND SUBTOPIC TITLE	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC
06.00	**COMPUTER SCIENCES AND APPLICATIONS** (Con't)									
06.03	RELIABLE SOFTWARE DEVELOPMENT						•			
06.04	KNOWLEDGE BASED SYSTEMS TECHNOLOGIES FOR AEROSPACE APPLICATION	•								
06.05	SOFTWARE SYSTEMS FOR MISSION PLANNING AND FLIGHT CONTROL				•					
06.06	COMPUTER SCIENCE ADVANCES IN COMPUTATIONAL PHYSICS	•								
06.07	LARGE MULTIPROCESSOR DATABASE TECHNOLOGY			•						

	TOPIC AND SUBTOPIC TITLE	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC
07.00	**INFORMATION SYSTEMS AND DATA HANDLING**									
07.01	FOCAL-PLANE IMAGE PROCESSING						•			
07.02	IMAGE DATA COMPRESSION AND ANALYSIS		•							
07.03	STATISTICS OF SPATIAL PATTERNS AND SPATIAL INTERACTION PROCESSES									•
07.04	SPATIAL DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEM (GIS)									•
07.05	SIGNAL AND INFORMATION PROCESSING		•							
07.06	INFORMATION PROCESSING TECHNOLOGY AND INTEGRATED DATA SYSTEMS						•			
07.07	SCHEDULING AND AUTOMATION TECHNOLOGY FOR UNMANNED SPACECRAFT OPERATIONS		•							
07.08	HETEROGENEOUS DISTRIBUTED DATABASE MANAGEMENT		•							
07.09	SPACECRAFT ON-BOARD INFORMATION EXTRACTION			•						

	TOPIC AND SUBTOPIC TITLE	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC
08.00	**INSTRUMENTATION AND SENSORS**									
08.01	INSTRUMENTS FOR SENSING ELECTROMAGNETIC RADIATION			•						
08.02	EARTH ATMOSPHERE SENSING FROM LOW EARTH ORBIT		•							
08.03	LOW-COST HIGH RESOLUTION AIRBORNE REMOTE SENSING INSTRUMENTATION FOR EARTH SCIENCES									•
08.04	SENSORS FOR AEROSOL AND CLOUD STUDIES						•			
08.05	POLARIZED LASER IMAGING OF THE EARTH'S SURFACE		•							
08.06	EARTH ATMOSPHERIC LIDAR REMOTE SENSING		•							
08.07	TUNABLE SOLID STATE LASERS, DETECTORS AND LIDAR SUBSYSTEMS						•			
08.08	COHERENT LASER RADAR								•	
08.09	EARTH OBSERVING SENSOR DEVELOPMENT FOR GEOSTATIONARY ORBIT								•	
08.10	FLIGHT INSTRUMENT TECHNOLOGY FOR EXOBIOLOGY	•								
08.11	INSTRUMENTATION FOR PLANETARY ATMOSPHERIC SCIENCES			•						
08.12	INFRARED TECHNOLOGY FOR ASTRONOMICAL APPLICATIONS	•								
08.13	DETECTORS AND DETECTOR ARRAYS		•							
08.14	LOW-COST CALIBRATORS FOR SPACEBORNE SYNTHETIC APERTURE RADAR			•						

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									08.00 INSTRUMENTATION AND SENSORS (Con't)
		•							08.15 EARTH-BASED AND PLANETARY PHOTOMETRY INSTRUMENTATION
		•							08.16 SUBMILLIMETER ANTENNAS, RADIOMETERS AND SPECTROMETERS
		•							08.17 ALTIMETRY TECHNOLOGY
		•							08.18 OPTICAL SYSTEMS AND DEVICES
	•								08.19 THREE-DIMENSIONAL REFLECTOMETER
	•								08.20 SPACECRAFT AND SPACE STATION CONTAMINATION MONITORING
			•						08.21 INSTRUMENTS FOR STS OPERATIONS
						•			08.22 CRYOGENIC FLUID INSTRUMENTATION FOR ORBITING SPACECRAFT

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									09.00 SPACECRAFT SYSTEMS AND SUBSYSTEMS
					•				09.01 CONTROL OF LARGE SPACE STRUCTURES
					•				09.02 GUIDANCE, NAVIGATION AND CONTROL OF ADVANCED SPACE TRANSPORTATION SYSTEMS
	•								09.03 COMBINED ALTITUDE CONTROL AND ENERGY STORAGE
			•						09.04 STS/SPACE STATION AND ROBOTIC TRACKING SYSTEMS
							•		09.05 SPACECRAFT METEROID/DEBRIS PROTECTION SYSTEMS
	•								09.06 TECHNOLOGIES FOR SCIENTIFIC BALLOONS
	•								09.07 HIGH TEMPERATURE SUPERCONDUCTOR APPLICATIONS FOR SPACE
	•								09.08 SPACECRAFT FLIGHT DYNAMICS
			•						09.09 SPACE STATION CREW WORKSTATION DISPLAYS AND CONTROLS
			•						09.10 SPACE ORBITER WHEEL BRAKE CONTROL SYSTEM
			•						09.11 MANNED SPACECRAFT AND PLANETARY BASED THERMAL MANAGEMENT SYSTEMS
	•								09.12 THERMAL CONTROL FOR UNMANNED SPACE APPLICATIONS
							•		09.13 SPACECRAFT SYSTEMS THERMAL ANALYSIS AND DESIGN
							•		09.14 COMPARTMENT VENTING

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									10.00 SPACE POWER
						•			10.01 SPACE POWER SYSTEM TECHNOLOGIES
		•							10.02 HIGH ENERGY DENSITY AND LONG LIFE BATTERIES
	•								10.03 SEPARATOR MATERIAL FOR AEROSPACE NI-CD CELLS
					•				10.04 PHOTOVOLTAIC LASER ENERGY CONVERTERS
			•						10.05 ELECTRICAL POWER CONTROL AND DISTRIBUTION SUBSYSTEMS
							•		10.06 SPACE POWER ADVANCED AUTOMATION SYSTEMS
		•							10.07 POWER TRANSMISSION APPLICATIONS OF HIGH TEMPERATURE SUPERCONDUCTORS

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE	
									11.00	**SPACE PROPULSION**
						•			11.01	SPACE PROPULSION SYSTEM TECHNOLOGIES
							•		11.02	LIQUID ENGINE INTERNAL FLOW DYNAMICS
							•		11.03	CRYOGENIC PROPELLANT MANAGEMENT FOR SPACECRAFT
							•		11.04	SOLID ROCKET MOTOR TECHNOLOGY
							•		11.05	HIGH POWER LEVEL ELECTRO-MECHANICAL THRUST VECTOR CONTROL
		•							11.06	CONTAMINATION FROM BIPROPELLANT ROCKER ENGINES EXHAUST PRODUCTS

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE	
									12.00	**HUMAN HABITABILITY AND BIOLOGY IN SPACE**
			•						12.01	MEDICAL SCIENCES FOR MANNED SPACE PROGRAMS
							•		12.02	ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS FOR SPACE STATION
			•						12.03	REGENERATIVE LIFE SUPPORT: AIR, WATER AND WASTE MANAGEMENT
•									12.04	BIOREGENERATIVE FOOD PRODUCTION
			•						12.05	HUMAN FACTORS FOR SPACE CREWS
			•						12.06	INTRAVEHICULAR SYSTEMS FOR SPACE CREWS
			•						12.07	EXTRAVEHICULAR ACTIVITY (EVA)
			•						12.08	BIOMEDICAL AND ENVIRONMENTAL HYGIENE SUPPORT FOR MANNED SPACE PROGRAMS
							•		12.09	CONCEPTS AND COMPONENTS FOR STERILIZATION OF ON BOARD WATER SYSTEMS
•									12.10	PHYSICO-CHEMICAL LIFE SUPPORT SYSTEMS
•									12.11	LIFE SCIENCES SPACEFLIGHT HARDWARE DEVELOPMENT
				•					12.12	BIOLOGICAL SCIENCES OPERATIONS
					•				12.13	PARAMETRIC NUCLEAR FRAGMENTATION MODEL
				•					12.14	ANATOMICAL IMAGE ANALYSIS TECHNIQUES

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE	
									13.00	**QUALITY ASSURANCE, SAFETY AND CHECK-OUT FOR GROUND AND SPACE OPERATIONS**
				•					13.01	GROUND OPERATIONS INSTRUMENTATION
				•					13.02	IMPROVED PROPELLANT HANDLING AT LAUNCH SITES
				•					13.03	LAUNCH AND GROUND WEATHER FORECASTING AND SITUATION MANAGEMENT
				•					13.04	FLUID SYSTEM COMPONENTS
				•					13.05	SHUTTLE LANDING FACILITY BIRD CONTROL
			•						13.06	TEST FACILITY INSTRUMENTATION AND SAFETY DEVICES
		•							13.07	QUALITY ASSURANCE OF VERY LARGE SCALE INTEGRATED CIRCUITS

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									14.00 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS
			•						14.01 COMMUNICATIONS FOR MANNED SPACE SYSTEMS
	•								14.02 ADVANCED DATA RELAY SATELLITE SYSTEMS
		•							14.03 MILLIMETER WAVE DEEP SPACE COMMUNICATIONS SYSTEMS
		•							14.04 SPACECRAFT TRANSPONDER ELECTRONICS
						•			14.05 ADVANCED SATELLITE COMMUNICATIONS SYSTEMS
		•							14.06 OPTICAL COMMUNICATIONS FOR DEEP SPACE
						•			14.07 LOW COST KA-BAND GROUND TERMINALS

Field Centers

ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	SSC	TOPIC AND SUBTOPIC TITLE
									15.00 MATERIALS PROCESSING, MICRO-GRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE
						•	•		15.01 MATERIALS PROCESSING IN SPACE
						•			15.02 MICROGRAVITY SCIENCE, TECHNOLOGY AND ENGINEERING EXPERIMENTS
					•				15.03 CHEMICAL VAPOR DEPOSITION ANALYSIS AND MODELING TOOLS
						•			15.04 COMMERCIAL OPPORTUNITIES IN SPACE POWER GENERATION, PROPULSION AND RELATED TECHNOLOGIES
							•		15.05 ACOUSTIC SIGNATURES OF FAILURE MODES IN STRESSED SPACECRAFT COMPONENTS
							•		15.06 SELF-HEALING INSULATION FOR SPACE-EXPOSED POWER TRANSMISSION LINES

LEGEND:

ARC – Ames Research Center
Moffett Field, CA

GSFC – Goddard Space Flight Center
Greenbelt, MD

JPL – Jet Propulsion Laboratory
Pasadena, CA

JSC – Johnson Space Center
Houston, TX

SSC – Stennis Space Center
Stennis Space Center, MS

KSC – Kennedy Space Center
Kennedy Space Center, FL

LaRC – Langley Research Center
Hampton, VA

LeRC – Lewis Research Center
Cleveland, OH

MSFC – Marshall Space Flight Center
Huntsville, AL

01.00 AERONAUTICAL PROPULSION AND POWER

01.01 INTERNAL FLUID MECHANICS FOR AERONAUTICAL PROPULSION SYSTEMS
Center: LeRC

Innovative techniques are sought for analyzing flows in aeronautical propulsion systems for low subsonic through hypersonic speeds:

- Internal computational mechanics: Application of parallel processors, expert systems, innovative graphics, and scientific database structures, etc. Accurate numerical methods for fixed grid density and increased convergence rates. Strategies for multi-block grids and zonal approaches combining two or more numerical methods. Geometry (3-D) and mesh generation techniques for complex surface description, grid-lattice construction, and solution adaptive mesh clustering. Turbulent 3-D flow codes with new turbulence models.

- Inlets and nozzles: Advanced steady-state and time-dependent flow analyses and benchmark data for component and systems performance, boundary layers, bleed flows, diffusion, jet mixing, separated flow, heat transfer, surface cooling, and external spillage.

- Fans and compressors: Advanced numerical flow field codes, physical models, and supporting validation data for unsteady flows, blade-row interactions, rotor shocks, viscous flows on blades and endwalls and secondary flows for advanced compression systems, including single and multistage axial, centrifugal, and mixed flow fans and compressors.

- Combustors and augmenters: Efficient computer models, and innovative means to supply validation data for the flows, physical processes, and reaction mechanisms in a combustor including fuel injection, spray evaporation and mixing, and basic reaction mechanisms and kinetic rates for hydrocarbon oxidation and soot formation.

- Turbines: Innovations to improve life, performance and reliability of large and small turbines for aircraft and aerospace application. Rigorous three-dimensional viscous flow models and subroutines for full passage codes that include heat transfer, unsteady flow, rotation, accurate treatment of boundary layer phenomena, and rotor blade tip clearance flows.

01.02 AERONAUTICAL PROPULSION SYSTEM COMPONENTS
Center: LeRC

Innovations are sought in three areas: turbine engines, rotary combustion engines (RCE), and drive train technology.

- Turbine engines: Innovative design concepts are needed for more efficient fans, compressors, turbines and combustors applicable to "small" sizes including:
  - Innovative concepts to improve cycle efficiency;
  - Advanced materials to minimize or eliminate coolant penalties;
  - Concepts for recuperators/regenerators which minimize weight, volume, and aerodynamic drag through innovative design and/or use of advanced materials.

- Rotary engines: Advanced, innovative components, material and subsystems are sought for Wankel-type rotary engines capable of burning jet fuel effectively, including:
  - High-speed, high output multi-fuel combustion system elements, including advanced fuel delivery and ignition methods;
  - Advanced seals, bearings and lubricants for high output RCE;
  - Advanced materials and fabrication technology for lightweight and/or heat-resistant (insulating) structural compo-

nents, such as rotors and trochoid and end housings;
- Advanced turbocharger/turbocompounding in the 0.5 to 1.5 lb/sec flow range having single stage pressure ratios of up to 8:1.

- Drive train technology: New concepts are needed to decrease drive system weight and noise and to increase reliability and strength such as:

  - Lubricants to extend operation temperatures of gear boxes to beyond 200°C;
  - Gear and bearing materials to extend operating temperatures beyond 200°C;
  - Transmission health monitoring systems;
  - New gear tooth forms for lower noise and better lubricant action;
  - New transmission concepts for large transmissions;
  - Transmission noise prediction methods;
  - Elastohydrodynamic film thickness predictive methods for bevel gear sets;
  - Expert systems and optimization methods for gear and transmission design.

01.03 AERONAUTICAL PROPULSION SYSTEM INSTRUMENTATION, SENSORS AND CONTROLS
Center: LeRC

The accurate measurement of pressure, temperature, strain, flow, and other parameters is important both to the design of advanced aerospace propulsion systems and to the operation and control of these systems in aerospace vehicles. To verify design codes, advanced non-intrusive or minimally intrusive instrumentation and diagnostic techniques are required as an essential part of propulsion system development programs. In addition, the increased thermal and aerodynamic loads to which propulsion system components are exposed require more precise measurement of the hostile operating environment and the engine condition for control, safety, and health monitoring considerations. Innovations in an advanced high durability, high temperature, and precise sensors and instrument system are needed in both aeronautical and space applications.

- Strain and temperature on both metal and ceramic surfaces (for up to 1900°C operation).

- Gas temperatures and pressures, both static and dynamic (for up to 1900°C operations).

- High-temperature electronics and integrated sensors.

- Fiber-optic-based sensors and control systems.

- Aerodynamic flow and turbulence measurements.

- Non-intrusive combustion and rocket plume diagnostics.

- Instrumentation and sensors for high speed propulsion research.

Improved performance and operability of propulsion systems and subsystems or components through the use of real-time intelligence in a closed loop control is required. The basic premise is that powerful onboard computing capability and new sensor technology will make possible optimized engine performance and life by incorporating feedback control. Innovative approaches are sought in:

- Real-time identification.

- Nonlinear or adaptive real-time control design for propulsion systems.

- Reliability enhancement through redundancy management or fault detection for propulsion systems.

- Improved component performance via compressor stall alleviation or combustor pattern factor control.

- Integrated system intelligence.

- High speed computation for Artificial Intelligence (AI) applications.

01.04 NOVEL PROPULSION CONCEPTS
Center: LeRC

Major improvements in propulsion system performance, weight, bulk, and cost are required for many important future aeronautical vehicles, especially for viable high-speed accelerators for transatmospheric vehicles and efficient cruise powerplants for supersonic and hypersonic airplanes. Innovative identification and analyses of new airbreathing propulsion system concepts or variations are sought that promise revolutionary advances in vehicle capabilities. Some examples of existing concepts include supersonic through-flow fans and supersonic combustion ramjets. Beamed energy systems and potential aero applications and benefits of newly discovered high-temperature superconductors may be of interest if shown to be feasible. Phase I projects solicited should include first-order system concept modeling and/or comparative evaluations against conventional powerplant baselines or other advanced alternatives, to indicate their desirability. And while specific, detailed component characterizations are not exclusive objectives here, only those Phase I proposals clearly indicating applications and feasible, hardware-oriented Phase II R&D continuations by NASA in the near future will be considered. Phase II must be oriented toward R&D for experimental verification of key elements of proposed concepts.

02.00 AERODYNAMICS AND ACOUSTICS

02.01 COMPUTATIONAL FLUID DYNAMICS
Center: ARC

More powerful numerical computation capabilities for predicting fundamental fluid flow phenomena can lead to improved aerodynamic characteristics and overall configurational optimization for advanced aircraft, missiles and aerospace vehicles of every type and application. NASA's interest in computational fluid dynamics (CFD) encompasses the entire spectrum of real gas aerothermo dynamic phenomena which may be encountered by aircraft and aerospace vehicles from subsonic to hypersonic speeds, including static and dynamic behavior, transient phenomena, maneuvering, stability and control, aerodynamic performance, heating and heat transfer. Applications include both external and internal flow fields and multiple body interactions including stores and separation effects. Innovations are sought in every activity related to CFD which could facilitate the foregoing objectives, including, for example:

- Numerical method innovations for solving the fluid flow equations which increase computational efficiency, accuracy, speed and utility. These include construction of new algorithms, improved computer languages, improved geometric modeling, new structured and unstructured grid generation procedures, advanced component-adaptive grid operation methods, improved boundary condition procedures, and other innovative techniques.

- Analytical, numerical, and experimental techniques that enhance the understanding of transition and turbulence phenomena and provide improved models for solving the Navier-Stokes equations. These include improved turbulence models, large-eddy simulation for high Reynolds Number flows, numerical methods for full and large-eddy simulation, improved subgrid-scale models for large-eddy simulation, and turbulence models application to aerodynamic flows with massive separation and wakes.

- Grid procedures: unstructured grid generation; combination structured/unstructured grids; solution-adaptive grid procedures; grid quality measures.

- Numerical methods for evaluating combined convection and radiation participation and chemical reaction in subsonic turbulent flows typical of high pressure combustion systems. This includes improved models for nongray radiation and finite rate chemistry as well as a math modeling package that accurately models complex shapes and surfaces.

- Scientist's workbenches with integrated, graphical tools for interactive: geometry definition; multi-block surface and field grid generation; evaluation of grid quality; distributed computation of the fluid flow solution; flow visualization; and solution validation (data from experiment and/or flight, exact solution, other computations).

- Application of automation techniques (e.g., knowledge-based system) to flow field discretion, flow solver operation, and flow visualization.

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

- Innovative methods for efficiently interfacing numerical grid generation and Navier-Stokes solutions to mechanical design in an applications oriented environment.

- Related multidisciplinary activities.

All Phase I proposals must identify definite Phase II continuation objectives and their ultimate applications.

02.02 EXPERIMENTAL FLUID DYNAMICS
Center: LaRC

Experimental techniques to advance the understanding of aerodynamic phenomena are needed. Desired innovations include the development of:

- Test section designs for transonic wind tunnels to reduce wall interference, reduce power requirements, and improve flow quality.

- Methods to study ground effect and transition aerodynamics of models of V/STOL aircraft in wind tunnels.

- Cost-effective ways to recover liquid nitrogen from the exhaust of cryogenic wind tunnels. (Exhaust gas is nitrogen at temperatures from 80°K to 300°K and pressures from 1.2 to 9 atmospheres).

- Methods to suppress noise and turbulence caused by flow disturbances in wind tunnels.

- Statistical methods to detect anomalies in wind tunnel data either during or after the test. The method should allow user definition of the list of anomalies.

- Automated on-line analyses of unsteady pressure data to provide boundary layer transition location.

02.03 THEORETICAL AERODYNAMICS AND VISCOUS FLOW
Center: LaRC

A broad spectrum of unsolved aerodynamic problems remain associated with the design and analysis of advanced aircraft configurations which require greater theoretical understanding of boundary layers, free-shear layers, recirculating vortex flows, and practical means of improving flow quality in critical areas and under actual flight conditions. Innovative new concepts and approaches, both analytical and experimental, are solicited, which may include, but are not limited to the following:

- Accurate prediction of compressible 3-D boundary layer stability.

- Numerical and analytical studies of laminar to turbulent flow transition.

- Theoretical studies of chaos leading to a better understanding of its relation to fluid dynamic turbulence.

- Theories and practical techniques for turbulence management and control, including skin friction reduction.

- Analytical studies and new measurement techniques leading to a better understanding of the physics of and structure of turbulent shear flows and high-speed shear layers.

All Phase I proposals must identify valid Phase II experimental continuations, analytical and/or experimental as appropriate, for NASA's possible interests in further developing or verifying Phase II continuations of feasible Phase I concepts.

02.04 HYPERSONIC AEROTHERMODYNAMICS
Center: LaRC

In addition to innovative concepts in computational and experimental aero/fluid dynamics which are solicited in related subtopics, this subtopic solicits innovations of special applicability to the understanding and prediction of hypersonic aerothermodynamic phenomena needed in the design and development of future vehicles such as second generation Shuttle, Aeroassist Orbital Transfer Vehicle (AOTV), the National Aero-Space Plane (NASP), hypersonic reentry vehicles, future planetary probes, and hypersonic transport aircraft. Areas of interest for analytical and experimental innovation include, but are not limited to, the following:

- Adding real gas physics to existing and future numerical schemes.
- Gas/surface interactions and chemical energy accommodation and surface catalytic reaction rates.
- Radiation and rates associated with excitation of radiation.
- Equilibrium and finite-rate chemistry flows.
- Transport properties and multi-component mixing laws.
- Chemical kinetic rates.
- Turbulence modeling and simulation.
- Experiments to guide development of model equations and verify benchmark computer codes.
- High velocity, high pressure and high temperature experimental techniques, including methodology for radiative and nonequilibrium flows and nonintrusive flow measurement techniques.
- High-order algorithms for performing unsteady simulations of transition and turbulence.
- High-order algorithms for computing shock/boundary layer and shock/turbulence interactions.

All Proposals must identify valid Phase II experimental continuations and ultimate applications.

02.05 RAREFIED GAS DYNAMICS
Center: MSFC

Innovative improvements are sought in methods for predicting rarefied gas dynamic phenomena of particular importance for aerodynamic and aerothermal load prediction techniques for aeromaneuvering and aerobraking vehicles during high altitude (rarefied) operations. Included among new concepts and methods could be:

- Inclusion of radiation production and transfer from weakly ionized gases in Monte Carlo flowfield simulations.
- Wake closure, impingement and heating on payloads shielded by an aerobrake, in both ideal gas and real gas hypersonic flow at low Reynolds number.
- Prediction of blunt face heating distribution, which include variable chemistry effects.
- New synergetic experiment plans using the twelve aeroassist flight vehicle experiments.
- Rarefied flow heating prediction methods for surface irregularities (tile gaps, fabric joints, etc.)

All Proposals must identify valid Phase II experimental continuations as well as continued analytical activities, and must lead toward ultimate applications.

02.06 CONFIGURATIONAL AERODYNAMICS INCLUDING VORTICES
Center: ARC

The development of experimental methods and data analysis procedures to enhance the understanding of vortex-dominated flows would have important uses in boundary layer management, high angle-of-attack aerodynamics, separated flows, rotor wake interactions, and vane-type vortex generators. Innovative experimental techniques using small-scale, laboratory-size facilities are needed to understand the interaction between vortices and boundary layers, shear layers, or solid surfaces. The extensive use of modern sensor technology and/or sophisticated computer-experiment integration is considered an important part of this area of interest.

This subtopic solicits proposals of innovative concepts and techniques related to new and improved aerodynamic configurations for aircraft, including but not limited to the following areas:

- Vortex flow control devices and wing configurations to improve body-wing-strake and slender wing performance.
- Nozzle-afterbody and inlet integration.
- A new approach, for solving 3-D aircraft configuration aero dynamic problems using the Euler and Navier-Stokes equations, but does not rely on well-structured, body-fitted coordinate systems.
- Expeditious methods for handling the extremely large amounts of data produced in experimental and computational research on aircraft configurations. Special visualization techniques are required and may need development of specialized software and hardware.

02.07 ROTOR AERODYNAMICS AND DYNAMICS
Center: ARC

Many aspects of rotorcraft aerodynamics and dynamics are not thoroughly understood or adequately modeled, and much remains to be done. Required are innovative methods which describe the basic phenomena involved in rotorcraft aerodynamics and dynamics, provide greater knowledge of the detailed characteristics of these phenomena, and permit well-verified accurate predictions to be made. Innovative developments with application to tilt rotors, single main rotor and tandem helicopters, co-axial helicopters, and rotors with circulation control (i.e., X-Wing type aircraft) are needed to define the next-generation rotorcraft. Examples of problems currently 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; and rotor noise. Innovations in new rotor concepts are also solicited.

02.08 WIND TUNNEL INSTRUMENTATION
Center: LaRC

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

- Miniature, smart multichannel sensors for pressure in the range of 1 to 100 psi at temperatures from 100°K to 1000°K.
- Miniature sensors for temperature and heat flux measurements in the range 1500°C to 3000°C.
- Infrared optical fibers for image relay from target to infrared imagers in the 2-5 μm and/or 8-12 μm ranges.
- Nonintrusive measurement of model angle of attack and deformation.
- Measurement of high level strains at temperatures above 1100°C.
- Spectroscopic flow visualization schemes.
- Nonintrusive global techniques for measuring fundamental flow field parameters.
- Direct measurement of skin friction in high temperature (1000°C) environment.

- Advanced specific chemical sensors for measuring gaseous constituents in high velocity, high temperature flows.

- In-situ measurement of gas composition and density profiles in the boundary layer or shock layer using instrumentation mounted in the model.

02.09 AIRCRAFT NOISE REDUCTION
Center: LaRC

Technology for controlling noise and associated acoustic loads is needed for developing acceptable aircraft and rotorcraft. Advancement of this technology requires understanding of fundamental noise source mechanisms, propagation paths, and response of receivers. Sources of noise and acoustic loads include: jet exhaust plumes, rotors, propellers, boundary layers, and turbulent flow and aerodynamic surface interactions. Propagation paths include inhomogeneous atmosphere and aircraft and engine structures. Receivers can be either people or aircraft and engine structures. In addition to the fundamental understanding of the source, path, and receiver, prediction methods and control/reduction concepts must be developed. Innovative research in noise generation, propagation, prediction and reduction are needed to provide enabling technology for quiet aircraft and rotorcraft. Research areas of interest include:

- Fundamental and applied CFD techniques for aeroacoustic analysis.

- Reduction concepts and prediction methods for noise radiation and associated acoustic loads of supersonic jet plumes.

- Reduction concepts and prediction methods of high-frequency fluctuating pressure loads on airframes and engine structures of supersonic and hypersonic aircraft.

- 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.

- Methods for predicting acoustic propagation through atmosphere including the ground effects.

02.10 AERONAUTICAL PROPULSION NOISE REDUCTION
Center: LeRC

Innovative concepts and analysis methods are desired which lead to highly efficient, low noise propulsion system designs for a wide range of aircraft types. Proposed innovations should include design approaches for advanced propulsors for subsonic, transonic, and supersonic flight speeds, supported by new analytical and experimental verification methods, to maintain high efficiency, low noise and structural integrity. Specific needs include:

- Aerodynamic and acoustic analysis and design methods and diagnostic or flow visualization methods, including unsteady flows.

- Approaches for increased efficiency, reduced noise, improved flutter margin, and improved strength and weight.

- Prediction of the steady and unsteady aerodynamics and acoustics of unducted and ducted propellers (ultra high bypass ratio fans) at off-design as well as at design conditions.

- Definition and analysis of advanced propeller configurations which reduce noise signatures while maintaining efficiency at higher cruising speeds.

- Source noise reduction concepts for supersonic high speed civil transports to allow federal and local community noise rules to be met while minimizing efficiency impact. Reductions in both jet and supersonic fan noise are of particular interest.

03.00 AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS

03.01 AIRCRAFT ICE PROTECTION SYSTEMS
Center: LeRC

Innovative concepts and analysis methods are desired which lead to highly efficient ice protection for helicopters, general aviation and commercial transports. Areas requiring improvements include:

- Ice protection systems that minimize weight and power consumption.
- Methods for predicting ice accretion on unprotected surfaces and the resultant aerodynamic penalties. Proposals should include validation experiments and flow visualization methods.
- Experimental and analytical methods and icing scaling laws to authenticate subscale model testing in icing wind tunnels.
- Instrumentation to measure ice accretion and supercooled cloud properties.
- Methods to predict aircraft performance and handling of icing during takeoff, landing, and cruising.

03.02 AIRCRAFT FLIGHT ENVIRONMENT
Center: LaRC

This subtopic focuses on effects of atmospheric processes on the design/operation of aircraft. Innovations should improve predictability, detection and avoidance of severe storm hazards and provide a database for safe design criteria for unavoidable hazards. Hazards to be considered are heavy rain, winds/wind shear, turbulence, and lightning. Innovations are required in airborne equipment suitable for measuring environmental effects and in algorithms for alerting the pilot/crew of impending changes in weather or flight hazard conditions.

- Lightning: Innovations are needed for assessing the effects of lightning on future advanced composite aircraft employing flight critical digital systems. Refined lightning characterization requires lightning/aircraft interaction models; techniques and methodology for interpretation and generalization of data for prediction of lightning/aircraft interactions methodology and direct strike data; and, techniques for predicting lightning-induced effects on systems in advanced composite aircraft.
- Wind Shear: Innovative airborne sensors for the premonitory detection of low-altitude wind shear are needed. Many microbursts are known to contain water droplets; therefore, conventional radar techniques may be useful for handling this problem. Radar designs must cope with the suppression of ground clutter effects, the achievement of adequate spatial resolution, and the recognition of an unambiguous, quantitative "signature" associated with the shear phenomenon.
- Innovative concepts for an airborne weather monitoring and processing system that will accept data from various sensor units (airborne and groundbased) to provide hazardous weather information to the pilot.

03.03 CONTROL CONCEPTS FOR FIXED WING AIRCRAFT
Center: LaRC

The traditional disciplines of aerodynamics, structures, and propulsion currently rely on advanced controls concepts to achieve enhanced mission performance, efficiency, and an expanded flight envelope. Modern high performance aircraft must maneuver quickly with agility. Characteristics of such aircraft include flight operations at high angles-of-attack and sophisticated avionics systems. Future aerospacecraft flight must be carefully tailored and controlled to avoid limits imposed by aerodynamics, heating, structural, and propulsion considerations. The use of numerous control effects and thrust vectored propulsive concepts requires complex flight control systems. Interactions between disciplines are at unprecedented levels. There is a need, therefore, to reexamine conventional control system design criteria and to develop improved synthesis methods. A key challenge will be to integrate the guidance and control systems with the pilot to augment mission effectiveness.

Innovative advanced concepts, algorithms, methodologies, and design approaches are needed to provide enabling technologies for the above classes of aircraft. Areas of interest include:

- Guidance laws and concepts, including trajectory optimization.
- Advanced command-control laws.
- Methods for implementing complex control laws over wider operating envelopes.
- Pilot/vehicle interface techniques.
- Knowledge based, expert systems concepts for aircraft guidance and control applications.
- Flying qualities and design oriented guidelines.
- Control system design metrics and aircraft performance metrics for providing optimization guidelines and criteria.
- Algorithmic approaches for reliable aircraft state estimation.
- High angle-of-attack modeling and parameter extraction.

All Phase I proposals must identify clear Phase II objectives leading to software/hardware-oriented applications suitable for NASA support.

03.04 FULLY AUTOMATIC GUIDANCE FOR ROTORCRAFT
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 would be the development of a fully automatic NOE flight-control capability. The NOE flight regime requires the helicopter to fly below tree tops whenever possible, following a preplanned nominal trajectory. The automated flight-control systems may use a combination of advanced sensors for mapping out the vehicle's surroundings for obstacle detection.

Innovative concepts are required to achieve the potential of providing better obstacle-avoidance guidance systems that accept the real-time obstacle information and issue maneuver commands to the autopilot. Potential new technologies applicable to the development of such flight-control systems include state-of-the-art techniques in computer vision, sensor fusion/processing, advanced control concepts, various expert-system disciplines and three dimensional computer graphics techniques for presentation of terrain information.

03.05 AIRCRAFT FLIGHT TESTING TECHNIQUES
Center: ARC

Innovative real-time measurement and analysis methods using both onboard and ground-based processing are sought which would improve the ability to accomplish any of the following objectives:

- Provide accurate real-time identification of structural mode characteristics.
- Measure inflight thrust for advanced turbojet or turboprop engines.
- Determine several aircraft performance parameters during integrated maneuvers.
- Estimate highly nonlinear characteristics of aircraft and propulsion systems.
- Apply expert systems in real-time monitoring and control during flight test.
- Help visualize and characterize local flow phenomena to determine location of vortex flows and laminar-to-turbulent flow transition in a wide variety of flight conditions.

03.06 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 safely expand the flight envelope of aeronautical and aerospace vehicles in subsonic, supersonic, and hypersonic flight regimes. Accurate measurement of pressure, temperature, strain, flow, and other parameters are important to the design of advanced aeronautical and aerospace vehicles.

Innovative concepts in advanced, minimally intrusive, fast response low power, and low volume sensors and instrument systems are solicited for aircraft and small rocket launched flight research payload. Sensor systems considered for aerospace vehicle application should be highly durable, low outgassing, and such that the boundary layer is not disturbed. Some specific needs are:

- Static and dynamic pressure sensor for external adaptation over fuel tanks without disturbing air flow in thin boundary layers.
- Non-intrusive sensor to detect transition frequency components of turbulence in the boundary layer in hypersonic flight.
- Sensor system to accurately determine angle-of-attack to within 0.1 degrees at velocities from Mach 4 to Mach 15.
- Non-intrusive sensor system to determine total temperature from Mach 4 to Mach 15.
- Surface acoustical measurements employing optical technology.
- Strain on advanced structures at temperatures of 1700°C and above.
- Smart angle-of-attack and angle-of-sideslip sensor easily adaptable to commercial and general aviation aircraft without the use of a boom.
- Miniature large-angle flow direction, velocity sensor for general aviation and scale-model application. Long life, low maintenance and capability of operation in extreme humidity are important.

All Phase I proposals must have clear Phase II hardware-oriented continuations of interest to NASA.

03.07 HYPERSONIC FLIGHT SYSTEMS TECHNOLOGY
Center: LaRC

New concepts in combined cycle engines, lightweight structural materials, cryogenic and high temperature insulation, subsystem components, and systems integration are emerging which make the vehicle dry weight fraction, propulsion and aerodynamic performance requirements of a true aerospace plane vehicle achievable. Ultimately, efficient commercial transportation will fly at more than 7 times the speed of today's airliners, and military vehicles will take off from conventional runways, fly to orbit, maneuver in space, and return.

Proposals for innovative concepts in the supporting technical disciplines are invited in other places in this solicitation, e.g., Topics 1, 2, and 4, and will not be considered in this subtopic.

The purpose of this subtopic is to identify opportunities for systems-oriented innovations, including, but not limited to, the following:

- Optimization strategies applicable to component and vehicle geometry.
- Identification of high effective specific impulse vehicle configurations and ascent trajectories considering hot and actively-cooled airframe structure.
- Identification of engine-wall cooling concepts to minimize coolant equivalence ratio.
- Metal-matrix composite materials.
- Structural concepts for vacuum jacketed integral cryogenic tankage.
- Engine/airframe leading edge cooling concepts and analyses.
- Multi-mode engine designs and analysis.

- Innovative thermal management approaches.

For each Phase I proposal, clear indication of Phase II continuations are essential which should lead to serious consideration in future hardware applications by NASA and other agencies.

03.08 VERY-HIGH ALTITUDE AIRCRAFT TECHNOLOGY
Center: ARC

This subtopic addresses research involving technologies applicable to subsonic flight at an altitude of 100,000 feet or above. There are two motivations for soliciting proposals in this area. First, NASA currently has no subsonic flight capability above 70,000 feet. Second, the physical properties of the atmosphere change so quickly with altitude beyond 80,000 feet that research involving solutions to new design problems in this region are of engineering interest. Atmospheric flight at such extreme altitudes currently poses significant challenges in all aerospace technologies, and solution to these challenges are the target of this subtopic.

Proposals for innovations from which NASA can gain practical insights to these critical flight domains affecting aerodynamics, propulsion, structures/materials, guidance/control/navigation, aeroelastic flight dynamics, or other related topic areas are being sought. The results may be either design solution or design tools. Studies involving the development of specific design configurations are not of primary interest unless they involve innovative concepts that have not been previously investigated in the open literature. Current interest involves a high-subsonic atmospheric sampling aircraft capable of at least three hours endurance at altitude with at 1,000 lb. payload, manned or unmanned.

All Phase I proposals must indicate clear Phase II objectives and suggest ultimate applications.

03.09 AERONAUTICAL HUMAN FACTORS AND FLIGHT MANAGEMENT SYSTEMS
Center: ARC

Advances in avionics technology and in the area of human factors provide many opportunities for improvements to the flight deck and to flight management techniques. Rapid developments in microprocessor technology and electronic display systems have made it feasible to automate many crew functions. One concern, however, is how to keep the crew properly involved in the flight management process as their role moves from that of an operator of the system to that of a manager of the system. Innovative approaches to improved flight management techniques are required to accomplish any of the following objectives:

- Exploration and development of control/display operational concepts and crew/system interfaces involving cockpit displays of flight management information that will insure the efficient and safe use of ATC system technology.

- Development and validation of electronic control/display technology for consolidating and integrating the man/machine interface, including electronic display media, pictorial multimode display generation, and multi-function controls.

- Establishment of a qualitative and quantitative data base for display format/arrangement factors.

- Expert or intelligent systems that monitor status and inform, advise or aid the flight crew, and other advanced input and output devices and methods such as voice synthesis and recognition, pointing, and touch devices which could increase the effectiveness of the flight crew.

- Planning/replanning and communication management to facilitate safe and efficient flight operations.

- Determination of single-pilot cockpit requirements for safer and efficient operation in the ATC environment.

- Development and validation of human response measurement technologies for a broad range of human functions including assessment of aerospace crew mental states.

- Development of the basis for reliable substitution of simulators for research applications involving atmospheric environment factors.

Considerations in each area should include the automation environment, crew information processing and decision making, and the associated cognitive workload. Phase II follow-on concepts which may include experimental continuations are mandatory in Phase I proposals.

03.10 COMPUTER-AIDED DEVELOPMENT, TESTING AND VERIFICATION OF FLIGHT CRITICAL SYSTEMS
Center: ARC

Integrated computer-aided techniques for the development, testing, implementation, and verification of flight critical systems are needed to support the emerging generation of both research and operational aircraft. These aircraft will rely on conventional and knowledge-based systems for correct and safe operation. The complexity of such systems requires the techniques for integrated system, control law, display, and functional specifications to be developed, documented, implemented and tested.

Innovative proposals are sought for computer-aided systems that:

- Provide better life cycle support for requirements through functional specification, design, implementation, testing and maintenance.
- Allow more effective automatic testing and verification of conventional and intelligent knowledge-based systems.
- Improve human-readable documentation for design, implementation, and testing.

04.00 MATERIALS AND STRUCTURES

04.01 STRUCTURAL COMPOSITE MATERIALS FOR PROPULSION SYSTEMS
Center: LeRC

Advanced materials for aerospace propulsion and power applications offer many advantages in terms of cost, weight, and performance. Innovations are sought in all the following areas:

- Whisker toughened SiC and Si_3N_4 materials with high reliability and reproducibility: techniques for providing understanding of relations among starting materials, processing parameters, microstructure, and properties; processing, (e.g., sintering and hot isostatic pressing) to minimize flaws, improve temperature capability and enhance fracture toughness.
- Fiber reinforced ceramic matrix composite materials: ceramic-matrix composites of improved toughness and reliability; ceramic fibers of improved high-temperature strength, purity and handle-ability; material models to predict and optimize ceramic performance based on matrix and fiber properties; Chemical Vapor Deposition (CVD) processing to coat fibers and composite materials.
- Polymeric materials: polymer matrix composites, adhesives, and oxidation resistant coatings suitable for use at temperatures above 650°K and amenable to design and fabrication using extensions of conventional technology including lower cure temperatures; optimization of process monitoring to allow adequate control and verification of chemistry changes during the fabrication of composite structures; computational methods to predict matrix and composites properties; new polymers and polymer matrix composites with good electrical conductivity (>10 $ohm^{-1}cm^{-1}$), and environmental stability.
- Materials for hypersonic propulsion: advanced materials concepts to provide the low density (below 0.2 lb/cu. in.) with high temperature (above 2200°F) retention of properties; the materials should provide high modulus, low thermal expansion, high

thermal conductivity, and must be amenable to fabrication into complex structures for hypersonic applications.

04.02 HIGH TEMPERATURE STRUCTURAL COMPOSITES
Center: LeRC

High temperature structural composites can be tailored to specified design requirements. This aspect makes them leading candidates for application to aerospace propulsion structures. Innovative approaches are sought in the following areas:

- Test procedures to determine fiber properties at room, cryogenic, and high temperatures, including time and nonlinear stress effects. Properties are: physical, thermal, mechanical, electrical, magnetic, etc. in both the longitudinal and transverse directions.

- Dedicated systems to monitor in-service life/durability of fiber composites to be located on board strategic locations so that the critical structural areas can be continuously monitored and be sufficiently sensitive to nondestructively pick up degradation in both stiffness and strength. The monitoring system must have provisions to accommodate deviations by real time probabilistic analysis and statistical inference.

- Adaptation of composite mechanics (micro, macro, fatigue, life) calculations to multiparallel processing computers to be performed simultaneously, in order to design composite structures in one pass through the multiparallel processor.

- Dedicated computational methods to predict fracture toughness in composite structures. There are strong indications that fracture toughness is a structural property where the material, the geometry, the supports, and the loading conditions contribute to it. It appears quite possible to computationally simulate the structure fracture toughness in terms of parameters such as critical crack length and strain energy release rate.

- Probabilistic structural mechanics for parallel processing computers and the adaptation of probabilistic structural mechanics to multiparallel processing computers.

04.03 COMPOSITE MATERIALS FOR AEROSTRUCTURE AND SPACE APPLICATIONS
Center: LaRC

Resin matrix composites offer potential for significant structural weight savings in aircraft. Innovations are needed to improve composite structural efficiency, reduce the cost of fabricated structures, and improve long-term, high-temperature performance. Advantages can include: damage tolerant fiber architectures using textile processes; new loom/machine concepts to produce multiaxial, multilayer fiber architectures; cost effective processing and automated fabrication concepts; new material forms (e.g., powder-coated tow); and science-based models and sensors for in-situ cure monitoring.

- Innovations are needed in oxidation-resistant carbon-carbon composites as hot structure on advanced hypersonic vehicles. These may include: thin, moisture-resistant coatings; concepts for improved coating adherence; effective, durable sealants and overcoats; improved interlaminar properties of 2-D composites; efficient fabrication methods for complex structural shapes;

- Innovations desired for ultra high-performance composites and fabrication processes for space applications include: high quality thin-gage composite tubes for precision space structures; composites and fabrication processes which minimize residual stresses including low coefficient of thermal expansion (CTE) materials; materials that can be rigidized remotely for on-orbit deployment of space structures; new methods to fabricate glass-matrix composites.

- Innovations are also solicited for improved metal-matrix composites for high-temperature applications: thermally stable fiber/

matrix interface; innovative low-cost fabrication techniques; and new high-strength high-temperature fibers.

04.04 ADVANCED ALLOYS, INTERMETALLICS AND METAL MATRIX PROCESSES
Center: LeRC

Innovations are sought in the following areas:

- Processing and alloying concepts for intermetallic compounds of near equiatomic iron, nickel, and niobium aluminides having high temperature strength and room temperature ductility. Concepts may include: melting powder metallurgy, and rapid solidification processing techniques to produce high purity materials; and alloying concepts to improve ductility, strength and oxidation resistance.
- Improved fibers and matrices for metal matrix and intermetallic matrix composite materials. Concepts may include: fibers having low density, high elevated temperature strength, high elastic modulus with thermal coefficients matching those of metallic and intermetallic matrices and that are chemically compatible with metallic and intermetallic matrices; matrices which are light weight and capable of high temperature (1500-3000°F) applications in aerospace structures; CVD and related methods to coat fibers; and innovative processing concepts for fabrication of fiber-reinforced metallic and intermetallic matrix composites.

04.05 COMPUTATIONAL STRUCTURAL METHODS
Center: LeRC

Computer simulation of the complex structural interactions which occur within the hostile thermomechanical loading environment of aerospace propulsion machinery is an extremely demanding computational problem. Advances in computer science and technology are providing new capabilities which will allow very costly experimental system development to be replaced with numerical simulation. There is a need for a change in current methods to achieve the benefits of modern computer science practice, especially those employing multiprocessor architectures.

Formal optimization and probabilistic methods are required due to lack of designer experience with novel structural and material concepts. Many re-analyses can result in extreme demands on computer resources or require drastic simplifications of the analysis model. Multiprocessor architectures provide opportunities to improve both optimization and probabilistic design methods.

Novel analysis and optimization methods are needed which fully exploit emerging computing hardware architectural concepts. Also needed are methods for adapting or converting existing structural analysis and optimization capabilities to effectively make use of these new computer systems.

Innovative methods which exploit modern computer science and emerging computer technologies are needed to fundamentally improve aeropropulsion structural analyses, such as: Advanced analytical methods which can fully exploit emerging computer hardware and software technology; methods for adapting and converting existing structural analysis and optimization methods to take full advantage of emerging computing technologies; evaluations of how applicable and adaptable a particular computer architecture is for solving particular aeropropulsion structural analysis and optimization problems; and evaluations of new hardware such as the emerging neural net technology to replace the need for many re-analyses.

Aeropropulsion system structures often have cyclical symmetry, often have nonlinear response, are subjected to high temperatures, operate with high speed rotations, and exhibit fluid-structure coupled response. The formulation and solution of these problems is of general concern, as are methods for exploiting new machine architectures.

04.06 NONDESTRUCTIVE EVALUATION TO CHARACTERIZE MATERIAL PROPERTIES
Center: LaRC

Innovations are desired in Nondestructive Evaluation (NDE) and measurement science for characterizing material properties. Traditionally, NDE has been a final checkout procedure for quality assurance. Today, the needs for NDE go far beyond flaw detection to fundamental quantitative measurements of material and microstructural properties. The results of such measurements need to provide real physical properties that can be evaluated to determine their effect on performance of the material or structure. Quantitative NDE should be applied at developmental 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/structures, reduced costs in developing and maintaining aerospace systems, and means to make informed decisions for safe and economical life extension of aging systems. The desired benefits should be applicable to NASA's national responsibilities and the commercial sector.

The focus must be on development of probing energies that can be used in a nondestructive fashion to determine aerospace material properties related to their performance requirements. NDE opportunities include the development of measurement science instrumentation for: characterization of new high temperature materials, effects of atmospheric and space environment of materials, effects of stress and fatigue, microstructural imaging/characterization, electronic materials NDE and in-situ lifetime monitoring of materials/structures relative to both future and existing systems. This should involve novel technology and new instrumentation suited to addressing the state of health of space systems as well as aviation systems, including current aging airfleet evaluation problems. Measurement capabilities need to function well in real world operating situations and under both normal and harsh environments.

04.07 BOND STRENGTH OF THERMAL SPRAYED COATINGS
Center: KSC

The increased use of thermal sprayed coatings in industrial and aerospace applications has resulted in the need for novel, innovative test methods to evaluate the bond strength in a manner which is representative of in-service conditions. The current ASTM test method (C633-79) loads the test specimen perpendicular to the plane of the TSC-substrate interface. Although the test method does provide a useable quality control tool, it has significant limitations. Sample preparation is a time consuming operation; the bond strengths measured are limited to the strength of the adhesive used in sample preparation; and the results reportedly do not always correlate with in-service conditions. The objective is to develop innovative, reliable, bond strength test methods which are easy to perform.

04.08 SPACE ENVIRONMENTAL EFFECTS AND SURFACE DEGRADATION
Center: MSFC

Spacecraft surface materials of the future must be stable when exposed to the combined environment effects of space for extended periods of time in excess of 30 years. Innovative materials, material modifications, material testing, and instrumentation must be developed to meet this challenge. Examples of required innovation include, but are not limited to:

- Atomic oxygen protective coatings for typical spacecraft surface materials that are also stable in the space environment and are low off-gassing.
- Coatings for stability when exposed to combined effects of the natural space environment, and the induced contamination from the spacecraft.
- Systems to analyze orbiting spacecraft surfaces for contamination or structural changes, by remote operation.
- Long life lubricants for orbital spacecraft application.

04.09 LIGHT ALLOY METALLICS FOR AIRFRAME STRUCTURES
Center: LaRC

Future aerospace vehicles will require higher structural efficiencies than currently possible with available metallics over the entire range of aerospace applications, from light alloy systems to low density refractories. Improvements in structural efficiencies may be attainable through innovative structural concepts, processing methods and new alloy products with significantly improved properties. Innovative approaches are sought to achieve these opportunities, examples of which might include:

- Alloy synthesis and development studies employing rapid solidification technology, powder metallurgy processing, and mechanical alloying have all resulted in laboratory quantities of materials with dramatically improved properties. Innovative exploitation of these advanced processing methods should produce new materials of non-equilibrium chemistries which will increase the upper use temperature for each principal alloy system (beryllium, aluminum, titanium) by at least 200°F. Materials should be amenable to processing to foil gage thickness as well as conventional product forms of extrusion, forging, plate, or sheet.

- Advanced materials, such as intermetallic compounds of binary alloys, have unique characteristics and properties. Literature indicates that the beryllides have such compounds that could be capable of withstanding temperatures in the 1800-2000°C range and be oxidation-resistant. These materials are usually difficult to produce and form in usable structures. The materials, if producible, would be useful for applications in various thermal protection systems and airframe surfaces of hypersonic vehicles. Needed are innovative methods to produce and characterize several of these compounds.

04.10 WELDING TECHNOLOGY
Center: MSFC

Innovation in welding, controlling and improving the properties of weldments are needed to achieve lower cost, lighter, more reliable components. Of particular interest are innovative techniques for:

- On-Orbit repairs and metal joining. This may include: compatibility of welding processes to the space environments; remote and/or autonomous control of welding process; joint design;

- Quality assurance schemes. Assembly constraints, including effects of distortion; tooling and fixturing; cutting and joint preparation; and space welding test and simulation facilities.

- Mathematical models of weld processes or weld-process features. The models are to be used for optimizing process design/setup parameters and as a software component of real-time control systems. Physically based models are considered more informative and trustworthy than purely empirical correlations, but both kinds of models are of potential interest. Weld processes used to manufacture critical aerospace hardware or those worthy of consideration for on-orbit applications are the chief interest. Testing and correlation schemes for relating the models to test results are also important.

04.11 SPECIAL-PURPOSE MATERIALS FOR SPACE FLIGHT APPLICATIONS
Center: GSFC

Innovative approaches are sought for new materials and processing techniques for use in and on research spacecraft and instruments. Areas of interest include but are not limited to the items listed below. Other advanced concepts are also solicited.

- Lubricants for space use that maintain near constant viscosity over a wide temperature range by means of electro-rheological control.

- Improved conductive paints (black and white) for space flight applications. In particular, a conductive flat black paint for cryogenic applications is required.

- Light-weight metal hydride collector that readily and safely binds hydrogen is required to allow hydrogen coolers to be used for Shuttle launched instruments without the expensive vehicle modifications that would be required for overboard venting.

- Transparent photo-elastic thin film materials that can be used for measuring and monitoring stress on structural member surfaces.

- An anaerobic compound that can be used for threadlocking applications and also meets spacecraft outgassing requirements.

- Cryogenic systems materials technology to satisfy thermal and structural requirements while maintaining their properties at extreme temperatures, exhibit low-out gassing in a vacuum and be compatible with manned and unmanned space flight safety restrictions, including: structural materials with low thermal conductivity; transition joints between dissimilar materials; thermal insulation materials; materials for bearing surfaces; materials for light weight cryogen tanks; electrical leads with low thermal conductivity; and inert films exhibiting low friction and long life at cryogenic temperatures.

- Alternative energy storage concepts suggested for spacecraft utilize composite material rotors in a magnetically suspended flywheel. Such rotors must be fabricated to achieve very high useable specific energy density under cyclical operation and will depend on new innovative approaches to be successful, possibly including: analytical techniques to model rotor rotational, residual, and curing stresses; analytical and experimental techniques to improve reliability through fabrication quality control; techniques to assure static and dynamic rotor balance quality; and techniques to prestress the flywheel rotor in order to achieve improved performance and eliminate radial delamination.

04.12 CONDUCTIVE COATING SYSTEMS FOR SCANNING ELECTRON MICROSCOPE IMAGING
Center: JPL

NASA plans to launch a cometary probe in 1995 (CRAF) to rendezvous with a comet early in its orbit and follow it in towards the sun. One of the spacecraft instruments is a miniature scanning electron microscope (SEM) that will capture micron size comet dust particles for analysis. For this mission and subsequent ones to other bodies, the SEM will provide high-resolution images for studying particle morphology and structure. An x-ray fluorescence detector will be used to determine elemental composition and generate element maps. The dust particles are mostly likely insulating and will thus need to be coated with a conductor prior to imaging and x-ray analysis.

New concepts and techniques are needed for applying up to several hundred thin (~20 nm), conductive coatings to micron sized particles over an area of ~1 mm^2. Metal, carbon or carbonaceous coatings are acceptable. The techniques should lend themselves to operation in a remotely operated spacecraft with a 10-year mission lifetime. They should be capable of automation and extreme miniaturization while needing only a few watts average power during operation. In addition, they should require little or no consumables, such as compressed gases, and require little or no instrumentation for insuring coating reproducibility. Since the samples may contain volatile ices and hydrocarbons, the coating process should not heat the samples. A vacuum of $< 10^{-5}$ torr and a few liters/second pumping speed can be assumed to be available for the processing stage of the instrument that would house the coating system.

Candidate processes include direct thermal evaporation of coating materials, decomposition or pyrolysis of metallic gases and compounds or binary chemical reactions. Ion sputtering of a solid target is another possible process. A variety of ion sources could be used; solid thermionic cathodes, liquid metal ion field emission or glow discharge. Other processes for coating are possible. Any of these processes that exist in the laboratory will require miniaturization and improvements in lifetime and reliability, and/or reduced power consumption to meet space mission requirements.

04.13 SPACECRAFT STRUCTURES AND MECHANISMS
Center: JSC

Future space operations must incorporate important innovations in all aspects of spacecraft development including unique structural configurations and new materials applications. Missions are being planned which will involve combined space and atmospheric flight, orbital transfer and aero-braking, planetary exploration, and other long duration space missions. Some suggested areas for innovative improvements may include:

- Structures that can be fabricated in space, deployed in space, or assembled in space.
- Structures that have a near-zero coefficient of thermal expansion.
- Designs for structural joints which have no free-play, can be easily mated and unmated, and can readily be replaced. Robotic manipulation capability is preferred.
- New methods of fabricating parts with reinforced metal matrix composite and reinforced ceramic matrix composite materials.
- Unique landing or docking impact attenuation materials and mechanisms.
- Improved mechanical connections for assembly in space, such as electrical and fluid umbilicals.

04.14 ACTIVE STRUCTURAL ELEMENTS FOR SPACE APPLICATIONS
Center: JPL

Future NASA missions will require the design of high precision structural systems. Such structural systems will have to maintain very high dimensional stability: typically the relative deflections during operation will not be allowed to exceed one micron over twenty meters. One way to achieve such accuracy is by developing active structural systems. Such systems will sense excessive deformations on orbit and take corrective action. To implement such a system a high precision sensing and actuation system will have to be integrated into the structure. Examples of such integration would be an active structural member, i.e., a truss member that would sense the relative deformation along its length and exert a corrective force or an element embedded into the facesheet of a honeycomb plate that would sense strain and exert a force to counteract such a strain.

Innovative concepts are solicited leading to such active structures to achieve high precision in space applications.

04.15 MATERIALS FOR SPACE TRANSPORTATION SYSTEM AND SPACE STATION
Center: JSC

Space Transportation System enhancement and Space Station programs require innovative new materials and improvement of current materials systems. Some fruitful areas of innovation may include:

- Ingenious new testing and analytical approaches to long life certification.
- Advanced composite materials having low coefficient of thermal expansion, low density, high specific strength and modulus, high damage tolerance, and resistance to microcracking when exposed to long term thermal cycling. Metal matrix, thermoplastic and liquid crystal polymer matrix and ceramic composites are all of interest. Application areas include space structures, Space Shuttle enhancements and advanced thermal protection materials.
- Protective coatings for improving materials life in the space environment are needed. Coatings should protect the substrate from atomic oxygen, UV and VUV radiation and should show minimal damage from micrometeoroid impact and prolonged thermal cycling. Operation at elevated temperatures is of interest as well as resistance to damage during ground handling and deployment. For many applications, the protective coating should not compromise the thermal control properties of the substrate (alpha/epsilon).

- Better techniques for measuring bolt tension during torquing operations.

- Advanced Thermal Protection Materials (TPS): Advanced low density ceramic materials for use at temperatures at or near 3200°F are needed as are ceramic thermal protection materials which show improved resistance to mechanical damage from rain drop impact during atmospheric flight (300-400 kts). A waterproofing methodology for existing Space Shuttle TPS which can survive repeated re-entry heating in air is needed as is an advanced low density ceramic TPS material which remains waterproof after repeated re-entry heating in air.

- Fluorocarbon materials having enhanced resistance to damage from UV, VUV and ionizing radiations while retaining resistance to atomic oxygen are of general interest for space applications. The engineering properties of the candidate fluorocarbon polymers should be similar to, but not necessarily identical with those of FEP teflon (a copolymer of hexafluoropropylene and tetrafluoroethylene).

Each Phase I proposal must clearly indicate Phase II continuation requirements including hardware-oriented applications ultimately by NASA.

04.16 HIGH TEMPERATURE SUPERCONDUCTING MATERIALS FABRICATION AND CHARACTERIZATION
Center: JPL

High temperature superconducting materials could offer significant benefits for many space applications. Potential applications include high frequency signal sources and detectors as well as reduced power and weight spacecraft circuitry. New concepts for applying these materials to high frequency circuits and spacecraft applications are desired, as well as development of deposition techniques for production of high quality thin films on suitable substrates for millimeter wave applications. In particular, innovations are sought in the following areas:

- Determination and production of low dielectric constant substrates suitable for epitaxial growth of high temperature superconducting thin films for high frequency applications.

- Development of chemical vapor deposition (CVD) techniques for growth of high T_c thin films at low temperatures on non-planar substrates such as microwave cavities.

04.17 HIGH TEMPERATURE SUPERCONDUCTORS FOR AEROSPACE PROPULSION, POWER, AND COMMUNICATIONS
Center: LeRC

High temperature superconductors for aerospace propulsion, power, and communications applications offer significant payoffs if issues such as ceramic superconductor current capacity and critical field capability can be resolved. Progress is required on issues such as durability, fabricability and strength. Innovations directed at fabrication of thin and thick films, bulk superconductors with improved electrical, magnetic and mechanical properties are sought. Examples include innovative deposition techniques, single crystals in bulk or fiber form, compositing to enable high-field magnets, techniques for controlling bulk microstructure to achieve optimum properties, and fabrication methods for producing high T_c superconducting wire suitable for use in unusual applications such as construction of magnets for wind tunnel magnetic suspension balance systems.

04.18 LUNAR MATERIALS UTILIZATION
Center: JSC

Eventual manned activities in space will require or be enhanced by utilization of lunar materials as sources of propellants, mass for shielding, volatile gases, metals, and ceramics or other construction materials. Early work is needed to define the best processes to carry out on either the lunar surface or in Earth orbit. Selection of appropriate methods and equipment will consider reaction thermodynamics, reaction rates, engineering requirements, and system characteristics. Specific areas for innovations are:

- Novel methods for extracting oxygen, other useful gases, metals, and non-metals from lunar materials.

- Highly automated mechanical equipment, sized for the lunar or earth-orbital environments, to extract and move lunar materials from their source to the processing facilities, and to concentrate and size the feedstock to material which can be most efficiently used in the processing facilities.

- Simplified, self-contained systems that can process metallic or ceramic material into useful shapes including bars, rods, wires, bricks, paving blocks, or habitat structural elements.

- Novel systems for transporting lunar materials.

- Novel uses of indigenous materials at a lunar base.

Because prospects for ultimate direct applications of this research may not exist for many years, it is imperative that Phase I proposals must lead to realistic nearer-term Phase II objectives which will contribute significantly to ongoing NASA research programs, and di rectly or indirectly provide expectations of non-NASA spin-off processes or products.

05.00 TELEOPERATORS AND ROBOTICS

05.01 TELEROBOTIC SYSTEMS TECHNOLOGY
Center: LaRC

Telerobotic systems, incorporating selected features of both teleoperator systems and automated robotic systems, will be needed for space tasks, including assembly, inspection, repair, and experiment operation. Innovative technology advances are sought in several systems technology areas which underlie all practical applications:

- Sensing and Perception: Automatic or operator interactive systems for the generation of geometric data base by processing video/range images from a standard view. Sensors and techniques for accurate determination of location and orientation of known objects (range less than 10m) for sensor based control or geometric data base verification applicable to the space environment.

- Manipulator Dynamics and Control: Modeling and control methods for multiple manipulator coordination, control algorithms for manipulators with redundant degrees of freedom, and analysis and ground simulation techniques for the evaluation of on-orbit assembly and manipulation of very large space structures including scaling techniques, flexibility, and compensation for 1-g test environment.

- Operator Interface: Efficient methods, displays, and controls for monitoring, failure diagnosis and correction of telerobotics systems performing complex assembly and servicing tasks. Operator interactive systems for the development of task sequence planning and spatial path planning including methods of dealing with fault detection and diagnosis, and error recovery and replanning.

05.02 TELEROBOTIC AND BIOMECHANICAL SYSTEM SOFTWARE DEVELOPMENT
Center: GSFC

Systems containing teleoperator and autonomous robotic capabilities are envisioned for a wide range of challenging technological problems. For both ground and space based applications, there is an evolving need not only to model the machine part of a dynamic man-machine system but also the human biomechanical part. This envisioned analysis capability will be required to quantify alternative control scenarios from a human factors perspective, optimize machine controller design relative to human operator capabilities, and address such related issues as cumulative trauma, muscle stress, pain and fatigue. Innovative advances in the technology of generating an integrated control, structure, ergonomic, biomechanical system design and analysis capability are sought for the fully coupled dynamic system. Implementation concepts should maximize use of existing technology while including the following capabilities:

- Approaches for interfacing general purpose anthropometric and biomechanical models into comprehensive ergonomic models of the human operator during man-machine interaction.

- Systematic methodologies for dealing with:

  - anthropometric representations of static body segments,
  - ligament and musculotendon lines of action,
  - biomechanical representation of body segment motion,
  - generalized representation for multi-bone body segments,
  - generalized representation for diarthrosis, movable joints.

- Computationally efficient algorithms within the framework of the associated general purpose software implementation.

05.03 TELEROBOTIC ELECTRO/ MECHANICAL SYSTEMS
Center: GSFC

Systems combining teleoperation and robotic/autonomous features are envisioned for many future space applications, including unmanned science experiments, space manufacturing, structural assembly, module replacement, and servicing and repair. Innovations in all areas of telerobotic technology, basic system design, and implementation concepts are sought, including:

- Mechanical robotic manipulators and actuators that can function very smoothly in near-zero gravity environments with relatively high acceleration, but does not disturb the acceleration level of the surroundings via reaction forces or moments.

- Real-time programmable robot joint stiffness and back drive-ability with fail safe joint locking.
- Rolling friction fastening systems and drives with special emphasis on high efficiency, reliability, compactness, strength and no backlash for robotic manipulators and effectors and their payload fastening systems.

- Heat-energized payload fasteners and sensors verifying the attachment.

- End effectors and integrated sensor systems.

- Cableless power and signal transfer across robotic wrist joint.

- Ultra strong and compact low power fail-safe brakes for end effector drives.

- Ultra-reliable strain gauge mounting techniques. Highly accurate strain gauge temperature compensation.

- Alternatives for strain gauge sensors which perform the same functions but which are not vulnerable to separating from the structure they are mounted on. Also these must be capable of being used on end effector fingers, sensitive, wide dynamic range and good immunity to temperature changes.

- Sensors to prevent robots from grasping or colliding with hot objects in space.

- Fiber optic-based end effector micro controllers, digital-to-analog (D/A) and analog-to-digital (A/D) converters and multiplexers/ demultiplexers, strain gauges and tactile sensors, and communication network on robot arm for coordinating distributed micro-controllers.

- Tactile, proximity, imaging (range and video), and force and torque.

- Real time control algorithms, dealing with all levels of driving the robot.

- Low level path planning.

- VHSIC - based distributed micro controllers with ultracompact power supplies.

- Robot wrist configurations capable of two independent rotary motions about a common center (for screwdriving and gripper manipulation) with the inner rotary motion continuous.

- Muscle-type actuators suitable for multiple, independent tendon drives.

- Sensing and Perception systems that permit real-time 3-D visual tracking of moving and stationary objects in a cluttered environment. Representation methods of forces and torques for teleoperation are needed to permit rapid and easy operator perception.

05.04 ROBOTIC ADAPTIVE GRASPING SYSTEMS
Center: JSC

Space robotic systems are envisioned to perform some tasks as assistants to or in lieu of extravehicular activity (EVA) crewmembers. Adaptive grasping of various objects such as tools and spacecraft components is required to minimize unique robotic end effectors. A dexterous, autonomous grasping system consisting of a mechanical hand and arm and the associated sensor and computer systems is seen as the method of implementing robotic adaptive grasping. Innovations are sought in the following areas:

- Robotic hand and arm design, especially the integration of a dexterous hand and a multiple degree of freedom arm.

- Sensor systems required to allow object sensing, adaptive grasping, and recognition of stable grasps, as well as integration of sensors with a robotic hand and arm.

- Computer systems for intelligent, autonomous control of robotic hand and arm operation.

- Integrated software systems combining object location and recognition, task planning, sensor fusion, and grasp control.

05.05 ARTIFICIAL INTELLIGENCE FOR SPACE STATION APPLICATIONS
Center: JSC

Artificial Intelligence will play a vital role in space operations in the Space Station era. Innovative approaches to the development of intelligent systems, both robotic and other knowledge based intelligent systems, are desired. Of particular interest are innovative approaches based on the concept that intelligent systems attempt to achieve goals based on the interaction between modifiable subgoals, dynamic descriptions of the environment, and dynamic descriptions of the intelligent system itself. Innovations that demonstrate simply and minimally specified descriptions or models interacting with updating information, e.g. sensor information, in order to perform functions in the following or other Space Station related areas are solicited:

- Intelligent control of robotics for autonomous navigation and for carrying out assembly and retrieval.

- Intelligent systems for process control functions, for automated diagnosis and repair functions, for data monitoring and reporting to the ground, and for planning crew schedules and activities, particularly in support of the Space Station operations management system.

- Hierarchical and distributed self updating systems for Space Station subsystem and system management functions, and hierarchical control mechanisms for distributed networks.

- Approaches to knowledge-based systems for engineering design knowledge capture, tools to aid crew and ground support in updating intelligent system software, innovative approaches to lower level controlling software and hardware in support of intelligent systems, and approaches to increasing the reliability of the Space Station through the application of intelligent systems.

- Approaches to the automation of Space Station computer code generation, (e.g., ADA code) from system specifications developed in AI development environments such as Knowledge Engineering Environment (KEE) or Automated Reasoning Tools (ART).

05.06 TELEOPERATION AND ROBOTICS
Center: JPL

Advances in teleoperation and automation modes for task sequencing hold the potential for substantially increasing the overall level of capability for Space Operations. Unmanned science experiments, space manufacturing, and man-assisted autonomous servicing, assembly, maintenance and repair in space are some of the potential applications. This expanded potential will provide alternatives to excessive dependency on ground operations personnel, will increase man's reach into the unique space environment, and decrease cost of operating and managing space assets. Planned space applications include the Polar Platform, the Space Station, the Space Servicer System and the Mars Rover. Innovations in basic design, implementation concepts, and hardware development are sought, including:

- System level fused displays; automatic multipayload operation profile generation; automatic on-line command sequence training; fault diagnostics and recovery; multi-mission co-registration ground support data base management; automatic mission operations; and ground teleoperation interfaces.

- Appropriate base and remote control architecture that reflects the necessity to perform off-line planning at the base and on-line planning/monitoring at the remote site.

- Appropriate heuristics, control, and error recovery management at the remote site that places a robot in a safe state with no damage to the task environment.

- Modeling/simulation of the time delay envelope as a function of the base and remote control architectures.

- Use of both local and global computer graphic simulations that allow the operator to control the simulation in the exact manner the remote manipulators are actually controlled, and give the operator the appropriate relational data not necessarily visible from the video camera feedback due to shadows or limits in the field of view.

- Sensory feedback (force/torque/video) which compensates for time delay.

- Operator error/damage assessment heuristics which provide warnings of impending catastrophic failures as a function of the imposed time delay.

- Work station architecture which monitors operator input and provides appropriate cues for mismatches between operator response and desired smooth system response.

- Manipulator Dynamics and Stability: High fidelity modeling and control methods for small, 3-5 meter manipulators for servicing scientific instruments. Requirements include manipulator flexibility and compensation for vehicle dynamics during attachment and stabilization; inverse kinematics and control algorithms for manipulators with redundant degrees of freedom; adaptive/distributive control methods for architectures for flexible manipulators and flexible/deformable end effectors.

- End Effectors: Reconfigurable designs with touch, force and torque and proximity sensing for space servicing of scientific instruments.

05.07 SPACE MECHANISMS
Center: LeRC

Mechanical automation, robotic manipulation, and mechanized operation will become an increasingly vital part of future space missions. Mechanisms will be required to perform an immense variety of operations. Innovations in all areas of basic mechanism concepts, design, and technology for mechanical motion control, smoothness and necessary reaction compensation are required, including:

- Mechanical technology development will eventually be required for machines for use on Lunar/Martian surface operations, e.g., exploration, excavation, mining. Robustness, fault-tolerance, efficiency, tolerance to environment, and long life are essential qualities.

- Magnetic bearings, cryogenic devices, speed reducers, and other devices to improve performance of future space machinery.

- Bearing design concepts, lubrication techniques, including dry lubrication to improve reliability, reduce torque ripple, and expand performance envelopes.

- Inherently ultra-clean (no outgassing, absorption, or particle generation) robots and mechanisms for operation in ultra-clean vacuum.

05.08 SERPENTINE ROBOTIC ARM
Center: KSC

The processing of spacecraft at KSC requires some assembly or reconfiguration and numerous system verification tests. This requires physical access to the interior as well as the periphery of these spacecraft. With the spacecraft installed in the launch vehicle, the peripheral access problem now becomes an interior access problem. This access presents numerous problems. Robotic systems have been proposed as an alternative to building small access platforms and having technicians perform the work. While robots can usually provide access to peripheral areas, arm clearances required for revolute systems limit the areas to which they can provide access and hence their usefulness. Since line of sight access is seldom available, cartesian, polar and cylindrical systems are also limited.

An innovative multi-jointed arm with each joint having pitch, roll, and yaw capability and the control system for this multi-jointed arm directing it to negotiate a sinuous path in a serpentine fashion is needed to perform these tasks. The system must have the capability to move into and through a defined opening (one foot diameter, one foot square, etc.) and follow a defined circuitous route (five foot radius with obstacles at one and three feet, straight two feet with angle for three feet with angle for two feet, etc.) while carrying an end-effector, maintained as a stable platform, while entering the "tunnel" and withdrawing from the "tunnel" without making contact.

05.09 MISSION EXPERIMENT SUPPORT TELEROBOTICS
Center: MSFC

Subsystems Long duration orbital experiments and missions will require telerobotic systems to adaptively support various phases of operations, which previously were manned or hard automated. Innovations are required to adapt current robotic systems to perform the tasks in the following areas:

- Passive targets (retroreflectors, gratings, holograms, rectennas, etc.) mounted on specimen carriers and modules which can be tracked in 3D attitude and position and an active tracking sensor which can terminally guide and register the telerobot for grasping or berthing the carrier or module.

- Robotic arm and end effector design to perform precision tasks within a closed volume with robust kinematics to maximize utilization of the volume for operations in orbit.

- User friendly intelligent visual inspection and monitoring system which can be taught to observe visual parameters in various wavelengths to detect short term differences, long-term changes, etc.

- Robotic hand and tool design which enhance terminal precision for material handling, module transfer and carrier manipulation.

06.00 COMPUTER SCIENCES AND APPLICATIONS

06.01 ENGINEERING COMPUTER SCIENCE
Center: LaRC

Application of high-speed computing to large-scale problems, as in the area of computational fluid dynamics (CFD), requires new capabilities for improved computational speed, for input and output data handling, and for presentation of results in understandable ways. The applications of interest require computations at rates on the order of a billion floating point operations per second on arrays of several million elements. Parallel processing is expected to be used to achieve these speeds. Innovative new concepts and approaches to these objectives are solicited:

- Software to ease the task of developing efficient programs for parallel processing computers and retain efficiency of programs transferred from one architectural design to another.

- Software to exploit the advantages of parallel computing in solving significant real-world problems, as in complex-geometry CFD for example.

- Data management, handling, and structuring systems for large scientific/engineering computational data bases.

- Software and hardware systems to facilitate the preparation of input and the analysis of results interactively using engineering workstations networked to supercomputers.

- Graphical concepts (implementable in software or hardware) to visualize computational results in ways which can bring new understanding to the physical phenomena being modeled, with emphasis on three physical dimensions and several display variables.

06.02 ADVANCED SOFTWARE DEVELOPMENT AND MAINTENANCE
Center: GSFC

- Innovations are required to assist the development, verification, maintenance, and enhancement of large scale, complex software systems. All support systems must provide good documentation and visibility for the users, and their potential applications may also apply to many other NASA activities. They may include:

  - Techniques, tools, and support environments to reduce life cycle costs and improve the process of specifying and meeting application requirements for software development projects involving complex spacecraft control and data handling functions and requiring large development teams;
  - Advanced support systems for management control and tracking, requirements analyses and design specification, analysis and verification methods, development languages and support libraries, reusable software base development and systems integration techniques, code verification and testing techniques, and adapting and maintaining software for long-term unmanned missions and projects (10 to 20 years);
  - Support systems for developing and testing time-critical applications, distributed system software, and fault-tolerant software.

- Innovations to improve handling large amounts of digital data stored during spacecraft testing using advanced technologies to enhance project resources, and improved storage technologies are needed to handle the growing mountains of data associated with increasingly sophisticated satellites. Innovative concepts are solicited to achieve these objectives:

  - Storage of multiple sources of information from a wide range of devices with different data rates;
  - Storage of different types of digital information;
  - An adaptable system which can assimilate data from multiple points,
  - Data space minimization with easy retrieval.

06.03 RELIABLE SOFTWARE DEVELOPMENT
Center: LaRC

Innovative approaches are sought for the development and verification of very reliable software. These might include computer-aided support of requirements analysis and design specification, executable specification languages, automatic program generators, programming language features to improve software reliability, automated testing and verification techniques, and software safety and risk assessment methods. Of particular concern are programming languages and environments for developing time-critical applications, distributed and parallel software, and fault-tolerant software. Potential applications extend across all NASA activities.

Offerors are cautioned not to propose concepts and approaches already studied extensively in recent years or currently being pursued in many related objectives funded by the Department of Defense.

06.04 KNOWLEDGE BASED SYSTEMS TECHNOLOGIES FOR AEROSPACE APPLICATION
Center: ARC

Knowledge understanding, representation, and implementation are the key elements to the effective development and implementation of advanced software systems for spaceborne, airborne, and earth-based applications. At the current time there exists a need for skilled knowledge engineers to translate the expert's knowledge to heuristic/rules for the applicable technical domain. Commercial "shells" are available which ease this translation, but they are very domain specific and are not efficient when interacting with unreliable data or with multiple technical domains. Development of knowledge engineering technology is needed in areas such as:

- Information extraction and understanding from multiple sensors with capability for automated interpretation of complex objects and data.

- Global knowledge understanding, representation, and control of multiple, domain-independent knowledge bases.

- Integrated data bases for distributed knowledge-based systems.

- Machine learning with automated capability for the generation of new heuristics.

- Automated programming development, data base management, verification, and validation.

- Hierarchical control architectures for distributed knowledge-based systems.

- Task planning and reasoning knowledge-based systems capable of operating in dynamic domains with rich representation capabilities to enable reasoning about concurrency and subsystem interaction.

- Man-machine interfaces capable of displaying integrated dynamic system relationships that are understandable and accessible to the human at a higher level of communication; i.e., allows the operator to input into the computer in a flexible and natural manner what is desired and the reason for the request.

06.05 SOFTWARE SYSTEMS FOR MISSION PLANNING AND FLIGHT CONTROL
Center: JSC

Innovative new concepts, such as AI and graphics, are needed to improve the techniques for pre-flight and real-time mission planning and control in support of flight operations of the Space Shuttle and the Space Station. Examples of areas of high interest include:

- Automated knowledge acquisition expert systems.

- Intelligent computer-aided training systems and computer-aided engineering (CAE) systems.

- Artificial neural systems

- AI applications, such as Concurrent AI on parallel processors, real-time distributed database systems for parallel processors, auto decomposition of programs on parallel processors, integration of different AI systems (vision, speech, expert systems, etc.), fuzzy logic, and porting AI software to Ada.

- High fidelity single frame graphics systems.
- 3-D graphics object generation systems.

06.06 COMPUTER SCIENCES ADVANCES IN COMPUTATIONAL PHYSICS
Center: ARC

Computational physics is a powerful and cost-effective tool for solving a large class of aerospace problems. Innovative computer science concepts are needed to move the state of the art forward and hasten its availability for greater use. Innovation, are sought in increasing computing speed, mass storage, longhaul communications, and computer graphics. Some examples are:

- Methods for applying parallel processing and for predicting system performance prior to construction. Architectures of interest include multiple instruction-stream multiple data-stream (MIMD), systolic arrays, data flow, demand driven and reduction machines. In addition to hardware architectures and performance prediction techniques, innovation in the supporting systems software (operating systems, programming languages, debuggers, etc.) is sought.

- Computer graphics for visualization of complex three-dimensional fluid flow phenomena derived from computation or experiment. Specific techniques include enhanced display of internal flow structures, depth perception, quantitative comparison of numerical and experimental fluid flow data, and high-speed but cost-effective image processing techniques suitable for analysis and synthesis of fluid dynamics data.

- Advanced data storage and data compression techniques.

06.07 LARGE MULTIPROCESSOR DATABASE TECHNOLOGY
Center: JPL

A number of distributed-memory multiprocessor machines with supercomputer performance levels are being developed. This class of machine typically is designed for configurations of tens to hundreds of processors. The processor may be a general purpose type such as a 68020, 80386, or T800, or it may be a custom design. Each processor has a physical local memory of a few megabytes, although there may be hardware features to enable the processor to address remote memory as if it were local for programming purposes. Message-passing is the usual programming model for interprocessor communication, often in conjunction with object-oriented programming techniques.

Such machines are capable of performing very complex computations, and they were originally developed to speed up computer-bound applications not requiring much input or generating much output data. A problem arises when these machines are used with applications that consume or generate vast amounts (gigabytes) of data at a high rate in an irregular manner.

Straightforward hardware support can be used to move well-organized data, such as that from an optical sensor, into this class of machine for processing. The problem is much more difficult when the data, which resides on (or is destined for) mass storage devices, is not organized in the same way that it is to be used. This is the case with applications such as simulations or analyses which use or generate standardized data such as that associated with digitized terrain, detailed equipment capabilities and characteristics, economic factors, inventories, personnel and weather records, etc.

Innovative techniques and algorithms are needed to facilitate rapid and efficient processor access to arbitrary data located in very large data bases on mass storage associated with these multiprocessors. These should be compatible with object-oriented programming and suitable for implementation in any appropriate programming language, including C++ and Ada. They should work on a range of distributed-memory machines, regardless of topological details or the specific implementation of mass storage, and be portable from one machine or machine generation to another. While performance will obviously be affected by the capabilities of the actual hardware, the algorithms should take full advantage of available hardware while not relying on specialized features not generally found on this class of multiprocessor.

07.00 INFORMATION SYSTEMS AND DATA HANDLING

07.01 FOCAL-PLANE IMAGE PROCESSING
Center: LaRC

The end-to-end performance of image gathering and processing for high-resolution television and vision-based robotics is severely constrained in many applications by the transformation of visual information from 2-D and 3-D image-gathering systems into a serial stream of data for subsequent transmission and processing by computers. Innovations in focal-plane image-processing techniques are solicited which would overcome this constraint. These innovations may typically be concerned with coding for image compression, detecting edges and segmenting images, analyzing features in the image for patterns of interest, detecting and tracking moving objects, and restoring or enhancing images. The techniques may typically include integrated sensor-array sensing and processing, multi-resolution parallel processing, Gabor elementary signal coding, correlation and feature extraction, shift- and distortion-invariant recognition, and optical and acousto-optic processing.

07.02 IMAGE DATA COMPRESSION AND ANALYSIS
Center: GSFC

As the spectral and spatial resolution of spaceborne remote sensing instruments increases, so does the volume of data to be stored, managed and analyzed. Advances in computing architectures and hardware, e.g., fine-grain parallel computers such as the Massively Parallel Processor (MPP), Distributed Array Processor (DAP), and the Connection Machine, and continuing developments in miniaturization make it feasible to use computationally intensive algorithms to ease the problems of managing such large volumes of data. Suggested specific areas of innovation are in the application of such new developments in technology to:

- Development of lossless and/or lossy compression algorithms for scientific data with potential for "real-time" implementation and low loss in information content to permit efficient storage and analysis.
- Development of pattern recognition and image analysis techniques (including Artificial Intelligence) for use with multispectral data which emphasize the use of both spatial and spectral characteristics of the data.
- Development of techniques for effectively assessing and analyzing data sets derived from sensors with non-congruent resolution and/or varying time observation.

The techniques of data visualization offer an obvious means of greatly enhancing the utility of any comprehensive data system. Visualization is the method of computing that gives visual form to complex data utilizing computer graphics and imaging technologies, and hence, can take advantage of the human eye-brain system quickly to ingest and understand very large volumes of information. Since future NASA programs would require extremely sophisticated data systems to support complex, interdisciplinary multidimensional space and earth sciences data sets, the ability of a potential scientific user to employ such capabilities would likely be very limited unless the most effective methods of data display are employed. Therefore, to provide a foundation for the creation of any future data analysis system, innovative visualization tools are required. Suggested areas of innovation would include, among others: generic object-oriented visualization of data, knowledge-based scientific data representation, and graphical Spatial Data Management.

07.03 STATISTICS OF SPATIAL PATTERNS AND SPATIAL INTERACTION PROCESSES
Center: SSC

Within scientific research areas pertaining to spatially oriented data sets (remotely sensed data, ancillary maps, etc.), there is a growing recognition of the importance of spatial statistics. Currently, most statistical techniques utilized in spatially related applications provide limited validity due to the absence of spatial auto-correlation among random time samples distributed over a given geographical location. Innovation will require emphasis in the following areas:

- Stochastic processes estimated from the design and construction of sufficient models to allow image restoration and reconstruction.
- Jackknifing and bootstrapping spatial data samples to convey elements of uncertainty.
- Smoothing over the parameter space.

07.04 SPATIAL DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEM (GIS)
Center: SSC

The development of geo-referenced databases for analysis of multivariate data within the environment of a Geographic Information System (GIS) has increased the use of remotely sensed data. Several techniques exist to input data from a wide variety of sources including map, photo, and digital cartographic data. Although these data are input through a wide variety of technologies, the time and effort to build a database is still great and represents a significant problem to the application GIS analysis to a wide range of problems. Furthermore, technical issues including the incorporation of expert systems technology, data structure conversion, and data storage are fundamental areas of investigation which would improve the use of this technology. Innovations are sought which would significantly reduce the time and effort to input data into a digital database and increase the analytical capability of GIS technology.

07.05 SIGNAL AND INFORMATION PROCESSING
Center: GSFC

- The recent development of heterodyne arrays requires the need to process the radio frequency (RF) spectral information from the array elements. An innovative approach, for example, might be multichannel acousto-optic spectrometer in which a layered Bragg crystal with independent RF input processes the IF signal of different array elements to obtain the high spectral resolution of the new class of heterodyne instruments. Other innovative approaches are also solicited.
- As future spacecraft and platforms become more complex and sophisticated, a significant portion of the spacecraft weight is due to the electrical harnessing wires for complicated connections among various components of the spacecraft systems to distribute electric signals. Innovation is required to reduce undesirable weight and complexity, possibly through multiplexing of signal processing, distribution network, application of fiber optics sensors, or other novel schemes.
- Optical data storage devices promise to replace the traditional magnetic tape recorders as the principal on-board spacecraft data storage system. Innovative or unconventional approaches to optical head assemblies are solicited to encompass the following: reduction in size and mass, e.g., 20 grams; a new methodology for the redirection of the optical paths internal to the optical head in order to recover more optical signal energy; lower cost through fewer optical elements and reduction in complexity of the manufacturing process; greater resistance to shock, vibration, and misalignment; design flexibility for both WORM and M-O erasable applications; greater resistance to temperature variations; and increased data reliability, perhaps through separate detectors for focus, tracking, and data collection.

- Present availability of technology to produce flight quality extremely low power, radiation tolerant PROMS and EEPROMS is currently limited or non-existent. Development of deep space and long term missions would benefit greatly from the availability of such components and innovative, new technology in these areas is sought.

07.06 INFORMATION PROCESSING TECHNOLOGY AND INTEGRATED DATA SYSTEMS
Center: LaRC

High performance, fault tolerant information data systems are needed for advanced aerospace missions to provide data communication bandwidths and processing services well above those projected for today's spacecraft and aircraft, particularly for data systems that have an integrated form where video, voice, and data are simultaneously distributed and processed. These data systems may also carry real-time data; therefore, both delays and variability of delay must be kept to a minimum for correct operation. For the higher level communications and processing functions, the delays and variability are dominated by the distributed operating system. For the lower level communications and processing, the delays and variability are dominated by the physical properties of the hardware implementation. Innovations are sought in both the areas of distributed operating systems and hardware implementation for meeting future data system needs. Suggested areas for innovation are:

- Distributed operating system concepts and implementations for high performance, real-time response, and fault tolerance.

- Distributed system concepts and implementations that are high performing and fault tolerant.

- Network architecture and topology forms that enhance performance and fault tolerance.

- Fiber optics and wave length division multiplexing for high speed data communications.

- Hybrid electro-optical and optical nodes for network control and high-performance interfaces to the network.

- Optical and electro-optical components/devices (waveguides, couplers, switches, transmitters, receivers, amplifiers) for optical networks.

- High speed gallium arsenide integrated circuits for network functions (coding/decoding, clocking, synchronization, protocol control).

- Simulation and modeling tools to evaluate candidate multiprocessing and distributed data systems.

- Components, devices, and systems for high-performance erasable optical disk recorder.

07.07 SCHEDULING AND AUTOMATION TECHNOLOGY FOR UNMANNED SPACECRAFT OPERATIONS
Center: GSFC

Spacecraft and instrument operations are conducted through a complex interaction of project scientists, network support managers and network control managers using mission planning terminals, payload operation control centers, network operations control centers and other facilities. One result of this interaction is the generation of schedules for the operation of spacecraft and instruments. New and innovative concepts are needed to improve and upgrade planning and scheduling systems and procedures so that they are fully able to meet the demands of the coming decade. The future environment will include independent control and operation of experimental payloads by experimenters from their home institutions, distribution of planning and scheduling functions, schedule integration and increasing evolutionary automation of the process. This will require innovation in the following areas:

- Scheduling algorithms that are efficient for distributed individually controlled resources.

- Planning and scheduling approaches and allocation of functions that are effective for the distributed environment of the coming decade.

- Design of distributed planning and scheduling systems for generating near optimal, conflict free spacecraft and payload schedules.

Once instrument and spacecraft schedules are established, spacecraft control center operations are required to analyze complex spacecraft and instrument relationships from telemetry data and mathematical models, to resolve resource conflicts, and to verify operator actions in real time. Innovative approaches are needed to assist operators in management, control, and fault isolation for more complex spacecraft and supporting networks and round systems. Potential areas for innovation include:

- Distributed expert systems in multiprocessor environments.

- Neural networks and hybrid neural network/inferential logic approaches.

- Knowledge representation.

- Automated knowledge acquisition and learning.

07.08 HETEROGENEOUS DISTRIBUTED DATABASE MANAGEMENT
Center: GSFC

A serious problem for the agency, both in the scientific and administrative realms, is the great diversity of databases and database management systems. To access data from sources other than their own, users are forced to learn a plethora of different languages and access methods. This frequently inhibits, delays or even prevents efficient use of existing systems and further increases the undesirable proliferation. Accordingly, innovations are needed in developing tools for uniformly accessing heterogeneous distributed databases. Possible approaches might include the following or other techniques:

- A software kernel with a universal data representation so that the data model can be layered on top of other heterogeneous data models (i.e., relational, hierarchical, network, text, image, etc.) without creating too much overhead.

- Programming language (C, FORTRAN, LISP, ADA, etc.) based database access that will enable users to read/update heterogeneous distributed databases.

- Terminal based database access that will enable users to read/update heterogeneous distributed databases.

- High-level, i.e., SQL-like, operators that will enable users to build new data objects from existing data objects.

- A "library-like" interface that will enable users to locate data in a manner similar to the way in which patrons locate books in a library.

- Automated retrieval aides that will interact with a user and help the user locate data to solve specific problems and when data is located help the user formulate the query or queries.

07.09 SPACECRAFT ON-BOARD INFORMATION EXTRACTION
Center: JPL

As the spectral and spatial resolution of spacecraft sensors increases, so does the volume of data which must be stored onboard and then subsequently communicated to earth. Improved onboard storage capacity, along with access time and data rate considerations, is required for telemetry link buffering, and ready access memory for real-time processing. Onboard data compression technology can dramatically reduce the required onboard storage capacity, on-board communication bandwidth, and telemetry link bandwidth required. Direct extraction, on-board the platform, of biophysical and other parameters can reduce the cost and complexity of ground data operations. This on-board information extraction capability can also enable fast response to short- and medium-term transient events. On-board data storage and processing technology remains a huge limitation to advancing space system capabilities. Suggested areas of innovation are:

- Tape/head life time improvements for rotary head recorders.

- Magneto-resistive heads to improve both the rate and capacity of longitudinal recorders.

- Compact form factor erasable optical disk systems which can be embedded in an engineering or instrument subsystem to support localized data processing and/or telemetry link buffering.

- Ultra-dense memory concepts based on technologies such as multi-dimensional optical storage, vertical Block line memory, and sub-light wavelengths or atomic level information storage using techniques such as scanning tunneling microscopy.

- Memory architectures and hierarchies which enhance the performance of memory devices and systems, such as increased concurrency in input and output stages, improved responsiveness of read/write structures including improved error correction codes, and the use of hybrid devices and systems.

- High ratio compression techniques and algorithms for multispectral and synthetic aperture radar imaging applications, for stereo imaging from orbit and/or on a planetary surface.

- High ratio compression techniques and algorithms using fractals or artificial neural networks.

- Efficient biophysical, ice and snow extent and depth, mineral type and other parameter extraction techniques and algorithms.

- Efficient architectures and implementations of the above data compression and information extraction techniques for space application.

08.00 INSTRUMENTATION AND SENSORS

08.01 INSTRUMENTS FOR SENSING ELECTROMAGNETIC RADIATION
Center: JPL

Innovations are required to advance the performance of instruments for planetary exploration, remote earth sensing, and astrophysics applications. Innovative technological advancements are needed across the electromagnetic spectrum.

- Charge-coupled devices: Improvements or alternatives to traditional overlapping gate structures utilizing state-of-the-art submicron fabrication techniques; reduced readout noise through the development of lower noise on-chip amplifiers; fabrications on monolithic non-silicon materials; dark current reduction techniques or structures.

- Infrared detector arrays: Innovative concepts for detector materials with cutoff wavelengths between 2.5 and 300 microns; advancements in multiplexer architecture, interconnect technology, and monolithic structures. Requirements include extremely low noise, high uniformity, very low dark current, and high radiometric fidelity. Of special interest are innovative concepts for area array focal planes operating with cutoff wavelengths longer than 14 microns and operating temperatures between 40° and 80° Kelvin. Bolometric arrays operating at He_3 temperature are also of interest.

- High-operating-temperature infrared detector arrays: New materials and innovative concepts are required for application of non-cryogenic infrared detector arrays suitable for operation in the 1.0 to 16.0 micron wave-length regions. Mapping spectrometer detector work in the wavelength areas of interest suffers from high noise or the requirement for operation at cryogenic temperatures, necessitating elaborate and massive passive radiative coolers or short-lifetime cryogenic cooling materials. Use of such non-cryogenic detector arrays would require concurrent technology development of appropriate multiplexing and interconnect architecture and materials. Requirements include low noise and dark current values, high uniformity and high quantum efficiency at the wavelengths specified.

08.02 EARTH ATMOSPHERE SENSING FROM LOW EARTH ORBIT
Center: GSFC

Satellite and supporting in situ observations of precipitation rates, cloud cover parameters, and broadband radiation parameters at the surface and top of the atmosphere are needed to satisfy global scale climate monitoring requirements. Innovations are especially desired in the following areas:

- Active (radar) and passive microwave technology for measuring precipitation.
- Improved techniques (direct and indirect) for measuring rainfall at the surface.
- Improved sensors and/or new approaches to measurement of micro-physical and macro-physical cloud cover parameters.
- Improvements in instrumentation and techniques for absolute radiometric measurements of broad-band earth radiation energy at the top of the atmosphere in the solar and terrestrial emission spectrum.
- Methods for global monitoring of broad-band surface radiation budget parameters, using satellite and ground-based observations.

Space-based laser altimeter sensors being developed for high-resolution topographic measurements of the Earth's surface from spacecraft platforms, require major technological innovations in electrical efficiency, sensor lifetime, ruggedization, and size reduction. Innovations are required in laser transmitters and optical receivers to ensure high signal-to-noise for each laser pulse measurement of range between the spacecraft and the Earth or planetary surface. The technology challenges of space-based laser altimetry include:

- Development of short pulse (approximately 1 nsec) laser transmitters employing diode-pumped solidstate laser technology.
- Integration of detector, preamplifier, pulse discriminator, range-gate, and time-interval electronics into a miniaturized, low-power altimeter processor.
- Implementation of waveform-digitization electronics to analyze pulse-spreading effects caused by interaction of the laser pulse with a rough target surface.
- Noise reduction in silicon avalanche photodiode receivers.
- Development of a compact, low power laser altimeter instrument-controller computer with on-board buffer memory and serial data interface.
- Development of lightweight receiver telescopes for spaceborne laser altimeters with diameters between 0.5 and 1 meter.
- Development of laser diode pumped solid state lasers which emit pulses with energies in the 10's of mj and widths of less than 10 nsec at repetition rates of several KHz.

08.03 LOW-COST HIGH RESOLUTION AIRBORNE REMOTE SENSING INSTRUMENTATION FOR EARTH SCIENCES
Center: SSC

Innovations are required for sensor system development to produce high resolution, low-cost, multi-spectral sensor data for Earth Science investigations. Spatial resolutions of 10 m, 5 m, 1 m and greater are desired for small area analysis. Instruments should have the capability to be mounted in a light aircraft or balloon with the ability for users to display and evaluate the data in real time. Multi-spectral bands between .4 microns to 14.0 microns are needed to address NASA's interdisciplinary research activities in such areas as forestry, agriculture, geology, urban geography, geobotany, and archaeology. Proposals emphasizing commercial applications, real-time capability, and adaptability to aircraft are of particular interest.

08.04 SENSORS FOR AEROSOL AND CLOUD STUDIES
Center: LaRC

Innovative improvements are solicited in sensor techniques, sensors, and sensor systems for ground-based, airborne and/or spaceborne monitoring of atmospheric clouds and aerosols produced naturally or from man's activities, including determination of:

- Vertical concentration profiles.
- Size distribution from submicrometer to micrometer-size particles.
- Particle composition and morphology.
- Aerosol optical properties.
- Aerosol spatial distribution and fluxes.
- Ancillary atmospheric data required for analysis of aerosol properties.

Desired attributes of new concepts might include reduced weight and power, greater reliability, greater resolution, and other significant figures of merit not currently achievable. Innovations are also desired in the elemental analysis of crustal samples.

08.05 POLARIZED LASER IMAGING OF THE EARTH'S SURFACE
Center: GSFC

Innovative concepts are needed to expand our understanding of polarization and depolarization as a parameter in remote sensing of the Earth's surface. In particular, an important area of need is an airborne laser as a controlled source to minimize or eliminate the problems of various atmospheric and solar angle effects which confuse analysis of surface reflectance. These data can be used to support theoretical analysis related to solar polarization research and for other purposes. Areas in which innovative concepts are solicited include:

- Means for either scanning or diverging (or a combination thereof) a laser beam to produce high resolution surface images from an aircraft flying at no less than 500 feet and around 200 mph. Techniques should be wavelength independent and eyesafe at the ground.
- Detector technology for imaging the Earth's surface using reflected laser light.
- Polarization filtering of reflected laser light to determine the surface degree of polarization (or depolarization for a polarized laser source), ellipticity, and azimuthal angle in each resolution element. Receiver optics must not effect the polarization of the return signal.
- Data acquisition which allows for real time imaging of the raw return signal for any of the various polarization filter angles as required for onboard calibration. Simultaneous measurements must be made at all polarization filter angles to be assured that subsequent calculations are for the same spot on the surface with virtually zero registration error.
- Software to record and display the images of the raw data and the various calculated polarization parameters along with image manipulation and enhancement.

08.06 EARTH ATMOSPHERIC LIDAR REMOTE SENSING
Center: GSFC

High accuracy measurements of the atmospheric temperature, pressure, and wind fields from aircraft and spacecraft platforms require the development of high resolution pulsed tunable solid state lasers. For operation from spacecraft, considerations of efficiency and lifetime are also of prime concern. Innovations are need in the following:

- Development of a single longitudinal mode pulsed alexandrite laser tunable over the 760 to 770 nm spectral region. Characteristics of the system include continuous tuning of the laser to better than 0.0005

cm^{-1}, long term frequency stability to better than 0.0005 cm^{-1}, energy per pulse of $\geq$0.15J at 10 Hz operation scalable to >1.0J per pulse at 50 Hz operation, an efficiency >1% for flash lamp pumping with design consideration for high efficiency diode laser pumping, and Q switched short pulse operation of a nominal 100 ns duration.

- Development of techniques for precise measurement and tuning of the frequency of pulsed and cw lasers at an accuracy of 0.001 cm^{-1}. The problem of measurement of the spectral energy distribution of pulsed multispatial mode lasers is also of considerable importance.

- High-resolution, tunable Fabry-Perot etalons having very high stability and large throughput. The etalon should be tunable over at least 1 FSR. A resolution of 0.005 cm^{-1} (etalon fringe FWHM) is necessary. The stability required will be >1 part in 10^9 short term and >5 parts in 10^7 long term. Plane parallel Fabry-Perot etalons will require apertures >12.5 cm. Spherical Fabry-Perot etalons meeting the resolution and stability requirements should also be considered.

- Single longitudinal mode pulsed solid state laser operating beyond 1.6 μm. A bandwidth and stability of $\leq$10-20 MHz is required.

- High sensitivity shot noise limited detectors operating at wave-lengths >1.6 μm. Frequency response in excess of 10 MHz is required.

- Development of large aperture holographic optical elements to replace large scanning telescopes in remote sensing instruments. High diffraction efficiency and single narrowband and multi-wavelength response systems are needed, especially for 532, 732, 760, 770, 1064, and 10600 nm. Low weight, cost, and simplified mechanisms for conical scanning or other scan patterns are important considerations.

08.07 TUNABLE SOLID STATE LASERS, DETECTORS AND LIDAR SUBSYSTEMS
Center: LaRC

Measurements to improve understanding of atmospheric chemistry and dynamics from a polar orbiting platform require development of new solid state laser and nonlinear optical materials, laser transmitters, detectors and LIDAR subsystems to meet requirements of energy-per-pulse, efficiency, lifetime and reliability. Tunable solid state laser technology covering the radiation spectrum from near UV to the near-to-mid IR is required to conduct scientific experiments to measure atmospheric aerosols, molecular species, and meteorological parameters. In addition to materials for efficient solid state lasers and frequency conversion, new materials must be explored for electro-magnetic radiation detectors for both active and passive remote sensing. Development of models, backed by experimental spectroscopic and laser studies, is needed to support investigation of the magnetic field with active ion and energy transfer in ion-ion interactions in solids. The use of semiconductor laser arrays as optical pumping sources for solid state lasers promises dramatic improvements in efficiency over conventional flashlamp pumping technology. Innovative developments in material, device and component technology for detectors, laser materials, laser transmitters, and LIDAR subsystems are required for LIDAR applications to both polar-orbiting and Space Station-attached payloads. More specifically, innovations are sought in the following areas:

- Tunable laser and frequency converter materials from 0.180 microns to 11.0 microns.

- Semiconductor arrays to optically pump solid state host laser materials.

- Nonlinear optical materials for efficient frequency conversion in the near-UV to mid-IR range.

- High-efficiency refrigerators to operate from 150°K to 300°K, with heat loads of tens of watts.

- High temperature superconductors for superconducting-insulating-superconducting (SIS) detectors in the 100 micron wavelength region.

- Lightweight mirrors based on expanded-metal matrix technology for the 10 to 100 micron range; Single-element detectors and time-delay-and-integration detector arrays with increased sensitivity at thermo-electric cooler temperatures.

- Heteroepitaxy devices for low-noise and high-speed applications.

- Hybrid or monolithic detector/preamplifier structures to reduce electronic noise.

08.08 COHERENT LASER RADAR
Center: MSFC

Coherent laser radars are being used in an ever increasing variety of applications. These range from ground-based to airborne to space-based applications. Innovative new concepts and developments are sought in the following areas:

- Improved laser transmitters; both cw and pulsed; both CO_2 and alternate wavelengths. Improvements are sought in the areas of lifetime, efficiency, stability, compactness, weight reduction, and reliability.

- Improved detectors, both single element and array. Improvements are sought in dynamic quantum efficiency, bandwidth, and performance at elevated temperature operation such as would occur using thermo-electric coolers.

- Improved signal processing techniques. Improvements are sought in algorithm development and system development for more efficient extraction of data in low signal-to-noise cases and to extract additional information from signal return.

- Improved calibration techniques.

- General system configurations. Improvements are sought in the general area of system configurations that would improve performance and extend measurement capability.

08.09 EARTH OBSERVING SENSOR DEVELOPMENT FOR GEOSTATIONARY ORBIT
Center: MSFC

Innovations are desired for the development of a new generation of instrumentation to be flown on the geostationary platform. The multi-sensor, multi-disciplinary specifications of the platform, will require significant improvements in spatial and spectral resolution relative to instruments that are presently flown on operational geostationary satellites.

The sensors that are expected to be flown on the platform include, but are not limited to: passive microwave radiometers, visible and infrared imagers and spectrometers, solar monitors and an x-ray image, a lightning mapper, trace gas detectors, radiation radiometers, a space environment monitor, and a laser ranger.

The geostationary platform is an integral part of NASA's earth observing system program. To meet overall program goals, advances are required in:

- Passive microwave technology for atmospheric sounding, sea surface and precipitation measurements. Specifically, advances are required in large aperture antenna systems, low noise, high frequency amplifiers, and multiple feed horn design.

- High resolution visible and infrared imaging techniques. Requirements include the development of advanced high performance focal plane arrays, on-board calibration and optical designs.

- Infrared imaging spectrometers. Innovations are required for data compression, calibration and on-board signal processing.

- Motion compensation and background suppression techniques. Real time image navigation and motion suppression techniques must be developed in order to meet pointing accuracy and stability requirements.

08.10 FLIGHT INSTRUMENT TECHNOLOGY FOR EXOBIOLOGY
Center: ARC

Exobiology studies continue to require a large and specialized cadre of analytical instruments and systems for flight experiments to be conducted both in low earth orbit and on planetary missions. These instruments and systems are required to be highly accurate and precise and be able to perform meaningful analyses on very small samples containing biologically important elements and their molecules. For flight experiments, those instruments are further required to be highly miniaturized and extremely efficient in their use of spacecraft resources and will require innovative concepts and approaches to develop. Examples include the following:

- Miniaturized gas chromatographs and subsystems including innovative detectors, columns, sampling devices, and sample treatment devices (e.g., pyrolyzers and thermal analyzers to rapidly detect and quantitate volatile and organic compounds at parts-per-billion levels).

- Components and systems to extend mathematical analytical techniques to the flight environment (e.g., multiplex gas chromatography, Fourier transform spectrometry).
- Miniaturized, highly rugged devices to measure electro-chemical properties (e.g., eH, pH of extraterrestrial soils).

- Infrared diode lasers and systems capable of operating at elevated temperatures, (>77°K) for high resolution (10^{-4} cm^{-1}) molecular spectrometry of gases in the range of 2-5 micro meter to measure biogenic molecules, e.g., C and N isotopes in CO_2 and NO_X with precision of 0.1% or better.

- Miniaturized elemental analysis techniques (e.g., gamma-ray and alpha backscatter spectrometers) with extended range and greater sensitivity for the biogenic elements (C, H, N, O, P, and S).

- Systems and subsystems for the production, manipulation, collection, levitation, observation, and analysis of 0.1-100 micrometer size particles inside an environmentally controlled chamber in a microgravity environment.

08.11 INSTRUMENTATION FOR PLANETARY ATMOSPHERIC SCIENCES
Center: JPL

- NASA and the European Space Agency are currently planning a mission which will consist of a Saturn orbiter and a Titan entry probe. An instrument has been proposed for the probe which utilizes a tunable diode laser infrared absorption spectrometer for the in-situ sensing of Titan's atmosphere. As currently conceived, the spectrometer would use several narrow bandwidth (0.0002 cm^{-1}) tunable diode lasers operating at selected mid-infrared wavelengths. Using this instrument, it should be possible to measure the vertical concentration profiles of several important infrared-active species including CH_4, CO, CO_2, C_2N_2, C_2H_2, and CH_2CN, all with a vertical resolution of several kilometers. Innovations are sought in: the development of lead-salt tunable diode lasers operating in the 3-10 micron wavelength region at temperatures at or above 77°K with single-mode output power greater than 100 microwatts, and design of advanced geometry laser devices with dual-ended output.

- Laboratory measurements of the ion-impact induced UV emission cross sections of various molecular species are planned. The data are needed for analysis of UV observations of the outer planets obtained from spacecraft. In this work, a beam of the molecular target gas is to be crossed with the ion beam, forming the collision volume. Excited molecules emit UV photons which are detected by standard spectrometric methods, and measurement of the emission rate yields the cross section of the ion-molecule interaction. Improved technology for the production of low energy, high current ion sources is needed. Protons are of principle interest, but ions of N^+, 0^+, S^+, and He+ are of interest, as well. Desired innovative source characteristics include: Ion energy from 20° eV to 20° keV, with minimum energy spread; current from 10 μA to 100 μA; 2 mm ion beam diameter at the interaction region; high long-term stability; high specie purity.

- The NASA Planetary Science Program carries out ground-based observations of planetary and satellite atmospheres and surfaces. New and innovative instrumental methods, such as acousto-optical tunable filters (AOTFs), and the associated technology are needed for the development of a rapid-scanning imaging spectropolarimeter. The desired instrument would: Be capable of imaging planets at wavelengths from 0.3 to 3.0 microns with selectable spectral resolution and with 0.25 arc-sec resolution; accomplish wavelength switching in less than 50 microseconds, approximately; and enable simultaneous acquisition of orthogonally-polarized images.

08.12 INFRARED TECHNOLOGY FOR ASTRONOMICAL APPLICATIONS
Center: ARC

Innovative concepts and techniques are needed to support spaceborne IR astronomical telescope projects:

- Achieving ultimate performance in low-background instruments, improvements in the sensitivity of discrete IR detectors and integrated IR detector array electronics operating at cryogenic temperatures. Means to extend the spectral coverage beyond 200 micrometers, and means to reduce device dark current and susceptibility to particle radiation are also required.
- Methods to count individual IR photon events, either directly or via up conversion.
- Novel techniques in long-wavelength (>20 micrometer) IR filter design and manufacture.
- High-quality, low-cost fabrication techniques for optics capable of diffraction-limited performance down to 1 micrometer. Included are both small optics for instrument applications, and large (>1 M) lightweight panels for use in segmented mirrors.
- Novel techniques are needed for in situ evaluation of image quality in cooled IR telescopes. This includes development of sensing instrumentation and algorithms for correction of focus.

08.13 DETECTORS AND DETECTOR ARRAYS
Center: GSFC

Detectors and detector arrays for space astronomy, astrophysics, geophysics, and atmospheric studies at varying wavelengths require improvements beyond the state of the art. Innovations are solicited in every area, a number of which are indicated below:

- Composite cryogenic or room temperature IR bolometers, using diamond films coated with metal for absorbing incident radiation, and attached semiconductor or superconductor thermometers for measuring the temperature change.
- Cryogenically cooled junction field effect transistors (JFETs) (2-4°K) with low noise at low audio frequencies (10 Hz) and low power dissipation.
- Miniature adiabatic demagnetization refrigerators suitable for space flight and capable of achieving 0.1°K, for cooling IR bolometers and X-ray microcalorimeters.
- Cryogenic low noise multiplexers for reducing requirements into dewars at 2°K, both for detectors and for engineering sensors such as strain gauges, thermometers, and accelerometers.
- Cryogenic low noise, low power amplifiers with voltage gain at 2°K for helping read out detectors.
- Complete line of electronic parts (field effect transistors (FETs), op amps, resistors, capacitors, inductors, sockets, cables, boards) suitable for operation at 2°K to support cryogenic detectors.

- Micro-antenna for efficient coupling to submillimeter heterodyne receiver mixer diodes.

- Microchannel plate arrays with no ion feedback, high quantum efficiency, high resolution, low radioactivity, controlled conductivity.

- High quantum efficiency near infrared photocathodes.

- Charge-coupled device (CCD) array improvements, including lower noise amplifiers (<5 els rms readout noise), low dark current, UV sensitivity, defect reduction, anti-reflection coatings.

- A spaceborne sensor is required for the direct measurement of magnetospheric currents in space.

- Linear-geometry photomixer detector arrays with integrated low noise preamplifiers, for 8 to 12 μm heterodyne spectrometers, designed for one-dimensional mapping of extended objects at ultra-high frequency resolution. The photomixer-preamplifier arrays should have a bandwidth extending above 3 GHz, with high heterodyne quantum efficiency and low (<2 dB) preamplifier noise figure. Power requirements must also be low, to minimize cryo-cooler requirements. Successful arrays will be extended and optimized for eventual space flight application.

08.14 LOW-COST CALIBRATORS FOR SPACEBORNE SYNTHETIC APERTURE RADAR
Center: JPL

Innovations are required to develop low-cost calibration devices for spaceborne Synthetic Aperture Radar (SAR) sensor to be used by individual experimenters and for engineering calibration. The devices, whose basic design will be a transponder unit are to be deployed on the ground within or near sites of scientific interest. Innovations are needed so that the device has:

- A precisely measured and calibrated radar cross-section (both amplitude and phase).

- The ability to calibrate at three or more frequencies, L-, c-, x- and possibly p-Band (24, 6,3, and 68 cm).

- An adjustable polarization signature, with good (better than -35 dB) suppression of unwanted polarization signals, or cross-talk.

- Low sidelobes for the transmit and receive device antennas (<-20 dB).

- Good stability over a wide range of temperatures experienced on the Earth's surface (0° ——>100°F).

- Optional ability to record received power as a time series.

- In-field calibration capability – this may require additional equipment.

08.15 EARTH-BASED AND PLANETARY PHOTOMETRY INSTRUMENTATION
Center: JPL

- The NASA Planetary Astronomy Program carries out ground-based observations of solar system processes in support of spacecraft missions. Occultations yield information obtainable in no other way. For example, a series of occultations of Io by Europa during 1991 will enable high spatial resolution mapping of the thermal radiation from Io's volcanos. A new class of infrared photometry instrumentation is needed for use on large telescopes for occultation studies. Data must be acquired with near-simultaneity in at lest two selectable pass-bands, with one or more within the wavelength range from 1.0 to 5.2 micrometers, and one or more within 8 to 13 micrometers. Very high sensitivity and approximately 100% duty cycle on-source during chopping are required due to the faintness of sources. Continuous data sampling and recording at a resolution of 0.01 s for 1 hour duration are necessary. Simplicity, ruggedness, and reliability are essential.

- Spacecraft operating on the surface of Mars could be used to monitor the state of the atmospheric opacity, which might vary from values of 0.1-0.2 to 2.0-3.0 or more. Measurements of the sky brightness in comparison with the solar disk brightness would help establish the nature of the opacity sources, such as dust or water ice clouds, as well as the particle properties. Development of an instrument design is sought. A candidate approach would be to observe the sun and sky with omnidirectional optics and a set of silicon detectors within the 0.3-1.1 micrometer wavelength range. Weight below 500 g and power consumption below 5 W are desired because the instrument might be deployed from rovers or balloons. The instrument might also find use in terrestrial meteorological observations.

Innovative new concepts in photometry instrumentation are solicited to achieve these advanced instruments.

08.16 SUBMILLIMETER ANTENNAS, RADIOMETERS AND SPECTROMETERS
Center: JPL

Submillimeter antennas and radiometers operating in the 0.1 to 1.0 millimeter wavelength range for space astronomy, astrophysics and atmospheric studies require innovations in the following areas:

- Antenna systems with apertures up to 4 meters. Multiple beams with scan angles of many beamwidths.

- Cryogenic low-noise sub mm radiometers with operating times of 2-5 years.

- Solid-state low power phase locked sub mm local oscillators up to 3000 GHz with output powers greater than 100 microwatts. These LO's should have DC power requirements less than 5-10 watts, be small and lightweight and have lifetimes of two to five years.

- Multichannel spectrometers to simultaneously analyze IF signal bandwidths up to 10 GHz with frequency resolutions of 1 MHz. Small size, lightweight and low DC power (< 10 mW per channel) along with high stability and life-times greater than five years. Acousto-optic or digital technologies may be the best choices.

08.17 ALTIMETRY TECHNOLOGY
Center: JPL

- A NASA dual frequency (K-Band, C-Band) radar altimeter will fly onboard the TOPEX/Poseidon spacecraft for observation of the mean ocean circulation. Altimeter performance is to be evaluated by use of transponders installed on platforms or towers at sea, or on land. Sea deployment will serve to calibrate EM-bias and ionospheric corrections, and land deployment will enable calibration of the absolute range measured by both channels, and may have use in orbit tracking. Innovative approaches are solicited for the design and development of suitable transponders which:

  - Receive altimeter signals at K-Band (13.5 GHz) and C-Band (5.3 GHz) with a 102.4 micro-second pulse width and 320 MHz bandwidth. Orbit altitude will be 1335 Km, approximately;
  - Transmit the received signal with sufficient power to force the altimeter to trace the transponder;
  - Possess phase stability of both channels equivalent to an accuracy of 1 mm over a broad temperature range;
  - Produce an audible tone for the duration of the satellite pass;
  - Record and display such data as pass number, received and transmitted power, time of closest approach, etc;
  - Provide simple operation over a 5-year expected lifetime.

- The NASA Geology Program conducts geomorphology research. Improvements in topographic measurement over current stereo-photogrammetry are sought. Radar-based or laser-based imaging altimeters carried by aircraft are envisioned, but other methods are not excluded. Requirements are:

  - Continuous swath or contiguous frame capability, with a swath width 1 km or greater;
  - Vertical and horizontal resolution each less than approximately 1 m;
  - Near real-time display for preliminary analysis, with digital storage for final analysis.

08.18 OPTICAL SYSTEMS AND DEVICES
Center: JPL

New optical systems modeling and optical component concepts and developments are needed to support optics technology development and optical instrument development for earth science, planetary science, and astrophysics. Innovative approaches are solicited in the following areas:

- Modeling of diffraction for the optimization of the optical design of IR and submillimeter systems.
- Analysis and software development of methods for optical image reconstruction from partial u-v plane coverage.
- Large area, low scattered light broadband (metal) optical thin films with application for whitelight all reflecting coronagraphs in the 80 to 400 cm aperture size category.
- Anodizing masks to control the amplitude and the phase of electromagnetic waves for hypercontrast (coronagraphic) optical imaging systems to one part in ten to the 10th.
- Analysis and software for the precision modeling of blaze efficiency of diffraction grating spectrographs for use in the visible, infrared, and submillimeter.
- Tunable and fixed reference (frequency stabilized) solid state diode lasers for remote sensing lidar systems and for space-based interferometers.
- Technology for high throughput adaptive spectrometers for use in the 300 to 1,000 nanometer range at spectral resolutions of 100 to 10,000 whose design approach could be space qualified. Examples are acousto-optic tunable filters and ultra-violet Fabry Perot spectrometers.
- High reliability, long lifetime optical coatings in the 9 to 11 micron region for beam splitter applications with pulsed TEA-CO_2 laser systems.
- Optical systems for efficient generation of tunable single mode IR laser radiation using nonlinear optical techniques such as optical parametric oscillators and sum/difference frequency mixing.
- Compact 3-D cameras for human and machine vision: light weight, high resolution single lens active systems with real time capability for navigation of autonomous and remotely operated vehicles.

08.19 THREE-DIMENSIONAL REFLECTOMETER
Center: GSFC

Innovative designs are needed for a 3-dimensional reflectometer/scatterometer which would allow the automated measurement of the complete bi-directional reflectance and transmittance functions of a variety of samples.

Minimum requirements for a fully 3-dimensional reflectometer include:

- Automated, programmable positioning of the source and detector(s). The distance from the detector(s) to the sample surface should be adjustable to accommodate a variety of sample sizes, from 0.5 to 20 cm in diameter. The automation system should include position control, data acquisition, and data analysis functions.
- Source and detector positions should range from +80 to -80 degrees zenith angle and from 0 to 360 degrees azimuth angle. The source position must be independent of the detector(s) position. Both positioning accuracy and reproducibility should be within 1 degree. It is desirable to be able to detect reflectance at 1 degree intervals; no grid coarser than every 10 degrees is acceptable.
- The system should function over 0.28 - 2.0 microns with a spectral resolution of a few nanometers. Sources and detectors should be easy to remove and replace.
- Polarization measurements should be possible. Specifically, the 4 Stoke's parameters should be over-determined, so that the data can be analyzed for internal consistency and estimates of error.

Additional, desirable innovative approaches can include the ability to make 3-D transmission measurements, absolute measurements, and direct backscatter (within 0.1 - 2 degrees of the source) measurements. Also, software compensation for the effects of sample curvature on the reflectance data is desirable.

08.20 SPACECRAFT AND SPACE STATION CONTAMINATION MONITORING
Center: GSFC

- Environmental monitoring is needed to verify the performance of spacecraft systems during orbital operations. The performance of attached payloads on the Space Station, for instance, will be optimized only if, at any given time, the experimenters have a clear understanding of the operational environment and its effects on the payload. Monitoring systems must measure reliably the concentration of the contaminant species surrounding the spacecraft and affecting parameters such as column density, surface deposition, spectral background, etc.

- The development and the verification of on-orbit mass transfer models depends on the in-situ measurement of the relevant environmental parameters, such as the relative concentration of natural species, and the amount, velocity and direction of molecules in the induced environment. New, innovative instrumentation to perform these tasks is needed. Particularly desirable are fast, highly sensitive detectors for real-time identification of undesired species. Ideally, the range of detectable molecular weight extends from 2-4 to ~150-200 amu.

08.21 INSTRUMENTS FOR STS OPERATIONS
Center: JSC

Innovative approaches are solicited for new or improved instruments to assist in Space Transportation System Operations:

- High Precision Analysis of Microscopic Samples: Techniques for chemical, mineralogical and isotopic analysis of microscopic samples, such as cosmic dust which will significantly improve existing capabilities in precision, accuracy or sensitivity. Characteristics should include at least the following:
  - Ion microprobe mass spectrometer techniques capable of discriminating isotopic and trace element contents on whole particles or on subelements of particles 10 micrometers in diameter or smaller;
  - Transmission electron microscopy instrumentation and techniques for mineralogical and chemical analysis;
  - Detectors and electronics for neutron activation analysis, capable of determining rare earth element concentrations of typical meteoric levels in particles with masses of $3x10^{-9}$ gm or less;
  - Mass spectrometers capable of analyzing individual particles.

- Remote Chemical and Mineralogical Analysis of the surface materials of the solid bodies of the solar system, including Mars, comets, asteroids and rocky satellites of the planets: Analytical techniques include mass spectrometry, gas chromatography, plasma ionization spectroscopy, electron, laser, or ion microprobes, and others. Novel ideas may also be proposed for sample preparation concepts which allow the physical separation of species in a complex sample of rock minerals. First mission opportunity will be the Mars Rover Sample Return mission, which will utilize remote analysis devices to select samples for return to Earth.

- Orbital Trajectory Sensing of Meteoroids and Space debris: The origin of Earth orbital debris fragments smaller than about one centimeter in diameter and orbital distribution and origins of interplanetary meteoroids, for masses less than about one milligram, are poorly understood. To determine either, each particle must be sensed and accurate orbital parameters obtained simultaneously to determine if it matches those of any known potential parent body. Innovative instruments and techniques should determine trajectories with vector velocity uncertainty of not more than one percent. Also desired is high transparency of the trajectory sensor to incoming particles so that they are not destroyed by structures within the sensor. Capture of particles is also desired for ground analysis.

08.22 CRYOGENIC FLUID INSTRUMENTATION FOR ORBITING SPACECRAFT
Center: LeRC

Innovative concepts and techniques are needed in the area of advanced instrumentation for spacecraft utilizing cryogenic fluids. Liquid hydrogen and cold hydrogen vapor are the principal fluids of interest; however, innovative concepts are solicited that are applicable to other cryogenic fluids such as oxygen, nitrogen and normal liquid helium. Areas of interest include:

- Flowmeters: Cold hydrogen vapor flowmeters with response times less than 0.1 second and with ratings up to 10 lb/hr; liquid hydrogen flowmeters with ratings up to 800 lb/hr. capable of measuring bi-directional flow as well as two-phase and vapor flow with the same instrument. Flowmeter output should be in mass flow units with an indication of the fluid phase and a measurement of the fluid quality when two-phase flow is present.

- Liquid Mass Gauge in Microgravity: mass gauging is required to determine the quantity of liquid hydrogen in an aluminum tank containing liquid and vapor in a micro-gravity environment. A nonintrusive instrument is required to minimize heat conduction to the fluid. The tank may also contain other components such as thermodynamic vent systems and screen devices for liquid acquisition.

- Pressure Control System: Cryogenic tank pressure control systems (including innovative methods of Joule-Thompson expansion and flow control for thermodynamic vent systems), in-tank fluid mixers with compact heat exchangers, and tank pressure relief (vapor only) methods suitable for use in a micro-gravity environment.

- Tank Wall Electrical Connector: A simple electrical connector for instrument lead wires that must pass through the wall of light-weight aluminum tanks containing liquid hydrogen at pressures up to 60 psia with zero ($<10^{-6}$ sccs) leakage to space vacuum.

09.00 SPACECRAFT SYSTEMS AND SUBSYSTEMS

09.01 CONTROL OF LARGE SPACE STRUCTURES
Center: LaRC

Future space missions are expected to require large spacecraft which are loosely coupled and highly flexible. These spacecraft will require new, innovative design concepts for control systems and components which are more reliable and more efficient than current systems. The objectives of these innovations must embody:

- Advanced control system analysis and synthesis techniques.

- Fault identification, isolation and reconfiguration.

- Methodology to integrate control/structure systems and associated components.

- Adaptive control strategies for systems with appreciable structural dynamics.

The focus should be on both control systems design and control devices and may involve ground validation of advanced system concepts and attendant breadboard hardware in Phase II or subsequent R&D activities.

09.02 GUIDANCE, NAVIGATION AND CONTROL OF ADVANCED SPACE TRANSPORTATION SYSTEMS
Center: LaRC

Future space transportation systems include heavy lift launch vehicles, HLLV's, AOTV's, Shuttle II, transatmospheric vehicles, and interplanetary spacecraft. To permit the economic viability of such systems, advanced techniques for guidance, navigation and control (GN&C) must be developed. These advances will be needed to improve system reliability, autonomy, and operational capability, and to reduce life-cycle costs. Innovations not based on conventional design or existing systems are solicited to improve existing practices:

- Autonomous GN&C techniques which can be implemented on a typical flight computer.
- GN&C methods which can readily adapt to environment uncertainties encountered by an AOTV or an HLLV during atmosphere maneuvers.
- Fault tolerant systems for major improvements in the probability of system survivability.

Phase I proposals must indicate realistic Phase II applications software or hardware-oriented continuations.

09.03 COMBINED ATTITUDE CONTROL AND ENERGY STORAGE
Center: GSFC

The potential of advanced flywheels in combined attitude control and energy storage for spacecraft systems has been studied in the past and currently is being developed for spacecraft power systems with a capability of a 2KW payload and greater. An energy storage wheel sized for 500Wh is presently being developed and shows potential performance improvements in current energy storage systems. The design methodology developed to date is capable of being applied in wheels sizes for a range of approximately 10 to 1, and therefore is limited in application for energy storage wheels of 5 to 50Wh sizes.

Innovations are being sought for the application of inertial energy storage for small scientific satellites with a payload power requirement of 100 watts. The combination of the energy storage and attitude control functions within a single set of hardware has the potential of yielding significant savings in weight and power. Magnetic suspension of the rotor, composite materials and their application in a high speed rotor, and high efficiency motor generator are key technologies which need to be addressed, with emphasis on the integration of the three technologies in one viable system for an energy storage wheel capacity of 20Wh.

09.04 STS/SPACE STATION AND ROBOTIC TRACKING SYSTEMS
Center: JSC

Innovations are sought in microwave, millimeter-wave, electro-optical, and Global Positioning System based spacecraft tracking systems as potential replacements for conventional microwave systems. Such systems are required to support spacecraft terminal rendezvous, station-keeping, and docking. Innovative laser tracking/vision systems to support robotics and automation space applications are also needed for future NASA missions.

- Solid state laser scanning device: The need exists for new and novel ways of scanning a narrow laser beam over a larger field of view. New approaches for doing this with no mechanical parts are sought.
- Hand-held optical radar: Recent studies have indicated that handheld, in-space skin tracking lidar can be built using new modulation techniques which enable operation over long distances in full sunlight. Direct measurement of range and range rate (Doppler) are required with accuracy of 1 percent range and 0.01 fps.
- Global Positioning System: The need exists for new and novel receiver and software implementation for accurate tracking and navigation for orbital operations.

- High resolution microwave and millimeter-wave radars/radar subsystems: Lightweight, low power radar systems are needed to solve various short range, rendezvous, station-keeping, and target tracking problems during manned and unmanned space operations. These operations will require higher tracking resolutions than are generally available. Examples include navigation aids for the Manned Maneuvering Unit (MMU), the Orbital Maneuvering Vehicle (OMV), and other proximity operations involving deployed satellites and scientific payloads.

- Laser diode, diode array, or diode pumped ND/YAG lidar systems for ranging, velocity, and bearing information.

- Optical sensor system for pattern recognition, ranging, and vision.

- New signal processing techniques and hardware.

- Improved optical components such as sources, detectors, couplers, switches, modulators, and lenses for imaging systems.

- Radars and lidars, operating from near zero range up to 100 nmi. for rendezvous and docking. Laser and video tracking/vision sensors for autonomous and teleoperated (end-effector) automation and robotics applications. These include programmable/adaptive, and high resolution 2-D video and 3-D high frame rate range/Doppler imaging radars and image processors for target/feature acquisition, identification, position/attitude determination, and tracking.

09.05 SPACECRAFT METEOROID/DEBRIS PROTECTION SYSTEMS
Center: MSFC

Structural design and analyses of future spacecraft must address a growing major challenge: designing the structure to a specified environment so that it protects crew and vital systems from the effects of a meteoroid or a space debris impact. It has been determined by measurement, experimentation and data extrapolation that the debris environment is now the critical design environment for most spacecraft. Innovations are needed to design and analyze structurally efficient protection systems that are lightweight and provide necessary protection against hypervelocity impacts caused by metallic and non-metallic meteoroids and debris. Phase I must emphasize innovative new concepts whose feasibility could be verified in subsequent Phase II activities. Suggested areas of concern include but are not limited to the following:

- Metallic and/or composite material usage for efficient bumper (shield) construction. Thickness, geometry, ply/angle layup, material combinations, etc. must be addressed as factors affecting protection efficiency.

- Causes and effects of spall due to non-penetrating impacts. Greater understanding of applicable fracture mechanics, spall velocity, spall size, shock phenomena, etc. is required research.

- Effects of impacts caused by non-spherical debris particles.

- Analysis methods which use theoretical as well as empirical/experimental data for quick running, efficient, and accurate evaluations of protection systems and probability of success.

- Techniques for weight optimization of protection systems.

- Methods/procedures for on-orbit repair of damaged protection systems.

09.06 TECHNOLOGIES FOR SCIENTIFIC BALLOONS
Center: GSFC

Balloons carry scientific payloads weighing as much as 6,000 pounds to altitudes as high as 140,000 feet. At the conclusion of these flights, the payload is separated from the balloon by electronic command at altitudes between 60,000 and 140,000 feet and allowed to parachute to the ground. The present payload recovery systems, which experience opening shocks in excess of 10 g's, utilize flat circular parachutes fully extended between the scientific payload and the base of the balloon. Once the parachute and payload are released from the balloon, control of the descent trajectory is almost non-existent. Accuracy of the predicted landing site is a function of the experience of the operating personnel. Innovative approaches are sought for the development of methods and techniques for balloon payload recovery systems. Suggested areas of innovation would include, but not be limited to the following:

- Shock reduction methods to reduce the opening shock to values less than 5 g's.
- Methods or techniques to reduce payload landing dispersion area.
- Maneuverable/controllable balloon payload recovery systems capable of "homing" or remote controlled descent into safe recovery areas.

Scientific balloons are fabricated from long narrow strips of thin (0.8 mil) transparent plastic film. Individual panels of film called "gores" measuring some 10 feet in width by several hundreds of feet in length are stacked in continuous strips on a flat table surface for assembly into a balloon. With current thermoplastic films a "band" heat sealer travels along the entire length of the table fusing layers of film with other reinforcing thermoplastic materials called load tapes and backup tapes. To strengthen the wall in the upper regions of the balloon extra layers of thin film are added to each gore. Thus, during the sealing operation four layers (two gore layers with upper and lower reinforcing tapes) can stepwise increase to ten during a single pass.

Innovative techniques and methods are sought for the sealing of thermoplastic films into large scientific balloons. Suggested areas of innovation would include but not be limited to the following:

- Methods to fully automate or significantly reduce the manpower required for present band sealing techniques.
- New techniques for the sealing of the thermoplastic films into balloons.
- Methods for real time non-destructive, automatic, and continuous assessment of seal integrity.

09.07 HIGH TEMPERATURE SUPERCONDUCTOR APPLICATIONS FOR SPACE
Center: GSFC

Innovative new or improved technologies using high temperature superconductors are sought. New superconducting materials with operating temperatures at or above liquid nitrogen temperatures have many potential applications for space. Areas of interest include, but are not limited to, those listed below:

- Sensors.
- Magnetic levitation, passive magnetic bearings.
- Pointing and attitude control system technologies.
- Microwave communication technologies.
- Material processing aids.
- Cryogenic applications.
- Superconducting electronics and high speed processing.

This subtopic does not solicit proposals in general HTS materials research, but it is recognized that certain NASA-unique applications may require optimization of film or bulk material characteristics, fabricability or special configurations. Such material developments directed toward acceptable device R&D is acceptable only if the primary task objective is the device itself.

Phase I proposals must indicate clearly the specific advantages expected in the applications proposed, and must suggest possible Phase II continuations and ultimate practical applications.

09.08 SPACECRAFT FLIGHT DYNAMICS
Center: GSFC

- The Flight Dynamics Facility at GSFC is involved in ground based attitude determination using a variety of spacecraft sensors and spacecraft unique processing algorithms. Future emphasis will be on generalized and efficient algorithms operating in a near real time environment. Innovations are sought for new attitude determination approaches and processes for onboard or ground attitude determination. These innovations should address future techniques to efficiently identify corrupted or erroneous sensor measurements, generalization of techniques to be non-sensor or spacecraft unique, and error modeling. AI techniques may be employed for preliminary data screening and response to anomalous conditions. Coupling of the attitude determination problem with the sensor calibration function is also an area for refinement of technique. Operation of any innovative technique must be exercised under a wide range of operational scenarios including cases where gyroless dynamic modeling must be performed and sensor availability may be non-continuous.

- An important operational requirement placed on GSFC flight dynamics support of spacecraft is the inflight calibration and alignment of attitude sensors. Star trackers, sun sensors, earth sensors, and gyros often require this on orbit calibration and alignment to provide precision attitude knowledge. These calibrations often show a large dependence on environmental conditions as well as shock and vibration before, during and after ELV or STS launch. New approaches are sought for performing the inflight sensor alignment and calibration function. Techniques proposed may be general or sensor specific, but should be computationally efficient and applicable to a wide range of missions. Under this subtopic approaches might also be included to quantify specific calibration and alignment shifts due to launch shock or inflight environmental effects and present techniques to compensate for the dynamic phenomena.

- GSFC spacecraft attitude dynamics and control simulators are used for maneuver analysis, ground command check-out, flight operations team training, and validation of control laws. Within the Flight Dynamics Facility (FDF), these simulators are designed and built assuming rigid body dynamics and use control system specifications provided by the spacecraft builder. New directions in the simulation area may focus on inclusion of flexible body dynamics and refinement of models using processed flight attitude data. Under this subtopic, new modeling techniques for evaluating spacecraft dynamic behavior and their proposed implementation in software systems may be included. Considerations such as flexible body dynamics, general sensor models, and fine tuning of dynamic parameters using identification techniques with flight data should be evaluated. Application of NASTRAN models in operational FDF simulators might also be an approach researched and evaluated under this subtopic.

09.09 SPACE STATION CREW WORKSTATION DISPLAYS AND CONTROLS
Center: JSC

The workstation design for a future Space Station must incorporate state-of-the-art display and control technologies and must provide a friendly and flexible user/machine interface. To accomplish this, innovations are needed in the following areas:

- Multicolor flat panel electronic displays: Currently available flat panel displays for Space Station applications offer only monochromatic capability. A small volume, low power, multicolor, flat panel display is needed.

- Input Devices: Develop input devices and mechanizations that (1) are simple to use; (2) the communication language results in high user efficiency; and (3) are reliable and easy to maintain.

- Data Storage: Develop high density local workstation data storage aids such as optical disks, disk RAM's, floppy disks, bubble memory, etc.

- Hand Controller: Develop compact hand controller devices with force feedback that could be used to support six degree-of-freedom master/slave type telerobotics space operations.

Only those Phase I proposals exhibiting innovative approaches to what could otherwise be conventional design applications of technology and which clearly delineate Phase II hardware-oriented activities and ultimate NASA applications will be considered.

09.10 SPACE ORBITER WHEEL BRAKE CONTROL SYSTEM
Center: JSC

Current orbiter vehicles do not have the ability to self-taxi and so cannot employ usual brake system development procedures. They require a brake pressure control system that is more amenable to laboratory testing and adjustment and is less sensitive to wheel and hydraulic system dynamics. Future or improved orbiter vehicles will require more capable braking systems during improved landings. Certain desired system attributes are noted as follows:

- An anti-skid control logic that can be integrated into the brake control system.
- An hydraulic brake pressure control valve that is much less sensitive to external wheel and line dynamic pressure disturbances.
- An integrated electronic brake system controller that combines the anti-skid and brake valve control functions and provides convenient means for adjustment of the system control parameters and compensation that affect dynamic response and stability.
- The use of electro-mechanical actuators for braking instead of hydraulics.
- The provision of a wheel spin-up capability in conjunction with the electro-mechanical actuator.

Innovative concepts to achieve these and other desirable characteristics are solicited which are not based on current designs or conventional practices used in aerospace braking systems. Phase I proposals must indicate clearly Phase II system hardware R&D possibilities and ultimate applications.

09.11 MANNED SPACECRAFT AND PLANETARY BASED THERMAL MANAGEMENT SYSTEMS
Center: JSC

Future large space systems will require efficient and economical thermal management because generation, transfer and usage of electrical energy needed for these systems will result in the dissipation of huge quantities of waste heat. Innovations to enhance the present state of the art are needed in acquisition, transport, and rejection technology. Some examples might include:

- Non-toxic thermal fluid: A non-toxic thermal fluid, which has a high heat of vaporization, low freezing point, high vapor pressure, high thermal conductivity and good capillary characteristics is needed for two-phase thermal bus application internal to manned spacecraft.
- Heat pump systems: High efficiency heat pump systems utilizing waste heat are sought to raise the temperature of spacecraft waste heat at the thermal transporter/radiator interface in order to achieve significant radiator weight and area reductions.
- Heat rejection on Mars: Innovative methods for rejection of waste heat to Martian atmosphere or soil as alternates for space radiators.
- Advanced space radiator systems: Revolutionary low risk–high payoff approaches compatible with high temperature heat rejection such as moving belt radiators, bubble membrane radiators, and super thermal conductors should be investigated in parallel to the heat pump systems for overall reduction of radiator system weight and size.

- Thermal management in variable-gravity environments: Analysis and conceptual demonstration of thermal management applicable to spacecraft with spin-induced artificial gravity environments are required to develop conceptual designs of thermal management systems for future spacecraft.

- Multi-phase fluid flow computational analysis techniques: Techniques for computational fluid dynamic and heat transfer analysis of multidimensional, multi-phase flows in a zero or low gravity environment are essential to provide vital information for development of advanced multi-phase thermal management technology.

All Phase I proposals must suggest meaningful Phase II activities for near-term support regardless of the timing of possible space mission applications, and must also discuss other potential uses of the proposed technology.

09.12 THERMAL CONTROL FOR UNMANNED SPACE APPLICATIONS
Center: GSFC

Future unmanned spacecraft and space facilities will operate at higher power levels, have many more load centers at dispersed locations, and will require more precise temperature control than current space systems. Many missions will be more distant from Earth and/or be of longer duration. These situations will increase significantly the requirements on the thermal control system. Areas of innovation include, but are not limited to:

- Fluid systems technology: modeling of multiphase fluid behavior and measurement techniques in a micro or partial gravity environment; detection of very small leaks in a multiphase, single component system; low temperature (i.e., 100-250° K) heat pipes; heat pipe evaporator interfaces including integral heat exchanges or heat pipe disconnects; modular, self contained heat pumps to allow equipment to operate at a temperature close to, but different from, a central thermal bus; design concepts to permit extremely long life with no maintenance for thermal components; and self diagnostic and self repair/correction subsystems for the thermal system.

- Special thermal system capabilities: utilization of low or medium temperature waste heat to drive a cooling system; integration of the thermal and power systems to minimize total weight; Hardware/Software to improve thermal engineering analyses techniques of actual flight temperatures.

NASA scientific goals will require instruments and facilities that operate at cryogenic temperatures ranging from 120°K down to 0.1°K or less. Cryogenic coolers will be required to provide these operating temperatures. Future unmanned facilities will have operational lifetimes of 10-15 years, requiring similar total lifetimes for cryogenic coolers. Technical areas of interest include, but are not limited to those listed below:

- Mechanical cooler technology: flexure bearing technology; magnetic bearing technology; gas bearing technology; regenerator technology, including magnetically enhanced regenerators; vibration compensation systems; low vibration cooler systems; vibration isolation systems; high reliability thermal switches; magnetic cooler technology; and interfacing mechanical coolers with sensors.

- Stored cryogen coolers: low thermal conductance structural support systems; support systems with on-orbit release; concepts to enhance safety; and innovative concepts for stored cryogen/mechanical cooler combinations.

09.13 SPACECRAFT SYSTEMS THERMAL ANALYSIS AND DESIGN
Center: MSFC

Analysis and design of spacecraft thermal systems require advanced technologies in the area of thermodynamic, thermal and fluid systems. This may involve innovative analytical techniques and component design concepts. Applications to be considered can be used with both manned and unmanned environments with potential commercial applications on earth.

Specific areas of interest may include the following:

- Advanced heat transport systems and concepts with acceptable safety characteristics (flammability, toxicity, and materials compatibility) which can be used in manned or unmanned systems.

- High temperature materials processing applications for both heat input and heat rejection in a manned environment.

- Advanced refrigeration and heat pump system technologies are sought to meet special thermal requirements on board manned spacecraft, for storage of food and biological samples. Applications may also include meeting requirements for heated water.

- Innovative high performance thermal insulation including both materials development, insulation manufacturing or application techniques to unique shapes and systems.

- Innovative techniques for graphics design and analysis of thermal systems with emphasis on micro-computers and compatibility with MSFC and other major software/hardware systems.

- Advanced techniques for low power thermal control systems in the area of coating and insulation systems and heater control circuitry. This area also includes advanced temperature sensing and data transmitting devices and components.

- Innovative applications of new and/or exotic materials for any area of heat transport, cooling, heating, and insulation or sensing components.

- Long term thermal control and storage of cryogenic or low temperature fluids, including vapor cooled shields, leak detection, and sewer systems.

- Innovative concepts for the detection and servicing of fluid leaks in the Space Station thermal fluid loops, components, and subsystems.

09.14 COMPARTMENT VENTING
Center: MSFC

Innovative analytical methods are required to improve current understanding of spacecraft equipment and compartment venting under all flight conditions. The desired software should run on existing PC's and interface with existing CAD packages to enable the designer to obtain the following information about a suggested design:

- Conductance behavior of complex vents, baffles, flappers, filters, etc. at various pressures, temperatures and trajectory parameters.
- Correct gas dynamic conditions for all design conditions of concern.

A flexible code is required that will allow the designer to vary internal and external spacecraft hardware configuration details, environments, and other physical assumptions. Graphical output of thermal conditions, gas flow, and pressure data is desired.

It is expected that in addition to NASA use, significant commercial potential exists in the aerospace industry for an easy to use software package that demonstrates a high degree of accuracy and reliability.

10.00 SPACE POWER

10.01 SPACE POWER SYSTEM TECHNOLOGIES
Center: LeRC

The Lewis Research Center has broad, NASA-wide responsibilities for research and development of advanced space power systems and their underlying disciplines. These responsibilities encompass: all areas associated with energy conversion systems (including all thermodynamic cycles and energy sources); electrochemical storage systems of all types; power management and distribution systems for simple and highly sophisticated applications over the entire spectrum of space mission applications; and space power system supporting disciplines and technologies for the development, improvement, and practical, reliable implementation of space power systems for all applications. Other NASA Installation also share in many of related responsibilities and are actively involved in R&D specific to their interests. Some of these are noted in other subtopics included within the Space Power Topic.

This subtopic solicits innovative new concepts to assist Lewis in its space power mission in any of the areas noted above. However, offerors wishing to propose innovations to this subtopic must avoid submitting identical or substantially the same innovation to any other subtopic specifically identified with another NASA Installation. As noted elsewhere in this Solicitation, NASA is not obligated to accept or to evaluate identical or substantially similar Phase I proposals that have been submitted to multiple subtopics.

Offerors are advised that only those innovations appearing to be feasible in the foreseeable future are of interest, although high risk-high payoff concepts are invited. Each Phase I proposal must suggest further activities which NASA might find useful to explore in Phase II or subsequent development programs, with emphasis on realistic applications.

10.02 HIGH ENERGY DENSITY AND LONG LIFE BATTERIES
Center: JPL

New concepts are sought to develop advanced lithium and other electro-chemical systems with improved energy density (by a factor of 2-3) and life (by a factor of 2) compared to Ni-Cd and Ni-H_2 batteries. Areas of interest for innovations are high energy density cathodes, stable electrolytes with higher conductivity, novel approaches that improve lithium rechargeability, separators. Proposed innovations should emphasize systems and components with increased efficiency, cycle life, active storage life, safety and reliability, while achieving reduced cost and weight. Specific interests are ambient temperature rechargeable lithium batteries, polymer electrolyte batteries, and molten salt systems. Advanced high risk-high payoff concepts beyond the present state-of-the-art which may result in considerable benefits are also of interest.

10.03 SEPARATOR MATERIAL FOR AEROSPACE NI-CD CELLS
Center: GSFC

The NASA standard rechargeable nickel-cadmium (Ni-Cd) battery, when operated under stringent charge control requirements, has demonstrated a charge/discharge cycle life of 5 years or more aboard low-earth-orbit (LEO) satellites. These NASA standards aerospace Ni-Cd cells utilized a nylon fiber separator material (Pellon 2505) to retain the potassium hydroxide (KOH) electrolyte and provide insulation between positive and negative electrode plates. However, for environmental reasons, this particular separator material is no longer manufacturable. Ni-Cd cells that were recently manufactured with a replacement nylon fiber separator material (Pellon 2536) have demonstrated a higher degree of performance degradation with the number of charge/discharge cycles; and may not meet high performance requirements for Ni-Cd battery cells. Such new materials and other innovative approaches to solve this problem are solicited.

10.04 PHOTOVOLTAIC LASER ENERGY CONVERTERS
Center: LaRC

Solar-pumped lasers are promising as part of a space-based laser power system. Photovoltaic-converters theoretically offer laser-to-electric conversion efficiencies approaching 50 percent if the semiconductor bandgap energy is well matched to the laser photon energy. Silicon is an appropriate semiconductor for use with promising solar pumped neodymium lasers. Radiant input power densities to the converter will be as high as 1000 watts/cm^2. Innovative approaches, such as series connected vertical multijunction converters, may be required to minimize series resistance and to take advantage of these high power densities. Innovative crystal growth techniques, such as molecular beam epitaxy and ion implantation, may be required to grow single-crystal, series connected, multiple p-n junction converters. A material system of interest is the silicon-crystal, vertical-junction converter with 500-1000 p-n junctions per cm. Innovations based on unconventional high risk-high payoff concepts are also solicited.

10.05 ELECTRICAL POWER CONTROL AND DISTRIBUTION SUBSYSTEMS
Center: JSC

Innovations are needed in the following areas pertaining to the area of aerospace electrical power distribution and control:

- Solid state high power switching components: In order to handle large amounts of power on new aerospace vehicles and to provide the necessary instrumentation to support expert systems, "smart," computer-controlled, high-power switching components need to be developed.

- High-efficiency 400 Hz converters: New aerospace vehicles require devices that can convert DC or unregulated AC into 400 Hz regulated power and provide maximum efficiency with minimum practical weight. Because of the many unique requirements of various loads, the approach to a modular design is desirable.

- High efficiency DC-to-DC converters: As new switching devices make high voltage DC more desirable for primary power distribution, the need for more efficient DC-to-DC converters becomes apparent. A design study should be conducted to find innovative ways of increasing the efficiency of these converters for relatively high power levels (1 to 5 KW). A second phase of the contract should deal with prototyping any concepts devised during the first phase.

- Remotely actuated (mate/demate) electrical connectors: Payload retrieval and construction in space make it highly desirable to have a series of electrical connectors which can be both mated and demated without assistance by the crew. The system should be reliable, lightweight, and simple and might involve the use of robotics.

- High efficiency contactless connectors: AC power is being considered for power transmission in space. It is desirable to have a series of contactless AC connectors to aid in vehicle assembly and extra-vehicular power transmission.

- High frequency transmission line terminations and splices: The use of high frequency (20 KHz and above) will require special conductor configurations and unique termination and splicing techniques.

- Non-intrusive ground or on-board system for early detection of electrical wire insulation degradation prior to actual failure.

10.06 SPACE POWER ADVANCED AUTOMATION SUBSYSTEMS
Center: MSFC

Innovations are sought in the area of advanced automation of electrical power systems for space applications. The ultimate objective is to develop completely autonomous power subsystems which interact intelligently with other subsystems, crew members, and ground support systems and personnel. These power subsystems may range in capacity from a few kilowatts to hundreds of kilowatts. The desired system autonomy will combine conventional and AI approaches which interact closely. The AI systems will consist primarily of knowledge-based approaches with some natural language interfaces. Other technologies, including neural networks, may provide alternative solutions. System autonomy emphasizes comprehensive fault management, including fault or anomaly identification, diagnosis, recommendation of corrective or recovery actions, actual implementation of recovery activities, and dynamic contingency loads rescheduling.

10.07 POWER TRANSMISSION APPLICATIONS OF HIGH TEMPERATURE SUPERCONDUCTORS
Center: JPL

Unique opportunities exist for applications of high temperature superconductors in advanced space power transmission. The reduced refrigeration requirements of high temperature superconductors should result in remarkable mass and cost savings. Innovative new concepts and applications are solicited in numerous areas, including: large energy storage capacity systems with low specific mass to energy ratios;

low loss energy conversion in ac and dc rotating machines and in electric power transmission.

- Key innovations needed to realize these objectives with high temperature superconducting materials should concentrate on improvements relating to: critical current density; magnetic field tolerance, stress tolerance and radiation tolerance; wire and busbar material integrity; high strength to mass ratio strengthening techniques; low mass active/passive electromagnetic shielding materials; on-board systems interaction with planetary and solar B-fields (torque shielding); long life, low mass, low gravity refrigeration and cooling systems; high magnetic energy field configurations (solenoidal, toroidal, monolithic rings); loss reduction techniques for rotating machines; power processing; and fast pulse switching.

11.00 SPACE PROPULSION

11.01 SPACE PROPULSION SYSTEM TECHNOLOGIES
Center: LeRC

Although shared with other NASA Installations, an important mission of the Lewis Research Center is to conduct research and technology development in all basic disciplines underlying space propulsion concepts and systems for all advanced missions. These missions encompass surface-to-orbit vehicles, launch vehicle upper stages, orbit-to-orbit vehicles, injection vehicles for transit to other celestial objects, and auxiliary propulsion for vehicles and applications such as Space Station Freedom, satellites and orbiting platforms.

Accordingly, this subtopic solicits innovations and new concepts to help facilitate new and improved space propulsion systems appropriate to Lewis technology objectives. Areas of interest include, but may not be limited to performance, operational flexibility, reliability and life, fabricability, testing, analysis and modeling, diagnostics, propellant management, synthesis of advanced subsystems and components, AI/expert systems, installations, and all the diverse fundamental disciplines upon which space propulsion systems and their practical operational applications are based.

Some of the specific interests of other NASA Installations sharing technological responsibilities in space propulsion are included in other Space Propulsion subtopics. Therefore, offerors wishing to propose innovations to this or any other subtopic included in the Space Propulsion Topic must choose carefully which subtopic or installation seems most appropriate for their proposals. As noted elsewhere in this Solicitation, NASA is not obligated to accept or to evaluate identical or substantially similar Phase I proposals that have been submitted to multiple subtopics.

Offerors are advised that only those innovations appearing to be feasible in the foreseeable future are normally of interest, and that each Phase I proposal must suggest further activities which NASA might find useful to explore in Phase II or subsequent development programs, with emphasis on realistic applications.

11.02 LIQUID ENGINE INTERNAL FLOW DYNAMICS
Center: MSFC

To advance design and optimization of present and future liquid-fueled rocket engines, innovative techniques are sought for modeling internal flows and coupling structural and fluid dynamic behavior. Flow environments to be addressed occur in geometrically complex domains and are often unsteady and incompressible. Rotational, multiphase, multispecie, and turbulent effects also dominate and/or influence the flows to be considered. Specific areas of interest in which innovative approaches are solicited include:

- Computational techniques for coupling 3-D time-dependent flow solvers to 3-D structural models.

- Multiblocking or zonal techniques for obtaining efficient Navier-Stokes solutions in complex 3-D domains.

- Analysis of incompressible, 3-D flow with phase change for turbopump bearing, seal, injector, and pump analysis.

- Analysis of unsteady incompressible and compressible flows over vaned elements in turbine and pump environments.

- Interfacing CAD/CAM IGES files to surface and grid generators used for structured mesh solvers for complex internal flow geometries.

- Efficient and accurate prediction of fluctuating quantities for incompressible internal flows in complex domains.

- Viscous flowfield calculation procedures to account for nonisentropic boundary layers in regeneratively cooled nozzles.

- Analysis addressing heat transfer and associated radiation levels for reacting and nonreacting flows, with emphasis on heat transfer in liquid engine combustion chambers and nozzles.

11.03 CRYOGENIC PROPELLANT MANAGEMENT FOR SPACECRAFT
Center: MSFC

A Long Term Cryogenic Storage Facility (LTCSF) and an Earth-to-Orbit cryogenic tanker will be required to resuppply a space-based Space Transfer Vehicle (STV) with liquid hydrogen and liquid oxygen propellants. Technical challenges associated with storing and transferring subcritical cryogens in a low-gravity environment include cryogenic instrumentation and thermal control. New, innovative concepts are solicited which could bring major improvements to existing techniques for all these areas of challenge and associated instrumentation including liquid/vapor detection, mass gaging, and leak detection. Feasible innovative techniques are solicited to reduce the heat leak into a tank through penetrations and support struts, and to remove the heat that does reach the cryogenic fluid. Low thermal conductance penetrations are required for fluid lines and electrical/instrumentation lines into the tank. The structural supports must be designed to handle launch and on-orbit loads and to minimize heat conduction to the fluid. Techniques to remove heat from the fluid may be passive or active in nature. All Phase I proposals must suggest significant improvements over current practices and means by which performance could be verified in subsequent Phase II activities.

11.04 SOLID ROCKET MOTOR TECHNOLOGY
Center: MSFC

The feasibility of new, innovative concepts and approaches for design, analysis, production, and testing of solid rocket motors (SRM) is solicited:

- Methods and test techniques for obtaining mechanical and physical properties of carbon-carbon and/or carbon-phenolic nozzles materials. Of particular interest are those properties which are used in thermo-structural analysis.

- Improved constituent materials for nozzles (fabric, resins, etc.) and manufacturing processes.

- Materials, design approaches, fabrication and processing methods, and inspection techniques which can result in high reliability, low cost nozzles and/or nozzle components.

- Test-derived failure criteria for carbon-carbon involute and/or carbon-phenolic materials, implemented in an algorithm for predicting failure, and including demonstration of algorithm validity in predicting failure of specimens at high temperature and with stress to failure.

- Methods to reduce the process variability and to reduce fabrication costs of filament wound composite cases.

- NDE methods to detect weak or "kissing" unbonds in the propellant-liner-insulation-case interfaces to a level compatible with acceptance inspection of large SRM's.

Weak bonds and "kissing" unbonds occur occasionally in solid rocket motors ("kissing" unbonds are defined as the condition where the surfaces are in firm contact, but not bonded together). There currently exists no methods for detecting them.

- New and/or advanced techniques for the measurement of temperature and strain in or on composite nozzle materials. Existing instrumentation techniques are inadequate in temperature range and response time for evaluation of SRM carbon-carbon and carbon-phenolic nozzle structures and/or validation of analytical models during hot-fired conditions. Current temperature/strain capability is limited to the range of 700°F to 1000°F, whereas accurate engineering data is needed for temperatures up to 4000°F and strain data at temperatures of at least 2000°F. New techniques must function accurately and reliability under high heat flux and transient thermal conditions with low strain rates.

11.05 HIGH POWER LEVEL ELECTRO-MECHANICAL THRUST VECTOR CONTROL
Center: MSFC

Recent advances in electrical and electronic components such as high power solid state switching devices, rare earth permanent magnet motors, and advanced storage batteries suggest that high power, i.e., 50 horsepower or possibly larger, thrust vector control (TVC) systems may be feasible and could compare favorably with conventional electrohydraulic systems in size, weight, performance, and overall reliability. Proposals to attempt to establish the feasibility and possible superiority of innovative new TVC concepts such as these are solicited. High risk-high payoff concepts and innovative alternative approaches are welcome. Proposals should identify areas requiring state of the art technical advances necessary for the desired improvements and should outline appropriate activities that might merit NASA Phase II continued investigations.

11.06 CONTAMINATION FROM BIPROPELLANT ROCKET ENGINES EXHAUST PRODUCTS
Center: JPL

The design of many spacecraft assigned to future planetary and Earth-orbit missions calls for the installation of liquid propellant rocket engines, not only for the main propulsion system, but also for the attitude control thrusters. Contamination of spacecraft sensitive surfaces by the exhaust from rockets is a prime concern to mission scientists and spacecraft system designers. Furthermore, in the near future NASA is contemplating missions to comets and asteroids which will include sampling of the spacecraft environment. The extent to which this environment is perturbed by the operations of the spacecraft systems needs to be predicted during the mission design phase. The magnitude, composition, and distribution of contaminants from small, pulsed bipropellant engines cannot now be predicted to within an order of magnitude; the first step to solving this problem is deemed to be a valid model which can later be verified by test data.

Earth storable bipropellant engines are known to contain in their exhaust, propellant residues of multiphase particulate and unburned vapors in addition to other high boiling point condensibles. The problem becomes more complicated when such systems are operated in transient (pulsed) mode. The capability of predicting these flow fields and exhaust constituents at the nozzle exit plane during transient as well as steady state operations is inadequate since the exhaust composition varies greatly from pulse build-up to the after pulse state.

Innovative approaches are solicited that will realistically model the extent to which engine design and operating parameters influence the flow field and composition at the exit plane. The capability to simulate trains of pulses corresponding to a given operation duty cycle is mandatory. Recognizing that the thermal environment of the thruster affects the quantity and quality of the exhaust contaminants to an unknown extent, the modeling must also include those thermal characteristics of thruster installation that are deemed important.

Phase I proposals must also identify realistic and practical techniques leading to experimental verification of predictive models which NASA may wish to support during Phase II activities.

12.00 HUMAN HABITABILITY AND BIOLOGY IN SPACE

12.01 MEDICAL SCIENCES FOR MANNED SPACE PROGRAMS
Center: JSC

Permanent manned presence in space, demands great understanding of the function of the human body and mind in the space environment. New technologies are essential for studies of physiology and psychology, and for providing health care over extended duration missions. Because these areas of concern are very important to future NASA missions, considerable research has been and is being conducted. Therefore, it is imperative that small businesses proposals emphasize only new and innovative concepts which could be key to achievement of any of these objectives, and which would be amendable to further development in well-thought-out Phase II and subsequent NASA activities.

- Methods for assessing physical conditioning and means to maintain it.
- Health diagnostic instruments and procedures.
- Imaging systems for internal body organs.
- Medical care for trauma and illness.
- Psychological assessment and treatment.
- Development of microgravity countermeasures.
- Dental care and surgery.
- Prevention/treatment of decompression sickness.
- Assessment/protection from ionizing radiation.
- Measurement of changes in bone mineral and muscle status and development of countermeasures.
- Prediction and prevention of space motion sickness and sensory motor disturbances.

12.02 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS FOR SPACE STATION
Center: MSFC

Environmental Control and Life Support Systems (ECLSS) are being developed to establish and maintain safe, habitable environments onboard the Space Station and later manned spaceflight missions. Similar technologies are also being developed for the Space Station Process Materials Management System (PMMS). Some example innovations to improve many system components and processes follow:

- Components and Processes
  - The Bosch CO_2 reduction process. Research is required to define all significant reactions and rates with respect to all dependent variables. Alternate catalysts which exhibit increased activity at lower temperatures and greater carbon packing densities are also required;
  - CO_2 removal processes. Hydrophobic molecular sieve materials which have high capacities for CO_2 in the presence of water vapor are required as are im-

provements to electrochemical catalytic processes;
- Fire and smoke suppressants to minimize hazards and penalties;
- Oil-less vacuum pumps for corrosive gas streams saturated with water vapor;
- Fluid disconnects for high purity water or hazardous materials handling systems which minimize leakage and preclude chemical/microbial contamination during use;
- Nonexpendable stabilization of waste waters prior to storage and/or processing and waste purge gases prior to overboard venting;
- Storage of liquids in microgravity not subject to life limitations of positive displacement bellows or bladder tanks;
- Storage and distribution of cryogenic fluids in microgravity.

- Sensors and Instrumentation:
  - Methods to remove dissolved carbonate and separate CO_2 from solution in organic carbon analyzers which must be completely reagentless and not require the use of purge gases;
  - On-line monitor for near-real time measurement of microbial contamination in water in the range of 1 CFU/100ml or below;
  - Detectors to detect, locate, and quantify air leaks from a pressurized module during ground-based and on-orbit operations;
  - Early-warning fire sensors to detect off-gassing by-products which may be indicative of imminent combustion.

All Phase I proposals must outline rational Phase II development and verification activities if Phase I projects are feasible.

12.03 REGENERATIVE LIFE SUPPORT: AIR, WATER AND WASTE MANAGEMENT
Center: JSC

Innovative concepts are sought that will provide for closure of regenerative life support systems for long-term manned missions (lunar and Mars colonies and planetary missions). The development of physical/chemical systems to date has been driven by requirements including zero-gravity and low power, volume, and weight. These requirements must shift to include high reliability, and utilization of surface partial gravity and in-situ resources. Also, system weight and volume become higher priority constraints than power consumption. Proposed innovations must include theoretical discussion of the concept, experimental data demonstrating viability, relevance to advanced mission requirements, benefits over existing technologies in the following areas, and describe practical and meaningful objectives for NASA support in subsequent Phase II activities:

- Air Revitalization:
  - CO_2 separation and concentration techniques, e.g., from Martian atmosphere which contains 95% CO_2 at a total atmospheric pressure of 6-7 millibars;
  - New contaminant control techniques that will replace expendable adsorption, e.g., activated carbon and absorption, e.g., lithium hydroxide methods in conjunction with high temperature catalytic oxidation, and remove ammonia which is subject to generation from waste materials and bacteria.

- Water Reclamation: Direct treatment of waste water (urine, wash water, and condensates) by processes not using any expendables to provide potable and hygiene water by reclaiming high water content of waste waters by any of the following:
  - Direct removal of the total water content;
  - Direct removal of the undesirable chemical impurities (organics/inorganics);
  - High temperature (250°F) reverse osmosis filters;
  - Filter systems which utilize lunar soil to purify water;
  - Techniques for low temperature disinfection;
  - Handling and treatment of processed water (post treatment) to remove trace contaminants and bacteria without expendables;
  - Phase-change treatment systems utilizing lunar/Martian gravity or microgravity, or

- Microbial techniques for removal of contaminants.

- Waste Management: Obtain useful products (N_2, H_2, CO_2) from organic waste materials; Microbial techniques for waste treatment in micro or partial gravity, i.e., lunar surface.

12.04 BIOREGENERATIVE FOOD PRODUCTION
Center: ARC

Long duration missions involving humans that are envisioned for the surfaces of the Moon and Mars, and for transit to Mars and an evolving Space Station, will require that increased emphasis be placed on reducing resupply needs for life support purposes. Innovative concepts are sought in areas that will increase capabilities for regeneration of food, as a part of maintaining a stable, high quality life support environment for crews. Specific areas of innovation include:

- Increased crop growth efficiency through automated crop cultivation, harvest, and food processing techniques; direct supply of sunlight and development of high efficiency lamps with spectral qualities needed for plant growth.

- Improved yields of food biomass through specific application of plant hormones; genetic engineering of crop species; utilization of cellulosic materials for food; identification of plant nutrient demands; measurement and maintenance of plant nutrient concentrations.

- Sensing devices for system monitoring and control for: specifications needed for plant nutrition; organic materials in liquids and in the atmosphere; fluid flow; microbial species and populations.

- System control: identification of monitoring techniques; establishment of control hierarchies; evaluation of system control models.

12.05 HUMAN FACTORS FOR SPACE CREWS
Center: JSC

Innovative devices and techniques must be obtained to allow crewmembers to perform all intravehicular and extravehicular inflight operations, of every type, including, inflight maintenance, construction and servicing, and to enhance and augment human capabilities and to optimize human performance and productivity in zero-g and reduced-g environments. Innovative concepts are also solicited for optimum spacecraft layout/arrangement and operations, especially for longer-term and/or reduced-g missions. Examples of desired innovations include:

- Means to acquire anthropometric and biomechanical kinematics and dynamic data to optimize human performance in space and to use in theoretical and applied design models for spaceflight.

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

- Innovations in the application of new technologies to enhance human/telerobotics and human/automation interfaces.

- Design and development of efficient lighting sources that are lightweight, utilize minimum power, provide high lumen output per watt, and are safe for inflight use.

- Methods to define, reduce and/or control spacecraft noise (e.g., materials, interior arrangements, crew aids) with consideration given to weight and volume penalties.

- Techniques for display of and interaction with multiple dimension data, such as multiple parameters of triply redundant systems. Volume and weight must be considered.

- Techniques for facilitating the layout and arrangement of spacecraft interiors to promote effective and efficient use of both the zero-g and partial-g environments in carrying out living and working tasks.

- Techniques for optimizing spacecraft interior decor. Consideration must be given to the spacecraft environment and mission/ operations constraints, including weight, power, materials and crew time.

- Methods to define and develop modular approaches to the buildup of zero-g flight vehicles and partial-g facilities, stressing onboard reconfigurability/modification and associated interfacing or support/handling equipment.

12.06 INTRAVEHICULAR SYSTEMS FOR SPACE CREWS
Center: JSC

Extended duration manned spaceflight and planetary missions create the need for new systems designs to increase the performance and productivity of the flight crews which also have a positive influence on their physical and mental well being. Innovations are desired in the following crew equipment areas. Phase I proposals suggesting conventional and familiar approaches and equipment for these purposes will normally not be considered responsive. Emphasis is to be on significant innovative concepts promising greater utility, efficiency and value to space crews on long missions.

- Crew Hygiene: Systems for male and female body and hair grooming, oral cleansing and shaving under microgravity and closed environmental systems conditions. Included are contaminant removal systems/filters.

- Temporary Solid Trash Handling: Systems for collecting, deodorizing, storing and packaging of paper, food scraps, plastic wrappers and other solid trash for processing onboard manned space vehicles.

- Equipment Tracking and Management: Systems and components to enhance or augment the tracking, stowage and inventory management of crew equipment and supplies (e.g., tools, food, clothing, wipes, pharmaceuticals, soaps and other expendables).

- Electronic Photography: Systems and components to enhance and augment high resolution electronic photography for space flight applications, including: electronic still frame recording devices having operations similar to a 35mm film camera, removable storage media and handheld automated operation; components such as high resolution electronic imagers, mass storage devices, flat screen displays, low rf emitting voltage converters, color imaging software, improved optics systems, data compression schemes.

- Data Transmission: Means of providing uplink, downlink, display, storage and archival of images and data are desired for spaceflight applications.

- Improved Imagery Systems: Devices and techniques to make images more dimensionally correct, eliminate the foreshortening effects of conventional telephoto systems, improve depth perspective of images both for film and video images.

- Visual Observation: Means to provide high resolution visual observation from intravehicular viewing stations/windows of targets and activities in the proximity of and at some distance from orbiting vehicles.

- Food Packaging and Service: To enhance the interface between man and the food service system during extended duration space and planetary missions, techniques adaptable to a microgravity environment for packaging, preparation and serving solid and liquid foods are required to provide a functional system for extended duration space and planetary missions.

- Food Storage: Techniques and methods for extending the shelf life of fresh fruits and/or vegetables.

12.07 EXTRAVEHICULAR ACTIVITY (EVA)
Center: JSC

Increased utilization of EVA to support space missions suggests numerous innovations to improve the efficiency and effectiveness of the operations. Proposals are solicited in a variety of areas, some of which follow:

- Space suit ancillary equipment to provide reliable, safe, and compact means for collection and storage of waste products including vomitus and urine during EVA work periods.

- Space suit hardware oriented design concept approaches for higher operating pressure EVA gloves, lightweight, highly durable, insulation material layups and efficient fabrication techniques for production of liquid cooling garments.

- Anthropomorphic, robotic devices for testing and measurement of space suit and EVA glove mobility/torque range and forces including performance of combined motion life cycle testing activities.

- Humidity/CO_2 scrubber: Techniques to remove water vapor and CO_2 within the oxygen environment of the EMU that are low power, reliable, and compact. Must allow regeneration and reuse without requiring expendables for a period of at least one year in the space suit environment

- Compact chemical oxygen system: Techniques to provide a compact, reliable emergency oxygen backup for either breathing or to sustain pressure integrity of the space suit.

- Trace contamination control; A compact, regenerable, low-power trace contaminant control technique is needed for use in space suits. The method must completely remove noxious and toxic contaminants and be easily regenerable to avoid the launch weight cost of an expendable system.
- Emergency breathing apparatus: Techniques to provide a reliable, safe, and compact means which allows breath-powered CO_2 removal in lieu of an open-loop purge for emergency operations.

- Zero-gravity dryer: Techniques for compact, low weight, low power dryers to remove water vapor from oxygen and hydrogen to the low dew points required to preclude icing in blow-down regulators.

- Astronaut rescue system: Small, simple and reliable translation device which can be carried by an EVA crew member capable of retrieving an adrift or disabled EVA crew person or an object.

- EVA worksite aids and assembly techniques for precise alignment mating, tool positioning and storage, illumination and tether systems as well as fastening, joining, cutting, drilling of metallic and non-metallic materials with collection of particle debris. In addition, splicing, cutting, joining and forming of electrical cables and fluids plumbing techniques are required to be developed.

All Phase I proposals must suggest rational Phase II continuation activities to establish the practicality of feasible concepts.

12.08 BIOMEDICAL AND ENVIRONMENTAL HYGIENE SUPPORT FOR MANNED SPACE PROGRAMS
Center: JSC

Long duration manned space missions and permanent human occupancy in space generate new requirements for a wide range of medical and biomedical activities including ground based research and development, crew support, and inflight investigations. Advanced capabilities will be required in the general areas of clinical laboratory operations, analytical chemistry, and environmental health. New approaches are solicited in many related activities, but only Phase I proposals based on fresh, innovative concepts, will be considered to be responsive:

- Collection, processing and analysis of biological specimens of minimum size.

- Measurement of potential changes in immune system during spaceflight and quantify effects of stress and radiation.
- Automated portable multi-gas sampling gas chromatograph.

- Method to estimate circulating red blood cell mass during flight.

- Simple means to measure mass of crew members and of biological samples in microgravity.

- Simple, rapid methods of detection, quantification and identification of microorganisms in biological and environmental specimens and estimation of their antibiotic sensitivity.

- Automated tissue culture systems for use in microgravity.

- Documentation, storage and retrieval of health related clinical and laboratory diagnostic information designed specifically for spaceflight use.

- Methods for maintaining surface and equipment cleanliness requirements within the habitation and laboratory areas and means of determining compliance with requirements.

- Treatment of laboratory, metabolic and other waste products to allow long term storage prior to returning to Earth.

- Inflight instrumentation to verify that recycled atmosphere and water meet human acceptability requirements (physical, organic, inorganic, and microbiological).

- Inflight, rapid method of assessing physiological acceptability of potable and hygiene water reclaimed from metabolic, laundry and hygiene wastes.

- Flameless atomic adsorption for inflight analysis of metal ions in water.

- Automated equipment for determining the organic constituents in reclaimed water.

- Methods for on-orbit cleansing and disinfection/sterilization of potable water systems.

- Methods to cultivate eukaryotic and prokaryotic cells in microgravity and methods to assess cell growth, structure and function.

All Phase I proposals must clearly indicate meaningful activities which could proceed into Phase II continuations and subsequent useful activities.

12.09 CONCEPTS, AND COMPONENTS FOR STERILIZATION OF ONBOARD WATER SYSTEMS

Center: MSFC

A major concern in the design of the Space Station Freedom is the sterilization of the onboard water system. Testing must be done to verify that a complex closed water system can be sterilized and kept sterile even when certain components - such as transducers, valves, pumps, and filters - are inserted, removed, or replaced. To understand the quality of water produced, analytical methods will need to be developed which will identify and quantify the organic compounds present in the water produced. These methods must demonstrate an accuracy of 90% to 100% using matrix spikes and be reproducible within a 5% range with a lower limit of detection of 20 ppb for each organic compound identified. Innovations are needed to determine:

- Proper materials to use for sterilization test hardware.

- Component designs which will ensure efficient sterilization.

- Procedures that will maintain a sterile system when inserting and removing test components.

- Proper methods for building a sterile closed test system.

- Methods to identify and quantify organic compounds reliably and quickly.

- Proposals should not be submitted which do not take into consideration the equipment market for existing analyzers and appropriate sources for new and innovative equipment.

12.10 PHYSICO-CHEMICAL LIFE SUPPORT SYSTEMS

Center: ARC

It is anticipated that advanced methods for physico-chemical life support systems will be needed for long term human presence in space and on other planetary bodies. Advanced physico-chemical concepts for the regeneration of oxygen, water, and food will increase the duration and extent of future missions and improve the quality of the space environment. Among areas in which innovations are sought include:

- Simulation software to model physico-chemical life support systems processes.
- Techniques to integrate qualitative and quantitative intelligent systems modeling methodologies into an automated modeling tool for physico-chemical life support systems.
- Fusible materials for life support thermal control.
- Materials for mechanical applications in life support.
- Concepts for the processing of waste streams into usable materials.
- Filters and filter technologies for life support.
- Integrated instrumentation systems for monitoring water quality.
- Integrated systems using biological and physico-chemical processes.

12.11 LIFE SCIENCES SPACEFLIGHT HARDWARE DEVELOPMENT
Center: ARC

Life science payloads provide basic scientific information on the response of living systems to the space environment as well as possible explanation of the human response and adaption to space. Innovation is sought in areas which will enhance or enable the full flight experiment potential of unicellular organisms, animals and plants through improved care, support, observation and monitoring techniques for the Space Station.

- Implant telemetry for direct biosystem monitoring or control.
- General improvement in physiological monitoring techniques for inflight and ground studies of cardiovascular, skeletal, vestibular, hematological, reproductive, and other changes occurring during spaceflight.
- Hardware for noninvasive measurement of intracranial pressure.
- Automated food delivery and waste management systems for measuring food and water consumption as well as waste product monitoring, volume collection, sampling and storage. Also metabolic holding facilities for rodents to permit complete waste collection and gas exchange measurements.
- Small scale breeding facilities for spaceflight use with animals such as monkeys, rats, mice, and frogs.
- Environmental control and monitoring systems applicable to various species for maintenance of desired temperature, humidity, vibration, atmosphere and other factors during spaceflight.
- Application of various techniques and hardware to zero-g conditions, such as animal holding and husbandry facilities, incubators, surgical techniques, wet chemistry processing, biochemical analysis, and continuous flow processing for aerobic and anaerobic fermentation.
- Centrifugation technology to prove an artificial gravity environment during spaceflight and a research tool for biological studies in microgravity.
- Techniques applicable to contamination control, contamination monitoring, biosolation, etc. e.g., cage cleaner.

Offerors are cautioned that significant research has already been conducted in many of these areas, and that NASA is interested in only those Phase I proposals which introduce original, innovative concepts and major improvements.

12.12 BIOLOGICAL SCIENCES OPERATIONS
Center: KSC

Innovations are required to enhance environmental monitoring capabilities and the development of systems to support plant biology in space. This includes instrumentation for remotely monitoring environmental parameters such as miniaturized infrared, RF telemetry, or other methods for determining chemistry, pH, physical parameters, and movement; miniature camera systems for in situ observations in both artificial (chambers) and natural environments. Supporting technologies require the development of specific sensors, e.g., water level, flow, pH, salinity, turbidity, to remotely monitor parameters, as well as computer software and hardware that will utilize environmental data through relational databases and geographic information systems.

Also needed is specialized research to solve specific problems anticipated for a Controlled Ecological Life Support System (CELSS), such as continuous monitoring and control of lighting and other environmental variables for plant growth; alternate methods to generate, transport, and collect light for plants; techniques for growing plants with special capabilities (including tissue culture and genetically improved plant material); compact and energy efficient systems for processing wastes and inedible biomass into foods or other reusable forms; and robotic and computer imaging systems to seed, harvest, and monitor plants.

12.13 PARAMETRIC NUCLEAR FRAGMENTATION MODEL
Center: LaRC

The ultimate limitation to long duration manned spaceflight outside Earth's magnetosphere will likely be cumulative exposure of astronauts to the high-energy heavy-ion component of galactic cosmic rays (GCR). To provide adequate spacecraft shielding from these radiations requires the development of comprehensive radiation transport computer codes which are computationally fast and accurate. A major source of uncertainty in these transport codes is the input nuclear fragmentation model which describes the breakup of the galactic heavy ions into secondary and subsequent generation particles.

Current nuclear fragmentation models are inadequate for precise radiation transport studies because they are either too inaccurate or too complex to use within a GCR transport code. In addition, none of the existing fragmentation models are capable of adequately predicting production cross sections for light ions.

Consequently, an innovative parametric model for heavy ion fragmentation, based upon a fundamental description of heavy ion collisions, is sought to insure reliable predictive capability. Recent advances in nuclear thermodynamic models of heavy ion collisions present the possibility of using these concepts to develop a parametric model for nuclear fragmentation. The thermodynamic model must be capable of representing the currently available fragmentation data, within stated experimental uncertainties, while using fewer than ten (10) adjustable parameters. It must be capable of providing fragmentation cross sections for all of the natural elements colliding with any arbitrary elemental target for incident kinetic energies above 25 MeV/nucleon. The final model should be capable of being FORTRAN-coded for use in existing galactic cosmic ray transport codes.

12.14 ANATOMICAL IMAGE ANALYSIS TECHNIQUES
Center: KSC

Accurate, serial, near real-time, and non-interfering, measurements of surface area and volume of the human body and regional parts are required for quantifying reference and time varying values during adaptive and stressed alterations of body mass. Such information is important to help understand extent and dynamics of fluid shifts in a wide variety of environmental situations as well as other causes of change or loss of body mass. In addition body surface area figures significantly in many diagnostic and therapeutic conditions.

Theory and technology using optical and main frame computer methods of stereophotogrammetry have already been developed and proven for this task. However, the intent here is to capitalize on new technologies in optical imaging and in microprocessor digitizing and analysis which has recently become prevalent, to produce the desired capability operable on off-the-shelf, ubiquitous, and relatively inexpensive hardware and software systems.

13.00 QUALITY ASSURANCE, SAFETY AND CHECK-OUT FOR GROUND AND SPACE OPERATIONS

13.01 GROUND OPERATIONS INSTRUMENTATION
Center: KSC

Ground testing and launch of space hardware involves measurement of a large number of parameters in a field operations environment. Following are examples of areas in which new, innovative approaches are sought to improve safety, efficiency, hazards detection and to reduce operational time delays:

- Contamination Detection:
  - Reliable, traceable calibration of commercial Aerosol Particle Monitors for particle counts as well as for particle size. Current methods provide size calibration, but do not provide absolute calibration of particle count;
  - Other innovative contamination monitoring techniques such as real-time automated detection and measurement of nonvolatile residues with remote reporting and readout.
- Hydrogen/Oxygen detection:
  - High reliability, low maintenance H_2 gas detector with range of 0-8% which can operate in air, N_2, He, or changing mixtures of all three. Portable meter and fixed 0-5 VDC sensor needed;
  - Improved mass spectrometer-based system for detection of trace or % LFL (lower flammability limit) H_2 and O_2 levels. (Detect H_2^{-10} ppm to 4%; 02-10 ppm to 4%; He^{-1} ppm to 10%; Ar-1 ppm to 1%.) The technical challenge is to meet or exceed present analytical capabilities (computer-controlled quadrupole mass spectrometer with triode ion pump) with pumping capabilities which (a) survive launch vibration and (b) do not become saturated with hydrogen within 4-6 months. Improvements are sought in (a) high vacuum pumping techniques, (b) ionizer design and (c) data handling techniques;
  - Multispectral color TV for hydrogen fire detection: Innovative color television system concept capable of imaging and displaying hydrogen fires with normal ambient background, including full day light with open sky background.
- Toxic vapor detection for N_2H_4, MMH, and for HCI:
  - Personal dosimeters capable of measuring TLVs with total accuracy of +25% on 5-minute exposure;
  - Portable survey meters with range of 0 to 10 times TLV with total accuracy of +25% and response time of 30 seconds for 90% of change to new value;
  - Length of stain tubes capable of measuring TLVs with total accuracy of +25% of reading in 30-120 seconds;
  - Continuous area monitors capable of operating 30-60 days without maintenance or adjustment, measuring over range of 0-10 times TLV with total accuracy of +25% of reading, and a response time of 30-60 seconds for 90% of change.

13.02 IMPROVED PROPELLANT HANDLING AT LAUNCH SITES
Center: KSC

Important opportunities exist for innovative concepts to improve the safety and reliability of propellant handling and transfer systems for launch vehicles. These include:

- Protective suits: Innovations in materials and protection concepts are solicited for

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totally encapsulated suits used as the Propellant Handler's Ensemble. These suits, including visor, gloves and boots must be resistant to toxic propellants: hydrazine, monomethylhydrazine, unsymmetrical dimethylhydrazine and nitrogen tetroxide. The protective suits, operating with a liquid air pack are worn for a two-hour on-station duration. Because of wear, material failures, and recycling costs associated with present methods, consideration could be given to the use of throw away suits.

- Ice elimination on cryogenic disconnects: The ability to reconnect a remotely operated, robot controlled umbilical to a flight vehicle after an abort and safely unload cryogenic propellants is directly affected by flashing of frost and ice on the disconnects when the umbilical is separated. Innovative approaches are sought to eliminate frost and ice buildup on the disconnects from the instant of separation. All approaches must include consideration of materials compatibility with liquid oxygen and hydrogen. Electrical approaches which could generate an arc or create enough heat to ignite the propellants can not be tolerated.

- Repair of cryogenic transfer lines: Vacuum jacketed cryogenic transfer lines often develop small leaks in the bellows due to external corrosion. These leaks cause the loss of vacuum insulating properties. Schedule constraints make it impossible to remove the individual pipe sections for repair or replacement of the bellows. Permanent repairs must be done in place. Innovations leading to the development of methods and/or materials to clean the affected area, permanently repair the leaks and prevent re-occurrence of surface corrosion are especially desired. Of specific interest is the development of coatings, materials and/or platings which can be sprayed, brushed or dipped in place.

13.03 LAUNCH AND GROUND WEATHER FORECASTING AND SITUATION MANAGEMENT
Center: KSC

- A weather forecasting technology development program is being conducted at KSC. This solicitation invites new, innovative concepts to improve and enhance that program. Of particular concern are:
  - Triggering of lightning by launch vehicles during ascent: Reliable assessment of the threat to a rising vehicle from disturbed atmospheric electric field conditions require innovations in several areas;
  - Assessing the disturbing effect of the vehicle including exhaust plume;
  - Assessing the charging of the vehicle by triboelectrification;
  - Techniques for remotely and directly sensing electrical characteristics of clouds and the neighboring atmosphere;
  - Correlations between the electrical environment and physical characteristics of clouds, for example: (a) precipitation phase, intensity, distribution (b) type, altitudes of bases and tops, horizontal and vertical extents (c) wind shear (d) transport of charge (e) temporal variations;
  - Measurements of physical variables needed to characterize the triggered flash for design purposes.

- Thunderstorm forecasting: Additional and new techniques are needed to generate a probability of thunderstorm forecasts for windows of 1/2 to 24 hours with a lead time of 1 to 72 hours. An accuracy of 90% is sought. The following are some of the concerns that need to be addressed through new, innovative techniques:
  - Forecasts for specific areas such as work complexes (diameters of 1 to 4 miles) as well as for KSC as a whole;
  - Improved exploitation of existing instrumentation;
  - Instrumentation having greater capabilities.

- Forecasting dispersion of substances: Innovations are needed to provide better forecasting of diffusion, vertical and horizontal transport, and reactions of toxic substances. Specific concerns include improvements in modeling and measuring techniques and means to verify models experimentally.

- Facility lightning protection assessment: KSC handles large volumes of ordnance and explosive materials. Existing design specifications cannot be related to specific lightning protection system performance in many cases. The goal is to develop innovative design methods for facility lightning protection systems that assure specific levels of lightning protection related to actual protected system susceptibilities. Innovation is solicited in the area of facility lightning protection assessment tools. These include:

  - Computer models of the current flow in facility lightning protection systems for determining the electromagnetic environment within the facilities as a function of various protection parameters;
  - Expert systems for use on CAD/CAE systems for design rules checking, and for development of design validation tools;
  - Sensors to measure the electromagnetic field environment within facilities for relating that environment to propellant system susceptibilities such as those of electro-explosive devices (EEDs).

Phase I Proposals must also suggest the means for realistic verification of the practicality of any model, expert system or sensor devices in Phase II or subsequent development activities.

13.04 FLUID SYSTEM COMPONENTS
Center: KSC

Innovative new concepts are solicited in the area of low maintenance, high reliability fluid system components used in liquid, gaseous and cryogenic systems. Phase I proposals not embodying new and innovative conceptual approaches and design concepts will not be considered.

- Helium regulator valves which by innovation in the design of the location, shape or size of the seat, or innovation addressing the seat material, will not be subject to failure from temperature excursions caused by the expanding gas.

- Flexible hoses and expansion joints are required to provide for thermal contraction and line movement in launch servicing cryogenic systems. Innovations such as liners to prevent excessive pressure drop and flow induced vibration caused by the convolutions and bellows are sought.

- Innovative cryogenic valves which, by innovative seals and/or welding techniques will not develop external leakage. Innovative methods to repair or replace welded valves are also sought.

- Liquid air self-contained breathing apparatus KSC is currently using a self-contained breathing apparatus (SCBA) which uses liquid air instead of compressed air. This device contains about 7 liters of liquid air and will last in excess of 3 hours in a resting demand mode. The dewar, however, is not attitude independent. In addition, if the SCBA is filled and not used for a period of time the liquid air becomes oxygen enriched due to the differential boiling of the oxygen and the nitrogen. Therefore, innovations are sought which will lead to the development of a cryogenic unit that can be used in ambient conditions, under water, is attitude independent, meets OSHA and NISOH requirements, and that can be stored with no enrichment in oxygen.

13.05 SHUTTLE LANDING FACILITY BIRD CONTROL
Center: KSC

Bird strikes have always been a serious and costly part of aviation. The Shuttle Landing Facility is located on a National Wildlife Refuge at the Kennedy Space Center. The Orbiter and Shuttle Training Aircraft are particularly vulnerable to bird strikes. KSC has been recently tasked to maintain an aggressive bird control program.

The present methods of bird control have not been particularly effective regarding soaring birds at altitudes above one thousand feet. Innovations leading to the development of new, harmless methods of native bird abatement are sought.

13.06 TEST FACILITY INSTRUMENTATION AND SAFETY DEVICES
Center: JSC

Testing of flight and ground Space components at the NASA White Sands Test Facility requires a number of state-of-the-art devices to monitor test specimens and to provide safety for the test support personnel and facilities. Areas of potential innovation include:

- Contamination Detection: A reliable and traceable method of calibrating commercial airborne particle monitors. Calibration must include accurately verifying the size and number of particles in a flowing fluid stream; a non-contact instrument that can quickly determine the quantity of organic contamination on small metal surfaces, and on surfaces that are not readily accessible, e.g., inside 1/4-inch diameter tubing; a real-time or near real-time method for determining the non-volatile residue or hydrocarbon contamination in Freon 113 after sampling a component for contamination.

- Hydrogen/Oxygen Detection: An innovative system for the detection and concentration measurement of hydrogen and oxygen gas under near vacuum conditions established during rocket engine testing.

- Toxic Propellant Detection: Techniques for the detection of toxic hypergolic propellant (hydrazine, monomethyl hydrazine, ammonia, and nitrogen tetroxide) on the surface of astronaut space suits and equipment in a vacuum.

- Propellant Composition Change Detection: Techniques to detect real-time changes in the chemical composition of propellants (hydrazine, monomethyl hydrazine, and nitrogen tetroxide) during compatibility testing activities. Changes can include increases in the typical propellant impurities, propellant decomposition products, and concentration of dissolved metal ions.

- Liquid Level Sensor: An innovative liquid level sensing probe to remotely measure the level of rocket propellants in a variety of storage and supply tanks.

- High Speed Gas Thermometer: Pneumatic impact initiated ignitions have been the cause of some serious fires in high pressure oxygen systems. Adiabatic compression of the system gas is one possible cause of the high temperatures leading to ignition. A high speed non-intrusive means of measuring the gas temperature is needed.

- Dynamic Pressure Sensor: An innovative technique is required to measure the near-field dynamic pressure in a free blast environment. Blast intensity will be in the range of 10 kg TNT equivalent. Response time should be in the order of a fraction of a microsecond.

- Signal Wire Isolation: An innovative method of sealing a stainless steel conduit containing signal wires to provide system isolation under temperature and pressure extremes in a vacuum chamber is required.

- Rapid Contamination of Personnel Protective Equipment (PPE): Innovative and economical techniques are solicited for rapid decontamination of PPE exposed to hypergolic propellants.

13.07 QUALITY ASSURANCE OF VERY LARGE SCALE INTEGRATED CIRCUITS
Center: JPL

Future spacecraft will use custom integrated circuits extensively in order to increase mission duration and spacecraft autonomy. A highly autonomous spacecraft would require electronics capable of performing complex functions with little assistance from the ground while very large scale integrated circuits would reduce the weight, volume, and power consumption of spacecraft electronics considerably. Such integrated circuits must operate as specified and be tested cost-effectively before launch to assure fault-free operation during the mission. Innovations are sought for assuring the quality and for predicting the reliability of complex digital electronic components such as microprocessors, co-processors, signal processors, and peripheral chips, applications-specific integrated circuits and others. Areas of innovation solicited include:

- Novel approaches for collecting meaningful data about a particular fabrication process in order to assess the quality and to predict the reliability of integrated circuits fabricated with that process. Identify the failure modes that might exist in the fabrication process and determine the appropriate testing methods for detecting them.

- New methods for test generation and fault simulation of modern microprocessor, coprocessor, and peripheral chips. The proposed methods must take into consideration the difficulty of modeling large digital structures and the computation time required for test generation and fault simulation.

- New logic design for testability and built-in self-test concept that facilitate test generation, faults simulation, and testing of very large scale integrated circuits. The new concepts should have a minimal impact on the performance and on the die area of the chip.

- New methods for functional verification of complex application-specific integrated circuits. These methods should ensure that a particular integrated circuit performs a specified function.

- Novel approaches for predicting the reliability of complex very large scale integrated circuits. These proposed approaches should consider the cost of destructive analysis, visual inspection, and other labor intensive activities.

14.00 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS

14.01 COMMUNICATIONS FOR MANNED SPACE SYSTEMS
Center: JSC

Both external and internal communications subsystems in manned space systems are complex from the standpoint of great variety of services (voice, commands, telemetry, video, text, graphics, etc.) and require a large number of interactive links. Multiple, simultaneous links will be required to communicate among the variety of elements within the STS and Space Station including satellites and extravehicular astronauts. Internal communications must accommodate increasing crew sizes, and management and control of the communications systems must be highly automated. These complexities demand new, innovative approaches to increase efficiency, capability, reliability and maximum utility. Many areas of significant innovative potential would include the following:

- Advanced multiple beam antennas with near-hemispherical coverage and communications systems at Ku-, Ka-, and W-bands for supporting simultaneous multiaccess users. Omni-directional low power, lightweight antennas with detection/switching schemes are needed.

- Personal communications systems for Space Station are needed. Multiple users, user access and remote controls, distributed antenna system, and portable data terminals are some key features for advanced systems implementations.

- Crew communications: Multiple-access wireless communications systems are required to allow simultaneous communication with no restriction on individual orientation within a single enclosure and between various enclosures of the spacecraft. Systems for enclosure to EVA astronauts are also required. Equipment worn by the crewmen must be small and lightweight to avoid interference with crew activities. Electronic noise cancellation is desired.

- Solid-state text and graphics: A device consisting of at least 4,000 individual light sources capable of illuminating corresponding points along a horizontal scan line.

- Communication system modeling and simulation: Generalized mathematical models and integrated software packages to allow simulation and evaluation of the performance of candidate communications systems. Should allow trade-offs of bit error rates, jamming environments, power requirements, complexity, and cost, and employ expert system and artificial intelligence.

- Video systems for robotics and automation: Small size, lightweight, digital, solid-state imaging, display, and processing systems. High definition for large scenes, high greyscale resolution, data compression of higher order with quality imagery.

- Automated Monitoring and Management of Communications Resources: Approaches for managing system scheduling, monitoring, fault diagnosis and fault recovery to satisfy real-time communications requirements for Space Station. Techniques for distributing expert systems on multiple processors; development of distributed real-time dynamic data base techniques; techniques for efficiently porting expert systems code in non-procedural languages to traditional computer architectures using C or ADA.

- Space-to-space laser communications systems for long range (LEO-GEO) and close proximity high data rate operations.

- Communications systems for telerobotic devices: Must simultaneously provide multiple channels of high quality video, high rate data, and command/control signals with a minimum two-way time delay control from earth orbit or ground.

14.02 ADVANCED DATA RELAY SATELLITE SYSTEMS
Center: GSFC

NASA's next generation data relay satellites require capabilities which exceed those currently achievable. Laser transmitter and receiver technology is required which will permit data transfer from low Earth orbit to Geosynchronous orbit with rates exceeding 300 MBits/sec, and communications across the geosynchronous arc at rates of 2 Gbits/ sec or greater. Innovations are required in several areas:

- Laser diode-pumped ND:YAG ring lasers could be attractive transmitters for coherent communications between satellite due to their small size, high efficiency, and very narrow line-widths. However, small lightweight external modulators are required which can impress either phase or amplitude modulation on the laser output at rates approaching 2 GBits/sec.

- Innovations in modulator design are required to minimize their required electrical drive voltage, to extend their modulation bandwidth, to improve their optical transmission, and to extend their modulation bandwidth, to improve their optical transmission, and to extend their optical power handling capability.

- Innovative approaches are required to control, tune and lock the center frequency of the ND:YAG ring oscillator laser to an external RF electrical standard. Long term stability of 2 KHz and a tuning range of over 1 GHz are required. The frequency response of the tuning circuit should exceed 10 KHz.

- Innovations are needed in the application of advanced signal processing techniques to increase the performance of the RF communication links between NASA's Tracking and Data Relay Satellite System (TDRSS) and TDRSS user spacecraft. It is desirable to significantly reduce the space and ground receive system threshold. It is also desirable to mitigate undesirable interference (pulsed and/or CW) on the space-to-space link which may be present in the data signal bandwidth or the communications channel bandwidth.

14.03 MILLIMETER WAVE DEEP SPACE COMMUNICATIONS SYSTEMS
Center: JPL

Increasingly sophisticated scientific instrumentation aboard advanced deep space missions have generated a demand for the transmission of greater data rates to earth. Most deep space missions operate near 8 GHz but these data rate demands may be more economically met by utilizing the 32 GHz downlink and 34 GHz uplink frequency bands allocated by the FCC. The development of innovative space qualifiable millimeter wave components and subsystems is needed to implement communications systems utilizing these bands.

Innovations are solicited for new innovative techniques for MMIC phased array distributions systems for millimeter wave, digital control and power signals and thermal control; millimeter wave integrated circuit hermetically sealed packaging; high efficiency solid state microwave discrete and monolithic integrated circuit transmitter components and subsystems; millimeter wave transponder components and subsystems; computer aided design tools for these systems; and array beam control and signal distribution system technology for phased arrays. For example:

- Innovative methods for distribution of millimeter wave and digital signals and dc power in phased array systems. Particular interest exists in MMIC phased locked oscillators referenced to optical signals modulated at microwave frequencies and transmitted through optical fibers. Optically transmitted digital data techniques for control of MMIC phase shifter and variable gain amplifiers are also of interest. These systems are required to be compact in size, have low mass and be power efficient.

- Repeatable, well characterized hermetically sealed packages for microwave integrated circuits at 32 GHz. These packages must be capable of being interfaced with microstrip or co-planar waveguide transmission line at 32 GHz as well as with power and digital control circuitry. Heat sinking and thermal expansion control over -55°C to +70°C in a vacuum environment is also required.

14.04 SPACECRAFT TRANSPONDER ELECTRONICS
Center: JPL

Innovations in transponder electronics for spacecraft operating in deep space missions will be required in the future. This subtopic solicits new concepts to enable such advances to be achieved. While the following technical requirements do not constitute specifications, they represent the kinds of improvements needed through innovations.

- Receiver monolithic microwave integrated circuit (MMIC) chip set designs:

  Advanced GaAs MMIC concepts that employ narrow band double conversion, coherent phase lock receivers. MMIC designs capable of high image rejection, coherent automatic gain control (AGC) function, high stability phase gain characteristics, and integrated phase lock loop (PLL) capability to phase lock coherent first and second local oscillators. The MMIC design should provide the capability to introduce a MMIC dielectric resonator oscillator as first local oscillator and a surface acoustic wave resonator oscillator as a second local oscillator in the corresponding PLL circuits for low phase noise receiver applications.

  Phase shift as a function of uplink signal variations must be minimal, including phase shift of the limiter channel used for the narrow band phase lock loop. Typical performance requirements are: input frequency 7.1 to 7.3 GHz; output frequency 50 to 200 MHz; noise figure 2.0 dB; input signal level range -156 to -70 dBm; AGC gain reduction 90 dB; PLL threshold bandwidth (2 BLO) of 20 Hz; reference oscillator frequency range 38 MHz to 39 MHz; temperature range -20°C to +75°C; and overall phase delay variation less than 3 nanoseconds.

- Numerically controlled oscillators (NCO):

  Innovative advanced CMOS and GaAs LSI IC concepts are required for implementation of low phase noise numerically controlled oscillators for advanced spacecraft communication, space based radar, and instrumentation applications. The NCO designs must provide low power operation, ultra-high frequency resolution, extremely low spurious signal levels, high frequency operation, and fast switching capability. Typical performance requirements are: frequency up to

1 GHz; frequency resolution 1 to 10 Hz, depending on clock; all spurious signal levels < -80 dBc; SSB phase noise of NCO synthesizer < -125 dBc/Hz at 1 KHz offset from carrier; switching speed < 150 ns.

14.05 ADVANCED SATELLITE COMMUNICATIONS SYSTEMS
Center: LeRC

Advanced concepts are required for devices, components, subsystems that support advanced civil applications. Applications at all allocated frequencies are of interest but with particular emphasis at Ka band and above, although many concepts may be frequency independent. Implementations using electronic technologies are being sought for near-term applications. Research in photonic technologies is desired for applications in the longer term (2000 and beyond). Innovative approaches are desired in the following areas:

- Concepts for components (solid state or free electron) and subsystems (frequency sources, receivers, amplifiers, mixers, combiners, power dividers, transmitters, etc.) which stress improvements in bandwidth, power, efficiency, noise figure, gain, reliability, or cost, as well as higher frequency performance, miniaturization, and improved circuit and packaging techniques.

- Flexible, fault tolerant, high speed, onboard data, packet or message switching/routing systems, including network control, at baseband or optical frequencies to meet the throughput and interconnectivity needs of efficient high and low-data-rate FDMA and TDMA communications networks. Important factors to consider are implementation complexity, reliability, size, weight, and power.

- Novel electronic or optical implementation of power and bandwidth efficient modems with 650 MBPS or 1.3 GBPS throughput for on-board data processing applications.

- Novel digital processing concepts and components that enable simultaneous multiple FDMA channel demodulation and all coding with a single device.

- Cost-reducing concepts and components for low-data-rate FDMA uplink, TDM downlink ground terminal digital systems for acquisition, synchronization, self test and fault tolerance, reliability, and terrestrial interface with CCDS and ISDN compatibility.

- Novel applications and implementation techniques for artificial intelligence and knowledge based systems technology to onboard and/or ground station autonomy and fault tolerance.

- Novel approaches for wide angle (up to hemispherical) scanning at Ka band using the large number of degrees of freedom inherent in arrays/array feeds with MMIC devices; concepts for systems or for critical elements of complete systems.

- Techniques for electrical control and thermal dissipation associated with large phased array antennas; research in optical and photonic technologies for transmitting signal and/or control information to the MMIC devices as well as packaging and assembly techniques for adequate thermal dissipation and control.

- New and improved devices for any of the above applications, incorporating high temperature superconductor technology.

14.06 OPTICAL COMMUNICATIONS FOR DEEP SPACE
Center: JPL

Deep space exploration spacecraft of the future will use optical frequencies to communicate back to near-Earth orbit or possibly directly to the ground. Numerous innovations will be required to facilitate these new systems.

- Due to the long propagation distances and stringent spacecraft power limitations, the signal intensities will be very small at the Earth. Innovative concepts are needed for developing lasers which have high power conversion efficiency (approximately 10%), produce single and stable far field beam profiles, and which can be easily modulated using a pulse position modulation format with high peak pulse energies (0.1mJ). CW laser sources are also needed for heterodyne systems which produce very stable output frequencies, as are design approaches and concept verifications for coherent optical transponder functions.

- The narrow beamwidths require accurate pointing and focal plane detector arrays which have the ability to provide pointing information electronically, but the readout rates of the arrays may limit the overall spatial tracking bandwidth. Therefore, innovations leading to a high gain, focal plane detector array with electronically controlled cursor readout would be very beneficial. A KHz readout rate (with single or multiple pixel readout), a gain of one million, and a responsiveness better than an S-20 photocathode are desired.

- For detection of such optical signals, large-aperture (greater than 5 meters in diameter), inexpensive, non-diffraction limited optical reception telescopes for use on the ground or in space will be required. Reception wavelengths for those "photon buckets" are in the 0.5 to 1.2 micron region. Concepts and design verifications are also sought for using such telescopes at small angles off the solar limb (i.e., at small Sun-Earth-spacecraft angles).

14.07 LOW COST KA-BAND GROUND TERMINALS
Center: LeRC

The Advanced Communications Technology Satellite (ACTS) currently under development is an experimental satellite that uses time division multiple accessing (TDMA) together with onboard switching and multiple narrow hopping beam antennas to route communications traffic among a network of small user Earth stations. The master control facilities necessary to manage a network of Earth stations are also currently under development. Innovations are needed to develop low cost, transmit/receive experimenter terminals to function with this satellite. These terminals will initially not need to address the TDMA aspects of the ACTS system but will operate with burst modems and controllers through an IF interface.

Innovative new concepts to achieve these objectives are solicited, with particular reference to the following areas and devices. Offerors are advised not to submit proposals which suggest design or development based on well-known or conventional devices which could be obtained through normal specification procurements.

- 30 GHz transmitters in the 10w to 20w range.
- 2.5 m diameter antennas.
- Upconverters (IF to 30 GHz).
- Downconverters (20 GHz to IF).
- Low noise receivers at 20 GHz.
- IF interface to burst modems at burst rates of 27.5 and 110 Mbps.
- Beacon receivers at 20 GHz for propagation measurements.

15.00 MATERIALS PROCESSING, MICRO-GRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE

15.01 MATERIALS PROCESSING IN SPACE
Center: MSFC
Center: LeRC

Opportunities for commercial processing of materials will exist in the low gravity of space. Some of the areas of opportunity, and in which research innovations are sought, are listed below:

- Materials
  - Electronic Materials: Improved materials for semiconductors and solid-state detectors of high purity, volume, or high intrinsic value for use in electronics, computers, communications, and medical instrumentation;

- Metallic Alloys: New alloys made from immiscible components, improved grain structures for alloys of miscible components, directional solidification, and process involving supercooling and rapid solidification from an undercooled state;
- Glasses and Ceramics: Containerless processing of glasses to eliminate crucible-derived impurities, give better control of nucleation sites, and provide the possibility for dealing with highly reactive melts. Improved optical fibers may result from surface tension forming from melts in a containerless process;
- Biological Materials: Processes for obtaining specific cell types, cell components, hormones, antigens, proteins, and other organic and crystalline substances with greater purity and throughput. Continuous electrophoresis and isoelectric focusing are two separation methods that benefit from the micro-g environment. In addition, the crystallization of proteins in order to determine structure and other properties is a topic of considerable interest;
- Electro-optical Materials: Processes for obtaining materials for electro-optical applications, particularly in the emerging new field of photonics. Both organic and inorganic materials are of interest.

• Technological Phenomena and Techniques

  - Fluid dynamic phenomena are involved in a wide range of technologically important processes that are affected by weightlessness. Multi-phase flows in a complex regime of thermal and solute gradients are altered by the weightlessness conditions of space. These alterations are applicable to a range of R&T such as crystallization processes, separation processes, phase change phenomena, solidification mechanics, solute-solvent processes, glass processes, etc. Innovation leading to improved understanding for thermodynamic and fluid processes in weightlessness will lead to greater exploitation of materials processing in space;
  - Processing Techniques necessary in the technology and scale-up of specific devices and processes include, for example, acoustic, electromagnetic and electrostatic levitation devices; continuous-flow electrophoresis; isoelectric focusing; cell culture and deposition; furnaces of all types; combustion processes; isotachophoresis; and surface tension manipulation. Approaches to developing new processes, instrumentation and control procedures, and characterization of materials are essential enabling activities.

• Apparatus and equipment, including containerless melting, solidification and fiber-pulling devices, heat-pipe furnaces for directional solidification, efficient furnaces for float zone growth and high temperature containers that can withstand large temperature differentials (greater than 500°C).

15.02 MICROGRAVITY SCIENCE, TECHNOLOGY AND ENGINEERING EXPERIMENTS
Center: LeRC

Definition and development of in-space experiments: Innovations leading to the definition and development of in-space experiments and the development of basic, core equipment and facilities required for quality space laboratory experimentation are solicited, for the study of microgravity processes/phenomena and the definition of space flight experiments using unique government research facilities which are available at the Lewis Research Center, Cleveland, Ohio. These facilities include several which provide varying degrees and times of simulated microgravity conditions and the Microgravity Materials Science Laboratory (MMSL). MMSL provides easy access and assistance to scientists and engineers from industry and universities wishing to conduct material research using Shuttle flight-type experimental equipment.

Of particular interest are proposals emphasizing innovative commercial applications. Areas of interest in microgravity science and applications are fluid and transport phenomena, combustion, metals and alloys, glasses and ceramics, polymers and electronic materials. Research, technology, and engineering areas include energy conversion and space power systems, fluid and thermal management systems, space environmental effects, and spacecraft fire safety. New concepts in basic laboratory equipment and practices range from fundamental diagnostic and property measurement techniques, data recording and storage to sample preparation and waste product disposal systems.

Space Station United States laboratory module experiments: During the definition and preliminary design phase of the Space Station Freedom, NASA has defined the functional characteristics of a range of microgravity experiment facilities to be accommodated by the pressurized United States Laboratory (USL) module. The requirements for these user-provided facilities are based on extensive discussions with current and potential users of microgravity facilities.

The microgravity experiment facilities of interest to LeRC are those needed to perform experiments in the Space Station USL module in the microgravity science and applications disciplines of metals and alloys, electronic materials, glasses and ceramics, combustion science, polymers and fluid and transport phenomena. General technology areas where innovative advancements are needed to enable or enhance development of these facilities include instrumentation and sensors, unique mechanical devices, high-temperature materials, automation/process control, non-intrusive diagnostics and acceleration/vibration environment control.

15.03 CHEMICAL VAPOR DEPOSITION ANALYSIS AND MODELLING TOOLS
Center: LaRC

Chemical vapor deposition is one of the key technologies of the electronics industry. To foster development, it is essential that predictive models be developed to compare the results of early microgravity testing with scientific theory and ground-based empiricism. Prediction of the fundamental fluid flow and reaction phenomena taking place under varying gravity fields requires innovations in computational methodology. This subtopic seeks innovative development of a general-purpose fluid flow simulation program that predicts in three spatial dimensions the mass, temperature, momentum, energy, and chemical species distributions during the chemical vapor deposition of electronic materials and presents the results in both tabular and graphical formats. Innovations are especially critical in the treatment of compressible fluids in high thermal gradients, of soot formation and growth in the fluid, and of time-varying reactor movement due to large-scale low-frequency vibrations.

15.04 COMMERCIAL OPPORTUNITIES IN SPACE POWER GENERATION, PROPULSION AND RELATED TECHNOLOGIES
Center: LeRC

While much of the early emphasis on commercial uses of space has focused on use of the microgravity environment, commercial opportunities may also exist in other areas. Three disciplines, power generation, energy storage and space propulsion, are regarded as being key to the exploration and exploitation of space. Innovations are therefore being sought in the following areas:

- Unique approaches to the generation, management, distribution, storage and transmission of electric power in space which, if successful, would create new commercial opportunities. The commercial potential of the proposed innovations may be the development, production and sale advanced equipment; licensing of the related technologies to give American aerospace companies competitive advantages in world markets; and the generation and sale of power produced by these new technologies to in-space users.

- Unique approaches to providing primary and auxiliary propulsion for spacecraft which have commercial potential as generally described above.

- New concepts for disciplines which support space power generation, energy storage and space propulsion. These include, but are not limited to, the storage and handling of reactants or propellants (including cryogens), thermal control systems, instrumentation and controls, servicing, repair and resupply, etc.

15.05 ACOUSTIC SIGNATURES OF FAILURE MODES IN STRESSED SPACECRAFT COMPONENTS
Center: MSFC

Spacecraft, from communication satellites to the Shuttle and the planned Space Station, constantly undergo cyclic stress. Where operations vary markedly, where personnel are involved, mechanical vibration signatures provide a detailed fingerprint of a component, sub-assembly, even a system. As one of those units ages, its characteristic acoustic signature will change. The concept is well understood but its application as a real-time diagnostic in the space environment has not been developed. Distinct classes of components are stressed in different ways, e.g., structural and electrical. Because the ability to interpret characteristic changes to predict incipient failure in each type of component would markedly reduce catastrophic space system failure risks, the importance of such capabilities to NASA is very great.

Major areas of concern are electrical power systems, basic structures and mechanical components. Electrical power systems for future space operations will be at power levels and power conditioning far in excess of current space experience and knowledge; and advanced lightweight structures with increased dynamic loading increases the potential for structural failure, particularly with any advanced concept systems on-board having moving parts.

This subtopic solicits new, innovative concepts and techniques for obtaining failure mode frequency characterization of electrical and mechanical components with predictive ability to provide early warning of critical condition on-set. In establishing the feasibility of such innovations, Phase I proposals must also indicate realistic continuations NASA may wish to support during Phase II with emphasis on ultimate operational suitability. Suitable concepts should preferably involve minimal overall complexity, maintenance and memory requirements, while possessing means for validation of accurate and reliable characteristics.

15.06 SELF-HEALING INSULATION FOR SPACE-EXPOSED POWER TRANSMISSION LINES
Center: MSFC

Power transmission lines for space applications may be coaxial (for shielding) or in bus configurations for ease of attachment (particularly for dc). Where such lines are external to a space structure, they are subjected to the space plasma and potential damage to insulating surfaces, to space dust, and micrometeorite debris. Puncture of the insulation may lead to electrical failure and power drain, and may also result in long-term material degradation and other hazards due to the exposed conductor.

Importance to NASA: Power lines external to space structures cannot easily be repaired. External activities (EVA) by astronauts for repair and maintenance must be minimized. Multiple redundancy is generally required, thus increasing system weight; alternatives to avoid these problems are needed.

This subtopic solicits innovative new concepts for power transmission line insulation which self-heals upon electrical or mechanical penetration in rigorous space environments. Phase I proposals must establish the basic feasibility of such innovations and suggest means by which NASA could further develop and validate their utility and effectiveness under realistic conditions during any Phase II continuation.

APPENDIX E
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
89-1 SBIR SOLICITATION
PROPOSAL CHECK LIST

NASA SBIR 89-1

Company: ________________________________

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Proposal Number: ________________________________

Proposal Title: ________________________________

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CHECK

___ 1. Offeror has read this Solicitation and understands that proposals not meeting all requirements may be nonresponsive and may be returned without consideration.

___ 2. Proposal and innovation is submitted to only one Subtopic (see Sect. 5.14-d).

___ 3. All information specified in Sect. 3.3 is included in order.

___ 4. Any proprietary information, if included, is contained in a Proprietary Addendum with required Notice (see Sect. 5.4-a).

___ 5. Certifications and Signatures on Appendices A and C.

___ 6. Period of technical performance does not exceed 6 months and funding request does not exceed $50,000.

___ 7. Proposal (including any supplementary material and/or Proprietary Addendum) contains no more than 25 - 8½ x 11 inch pages. Check list is not included in page count.

___ 8. Proposed innovation is clearly identified in Part D-1 of the proposal.

___ 9. Phase II continuation, potential commercial applications and Phase III approach are discussed.

___ 10. Proposal package includes:
   a. Five (5) copies of Proposal
   b. Original Cover Sheet and Proposal Summary (red forms, Appendices A and B) clipped (not stapled) to Check List.

___ 11. Offeror understands that proposals must be received in NASA Headquarters by 4 p.m. EDT June 28, 1989.

*U.S. G.P.O. 1989- 622-304S