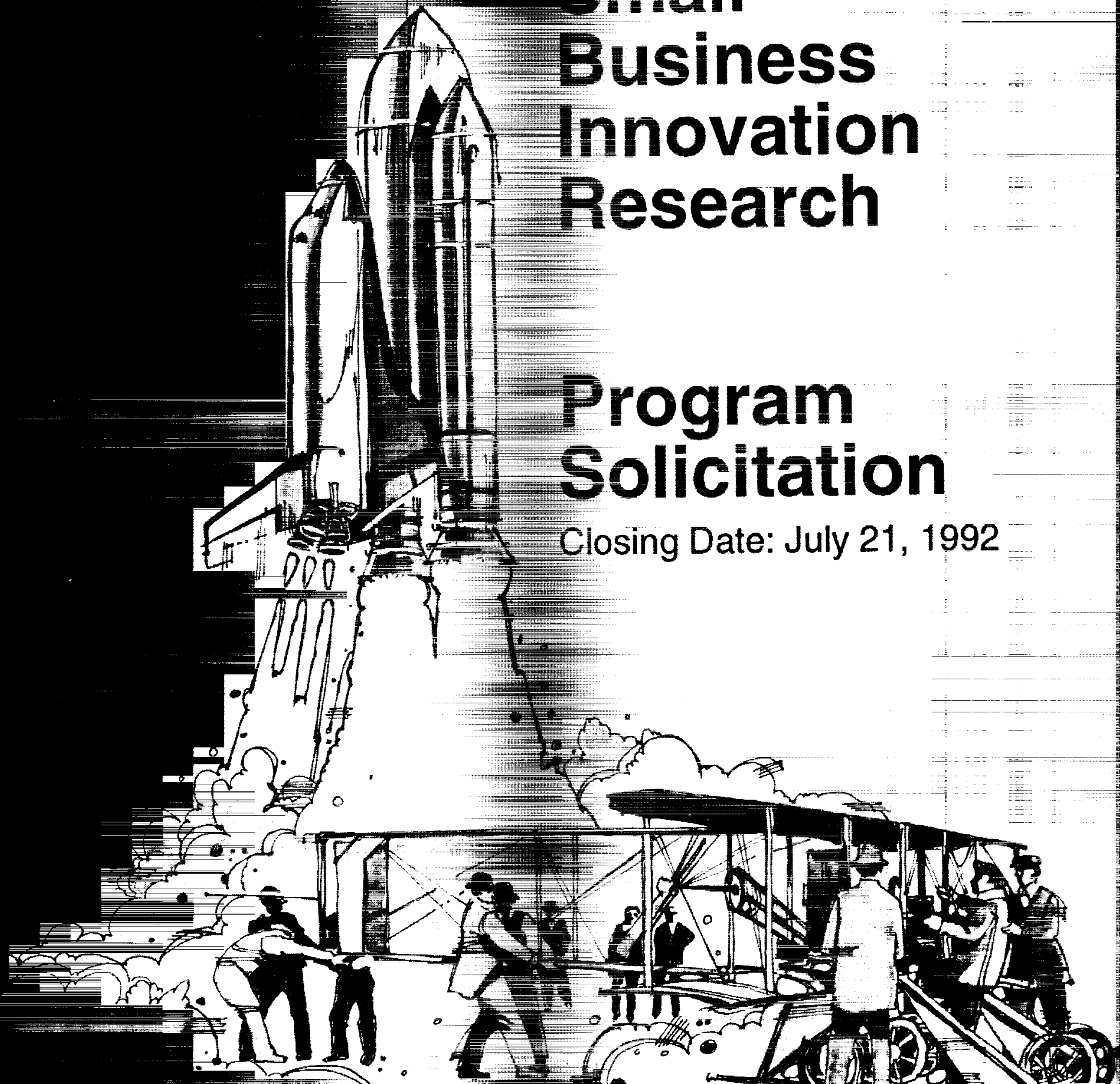
SBIR 92-1

Small Business Innovation Research

Program Solicitation

Closing Date: July 21, 1992



NASA

National Aeronautics and Space Administration
Washington, DC 20546

(NASA-TM-107795) SMALL BUSINESS INNOVATION RESEARCH PROGRAM SOLICITATION. CLOSING DATE: JULY 21, 1992 (NASA) 116 p

N92-31253

Unclas

G3/81 0089771

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 surrounding, 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 environments, and safer.

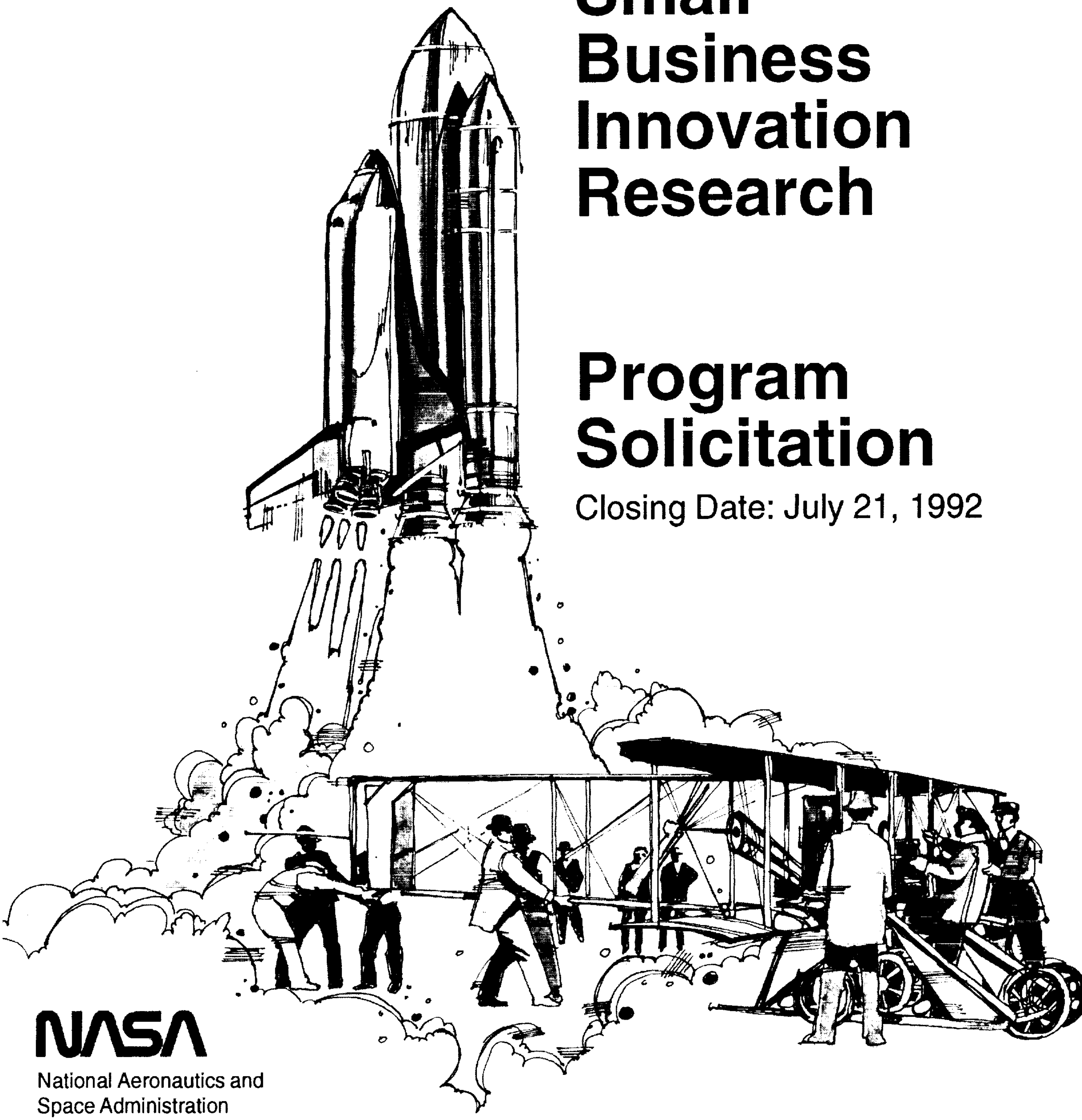
89771

SBIR 92-1

Small Business Innovation Research

Program Solicitation

Closing Date: July 21, 1992



NASA

National Aeronautics and
Space Administration
Washington, DC 20546

Warnings to Offerors

1. Proposals must meet Solicitation requirements.

Please read this Solicitation carefully before developing a Phase I proposal. Verify that each proposal conforms to the requirements specified herein, especially those emphasized with boldface type. Certain requirements and subtopics in the NASA 1992 Solicitation differ from those in previous years. Proposals that do not meet all of the requirements of this Solicitation may not be responsive and may not be evaluated. A check list of important requirements is provided as Form 9.D.

2. SBIR Solicitation requirements vary among Federal agencies.

Proposals prepared for other agencies should not be submitted to NASA unless they conform with this entire Solicitation.

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

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

4. There are constraints on submitting proprietary information.

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. Emphasis is placed on Phase III potential.

"Increasing private sector commercialization of innovations derived from Federal research and development" is one of the objectives of the SBIR legislation. NASA requires SBIR offerors to indicate whether or how their proposed project results may lead directly or indirectly to commercial applications and their plans to pursue such applications. This information is taken into consideration during proposal evaluations and selections for award negotiations.

Contents of NASA SBIR 92-1 Program Solicitation

NASA

Small Business Innovation Research

1992 Program Solicitation

1.0 Program Description

1.1 Summary

The National Aeronautics and Space Administration (NASA) invites small businesses to submit Phase I proposals in response to its Small Business Innovation Research (SBIR) Program Solicitation 92-1. Firms with research or research and development capabilities (R/R&D) in science or engineering in any of the areas listed are encouraged to participate.

This, the tenth 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, the technical topics and subtopics in which SBIR Phase I proposals are solicited in 1992. 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. The NASA SBIR program seeks innovative approaches that respond to the needs, technical requirements, and new opportunities described in the subtopics. The focus is on innovation through use of emerging technologies, novel applications of existing technologies, exploitation of scientific breakthroughs, or new capabilities or major improvements to existing technologies.

NASA plans to select about 320 high-quality research or research and development proposals for Phase I contract awards on the basis of this Solicitation. Phase I contracts are normally six months in duration and funded up to $50,000, including profit. Selections will be based on the competitive merits of the offers and on NASA needs and priorities.

NASA anticipates that approximately 50 percent of the Phase I projects--those deemed to have greatest value to NASA--will be selected competitively for further development under Phase II. 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

1.2.1 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. The current revision became effective on June 28, 1988.

1.2.2 Objectives. SBIR program objectives established by law 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.

1.2.3 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.

1.2.4 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 NASA funds.

1.3 Three-Phase SBIR Program

1.3.1 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, but all must be directed toward development of products, processes, or techniques for NASA's use. Projects should also have direct or indirect commercial applications in Phase III. Unsolicited proposals and those not responsive to a subtopic are not eligible for consideration in the SBIR program.

To reduce the time and cost for to prepare a responsive proposal under this Solicitation, the entire Phase I proposal is limited to twenty-five 8½ x 11 inch pages, including all forms and any attachments or enclosures.

The Phase I proposal must concentrate on means to establish the scientific or technical feasibility of the proposed innovation to justify further NASA support in Phase II. It must conform to the format described in Section 3 of this Solicitation. Evaluation and selection criteria, which are described in Section 4.1, emphasize technical merit and innovativeness, value to NASA and to the economy, the ability of the offeror to conduct the research, and NASA priorities. NASA alone is responsible for these determinations.

Phase I funding agreements with NASA are fixed-price contracts. Simplified contract documentation is employed. NASA funding for Phase I is limited to $50,000.

Successful offerors will have up to six months to complete their Phase I research and submit their Phase I final reports.

1.3.2 Phase II. Phase II is the principal research effort in SBIR. Its objective is development of innovations shown feasible in Phase I. Projects selected for Phase II are those that have the highest potential value to NASA and that may also have subsequent commercial value to the U.S. economy. It is planned that in 1993 approximately half the Phase I projects resulting from this Solicitation will be selected for Phase II. Phase II projects may be funded for as much as $500,000 with periods of performance not usually exceeding 24 months.

Competition for Phase II continuations is limited to Phase I contractors who complete Phase I projects and who meet all SBIR eligibility requirements.

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 Installations during Phase I. Phase I contractors competing for Phase II must meet the Phase II proposal schedule provided by the NASA Installation requesting Phase II proposals.

Selection criteria for Phase II awards are similar to those for Phase I. In addition, they 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 reasonableness. Selections also depend on NASA program priorities and availability of funds. These criteria are described in detail in Section 4.2.2 of this Solicitation.

Among Phase II proposals determined to be suitable for award and to have essentially equal merit, NASA will give special consideration, i.e., selection priority, to those that have obtained valid non-Federal funding commitments for Phase III activities.

1.3.3 Phase III. Phase III of SBIR consists of (1) the privately financed pursuit of commercial applications of the results of SBIR projects, or (2) continued Federal Government support of the research or acquisition of end products for government use, or a combination of (1) and (2). SBIR set-aside funds will not be used to support Phase III activities. Offerors are encouraged to seek non-Federal funding commitments (see Solicitation Section 4.2.3) and to secure them prior to NASA's completion of Phase II proposal evaluations since such commitments can be a discriminator in Phase II selections. Further information on Phase III commitments will be provided to those selected for Phase I awards.

1.4 Eligibility To Participate in SBIR

1.4.1 Small Business. Only firms qualifying as small businesses as defined in Section 2.2 of this Solicitation are eligible to participate in the SBIR program. SBIR eligibility does not require that the offeror qualify as a minority and disadvantaged small business (see Section 2.3) or as a women-owned small business (see Section 2.4).

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

1.4.3 Principal Investigator. The Principal Investigator (PI) is presumed to be key to the success of an SBIR project. The PI must have the technical competence and authority to plan and guide the proposed research and must make a substantial contribution to the project as indicated by the time and effort identified for the PI in the proposal. Co-Principal Investigators are not acceptable, and substitution of a 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 research. Primary employment with the small business requires a minimum of 20 hours per week (average), and it precludes full-time employment with any other organization or full-time student status in an academic institution.

The offeror must state that the primary employment of the proposed PI will be with the small business during the conduct of the SBIR contract and explain the anticipated eligibility of a proposed PI who, at the time the proposal is submitted, has primary employment other than with the offeror. If eligibility is not clear, NASA may require additional information from the offeror. Should appropriate information not be provided, the proposal will not be considered for selection. A similar certification will apply to Phase II Principal Investigators.

A person employed in any capacity by an academic institution can be a Principal Investigator if, during SBIR contract periods, the PI limits obligatory activities of all types with that institution to less than half the number of hours per week required of and provided by the PI under the normal full-time employment agreement with the institution. In no case will the reduced activities exceed 20 hours per week. The offeror must provide a certification from the academic institution that primary employment of the PI with the small business during SBIR contract periods is acceptable to it and that is approves the required reduction of workload and schedule for the PI during such periods.

1.4.4 Eligibility Clarification. Any questions regarding eligibility to participate in the SBIR program that are not covered by this solicitation should be addressed to:

U.S. Small Business Administration
Office of Innovation, Research and Technology
409 Third Street SW, 6th Floor
Washington, DC 20416
Tel: 202-205-6450

1.5 General Information

1.5.1 General Information About the SBIR Program. Requests for general information about the NASA SBIR program should be addressed to the SBIR Program Office **in writing:**

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

A **NASA SBIR bulletin board** will provide the opportunity to read announcements, explore information on recent awards, and leave messages and requests. The bulletin board may be reached by calling either 703-271-5673 or 703-271-5674.

Inquiries may also be made through the **NASA SBIR facsimile machine.** The telephone number is 703-271-5566. Inquiries must include the name and telephone number of the person to contact, the organization name and address, and the specific questions or requests.

Telephone inquiries may also be made using the **NASA SBIR telephone inquiry number, 703-271-5672,** which will record them for attention by the SBIR office. Inquiries must include the name and telephone number of the person to contact, organization name and address, date and time of inquiry, and the specific questions or requests.

1.5.2 Questions About This Solicitation. To ensure fairness, questions relating to the intent and content of subtopics and for advice on proposal writing can not be answered during the Phase I solicitation period ending July 21, 1992. Only questions requesting clarification of solicitation instructions, supporting information, or administrative matters will be answered.

1.5.3 Questions Regarding Proposal Status. Evaluation and selection of proposals for negotiation leading to contract award will require about three months. No information about proposals status will be available until final selections are announced except for the postcards mailed by NASA to confirm the receipt of proposals, as noted in Section 6.5 of this Solicitation.

1.5.4 Additional copies of this Solicitation or of Forms 9.A and 9.B may be ordered by writing the SBIR Program Office, using the bulletin board, sending a fax, or by leaving a recorded request at the telephone inquiry number. See Section 1.5.1 for information on how to do this.

1.5.5 Technical Background Information. The subtopic descriptions in Section 8 of this Solicitation include references to documents describing the background and status of the technology areas of interest. Section 7 lists sources of many of these references.

A variety of organizations, some of which are listed in this Solicitation, offer assistance to firms preparing SBIR proposals. Although the NASA SBIR Program Office has identified such resources, it cannot accept responsibility for their interpretations of the intent or content of the subtopics and the requirements set forth in this Solicitation, or for proposal assistance they may provide to offerors.

1.6 Technical Topics and Subtopics

1.6.1 NASA SBIR Topics. The range of technologies relevant to the NASA program is broad. The fifteen technical topics described in Section 8 of this Solicitation follow.

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

Each of these topics is divided into subtopics that may vary from year to year. Subtopics are developed by project managers and researchers at all NASA Installations and reflect the Installations' needs and priorities. All subtopics are candidates for the selection of Phase I projects and there is no quota for selection in any subtopic.

1.6.2 Multiple Proposal Submissions. An offeror may submit any number of proposals to any number of subtopics, but **every proposal submitted must be unique, must be limited in scope to just one subtopic, and may be submitted under only one subtopic.** Should an innovation have relevance to more than one subtopic, the offeror must make the choice of a single subtopic under which to submit it because **neither an identical nor a substantially similar proposal based on the same innovation may be submitted under more than one subtopic.**

Offerors should be aware that any identical or substantially similar proposals submitted in response to this Solicitation will not be evaluated.

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 new materials, devices, systems, or methods, including the design, development, and improvement of those in existence in order to meet specific requirements.

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

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

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

- Has, including its affiliates, a number of employees not exceeding 500 and meets the other regulatory requirements found in 13 CFR Part 121. Business concerns, other than investment companies licensed or state development companies qualifying under the Small Business Investment Act of 1958, 15 U.S.C. 661, et seq., are affiliates of one another when, either directly or indirectly, (1) one concern controls or has the power to control the other or (2) a third party controls or has the power to control both. Control can be exercised through common ownership, common management, and contractual relationships. The term "affiliates" is defined in greater detail in 13 CFR 121.3(a). The term "number of employees" is 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 Concern: 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: African 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. In this context to "control" means to exercise the power to make policy decisions; to "operate" means to be 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 3.5 Part 9 and 5.12 of this Solicitation.

2.7 Innovation Research: R/R&D on an innovation. Innovation in the context of the NASA SBIR program includes, but is not limited to, invention. Innovation encompasses new, original, and imaginative approaches to the solution of new and old problems; 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 activities that do not require innovation as defined above are not acceptable in the SBIR program.

3.0 Phase I Proposal Content and Preparation

3.1 Proposal Objectives and Considerations

The purpose of an SBIR Phase I proposal is to provide sufficient information to persuade NASA that the proposed work represents a sound approach to investigating the feasibility of a valuable scientific or engineering innovation that is responsive to a Solicitation subtopic. A proposal should be self-contained and written with the care and thoroughness accorded papers for publication. Important considerations include the following.

3.1.1 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. **Each project must develop specific end products or results** for delivery at the conclusion of the Phase II project. These may include data, hardware, or software programs, but in every case a final report is required.

3.1.2 Scientific or technical merit of the proposed innovation and its value to the NASA program are primary factors without which no award will be made.

3.1.3 An SBIR proposal must respond to only one of the subtopics in Section 8 and must address a NASA program objective or opportunity described therein. Ideally, the proposed innovation should also serve as the basis, directly or indirectly, for new commercial products, processes, or services that may benefit the general economy through the entrepreneurial activities of the small business.

3.1.4 Proposals directed toward market research, commercial development of existing patents or products and concepts should not be submitted for SBIR support. Such activities are considered responsibilities of the private sector and will not be funded by SBIR.

3.2 General Requirements

3.2.1 Page Limitation. A Phase I SBIR proposal shall not exceed a total of 25 standard 8½ x 11 inch pages. All material supplied except the check list (Form 9.D in this Solicitation) will be included in the page count. Supplementary material may be included at the option of the offeror, but such pages must be included in the 25 page limit. **Proposals exceeding the 25 page limitation will be rejected without consideration.** Samples, videotapes, slides, or other ancillary items will not be accepted.

3.2.2 Type Size. No type size smaller than 11 point is to be used for text or tables, except as legends on reduced drawings. Pages are to be printed on one side only, and may be single or double spaced.

3.2.3 Brevity and Organization. The proposal should be direct and concise. Offerors are requested not to use the entire 25 page allowance unless it is actually necessary. Appropriate brevity facilitates proposal evaluations. Good proposals are well-organized and written in a direct style. Their work plans are logical and realistic. Promotional and non-project-related material should not be included.

3.2.4 Content and Format. All required items of information are to be covered fully and in the order set forth in Sections 3.3 to 3.7 of this Solicitation, but the space allocated to each will depend on the project chosen and the Principal Investigator's approach.

3.2.5 NASA Use of Optical Character Readers. To facilitate proposal processing, NASA may employ optical character readers to record proposal cover sheet and project summary information wherever possible. Therefore it is required that the proposal cover sheet (Form 9.A) and the project summary (Form 9.B) be typed using a mono-spaced font--such as Courier, Letter Gothic, Pica, Elite, or Prestige--in 10 or 12 characters per inch (pitch) or 12 point.

IMPORTANT: Do not use a proportionally spaced font on Forms 9.A and 9.B.

3.3 Required Format

The following format is required for all Phase I proposals. A Phase I proposal consists of a cover sheet, a project summary, a technical proposal, and a proposed budget. Each of these must be addressed in this order. **Each page shall be numbered consecutively at the bottom.** Detailed descriptions of all parts of the proposal follow.

3.4 Introductory Pages

3.4.1 Page 1: Cover Sheet. The offeror shall complete an original copy of the cover sheet, Form 9.A in this Solicitation, and sign it in ink. (Instructions are provided on the back of the form.) The offeror shall include a photocopy of the completed Form 9.A as page 1 of each copy of the proposal. (The original 9.A is submitted as a separate page; see Section 6.1.) No other cover sheet is permitted. The proposal title must be concise and descriptive of the proposed product or innovation. Avoid the use of acronyms in the title, and **do not use the subtopic title as the proposal title.**

3.4.2 Page 2: Project Summary. The offeror complete an original copy of the project summary, Form 9.B. (Instructions are provided on the back of the form.) The offeror shall include a photocopy of the completed Form 9.B as page 2 of each copy of the proposal. (The original 9.B is submitted as a separate page; see Section 6.1.)

The technical abstract section shall include (1) the **specific proposed innovation** and how it addresses the stated subtopic problem or opportunity, (2) the project objectives, (3) the effort proposed, (4) the results anticipated, and (5) the expected NASA applications and benefits. Other information to be included on the project summary include potential commercial applications and key technical words for reference. The project summaries of successful proposals will be published by NASA; therefore it is required that the proposal summary contain no proprietary information.

3.4.3 Page 3: 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 sections of the proposal.

3.5 Technical Proposal

The Technical Proposal shall consist of the following eleven parts.

Part 1: Identification and Significance of the Innovation. The first paragraph of the proposal shall contain (1) **a clear and succinct statement of the specific innovation proposed and why it is an innovation,** and (2) a brief explanation of how the innovation is relevant and important to meeting the need described in the subtopic. The paragraph shall contain no more than 150 words. **NASA reserves the right to reject proposals that lack this introductory paragraph.**

Part I may also include appropriate background and elaboration to explain the proposed innovation and its anticipated value to NASA.

Part 2: Phase I Technical Objectives. This 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 innovation.

Part 3: Phase I Work Plan. Part 3 should be comprehensive and explanatory. 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. 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.

The Phase I Work Plan must be complete and self-contained. See Section 5.4.1 of this Solicitation regarding proprietary information. Offerors are advised to avoid including proprietary information if at all possible.

Part 4: Related R/R&D and Bibliography of Related Work. The purpose of Part 4 is to make clear the offeror's awareness of key recent developments by others in the specific subject area. It should include any significant R/R&D directly related to the proposal that was conducted by the Principal Investigator or by the offeror. Any planned coordination with outside sources during the course of the proposed research should also be stated.

At the offeror's option, this section may include concise bibliographic references in support of the proposal if they are confined to activities directly related to the proposed work.

Part 5: Relationship with Phase II or other Future R/R&D. In Part 5 the offeror shall explain why the expected Phase I results should warrant Phase II continuation, state the anticipated Phase II objectives, and include the offeror's recommended applications by NASA. Any other planned R/R&D related to the proposed research should also be described.

Part 6: Potential Commercial Applications. Commercial applications of research innovations supported by Federal R&D is an important SBIR goal. Offerors shall discuss in Part 6 the potential direct or indirect commercial applications of the results or products of their proposed research . Their intentions, abilities, and plans to pursue commercial applications in Phase III shall also be included in Part 6.

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

A description of the firm's business organization, operations, R/R&D capabilities, and experience is to be provided. All firms, including start-up firms, are required to outline how the proposed SBIR project would fit into their business objectives or plans. This description should include information on the history of the firm and the current number of full-time-equivalent employees.

This section must also provide a description of the firm's physical facilities including any 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.

Part 8: Key Personnel. In Part 8 the offeror shall identify the key employees to be committed to Phase I activities. Key personnel are the Principal Investigator and other individuals whose expertise is essential to the success of the project. Information on their education, experience, and any directly related publications 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 must indicate the extent to which (1) other proposals recently submitted or planned for submission in 1992 and (2) existing projects would commit the PI's time concurrently with this proposed activity.

Part 9: Subcontracts and Consultants. In Part 9 the offeror must describe any proposed subcontracting 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 the functions, services, time intervals, and extent of effort to be provided.

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 permits the firm to conduct more valuable research or improve the prospects for commercial success.

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.

Part 10: Related Proposals to and Awards from Other Agencies. If the offeror (1) has received Federal government awards for related work, or (2) has submitted currently active proposals for similar work under other Federal government program solicitations, or (3) intends to submit proposals for such work to other agencies during 1992, those awards, proposals and intentions shall be identified. For all such awards and for active or intended proposals in 1992 the following information is required in Part 10:

(1) The agencies to which proposals have been or will be submitted or from which awards have been received.

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

(3) Solicitation numbers under which proposals have been or will be submitted or awards received.

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

(5) Titles of research projects.

(6) Name and title of the Principal Investigator for each proposal that has been or will be submitted or award received.

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

Part 11: Previous NASA SBIR Awards Received. Offerors who have received previous NASA SBIR awards shall provide a list including contract numbers, titles, the years of award, and the NASA Installations making the award. If no NASA awards have been received, the offeror shall so state.

3.6 Proposed Budget

3.6.1 Summary Budget. Following the instructions on the back of the form, offerors shall complete Form 9.C, SBIR Summary Budget, and include it and any budget explanation sheets if needed as the last page(s) of the proposal. Items on Form 9.C that do not apply to the proposed project may be omitted. What matters is that enough information be available to allow NASA to understand how the offeror plans to use the requested funds and to determine whether the proposed budget is realistic and cost-effective. Special attention is directed to the following items:

3.6.2 Property. Because NASA will not normally fund instrumentation, equipment, or facility acquisition under Phase I, the inclusion of such items should be avoided.

3.6.3 Travel. Budgets for travel funds are not normally acceptable. If proposed, however, travel must be justified as essential to the conduct of the project, and an explanation of how the costs were developed should be included.

3.6.4 Profit. A profit or fee may be included in the proposed budget as noted in Solicitation Section 5.9. The reasonableness of a proposed profit is examined by the Contracting Officers during contract negotiations; their determination is based on a variety of factors.

3.6.5 Cost Sharing. See Section 5.8.

3.7 Check List

The Check List (Form 9.D in this Solicitation) is provided to assist both the offeror and NASA. One copy of Form 9.D is to be completed and included with the original signed copy of the cover sheet and the project summary sheet. The Check List is not counted as a proposal page.

4.0 Proposal Evaluation and Award Selection

4.1 Phase I

4.1.1 Evaluation Process. The initial step in the evaluation process is screening for compliance with administrative requirements of the Solicitation. Proposals that 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 under Section 4.1.2.

Proposals are evaluated at the NASA Installation responsible for the subtopic, but other NASA Installations may also conduct evaluations and make recommendations for selections of any proposals accepted for evaluation.

Evaluators base their conclusions only on information ccontained in the proposals. Offerors should not assume that evaluators are acquainted with the firm or key individuals or with any experiments or other information that has not been published in refereed professional journals or equivalent sources. Any pertinent references should be noted in Part 4 of the technical proposal; however, such references may or may not be used by the evaluators.

4.1.2 Phase I Evaluation Criteria. Each proposal is judged and scored on its own merits using the established uniform scoring procedure described below. Of the maximum possible score, approximately forty percent is allocated to the first of the following four criteria; the remaining three receive approximately twenty percent each.

4.1.2.1 Scientific/technical merit of (a) the proposed innovation and its relevance to the needs stated in the selected subtopic, and (b) the proposal's objectives and approach for addressing questions of feasibility. Innovativeness and originality are essential.

4.1.2.2 Qualifications of the principal investigator, other key staff, consultants and subcontractors, if any, and the adequacy of available or obtainable instrumentation and facilities for the project.

4.1.2.3 Anticipated benefits (technical and/or economic) to the NASA mission through applications after Phase II, and the potential for direct or derivative commercial applications.

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

4.1.3 Selection Process. After a proposal is scored, it is ranked relative to all others evaluated under the same subtopic. Those considered suitable for selection are recommended for further consideration by the NASA Field Installation SBIR Committee. The Committee prepares final recommendations for selection in priority order, based on proposal merit, program balance, and Installation needs. These recommendations are then forwarded to NASA Headquarters for final selection decisions that 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 negotiations leading to contract award.

4.2 Phase II

Phase II is initiated by a separate request for proposals issued by the NASA Installation awarding the Phase I contract. Such requests are issued solely to Phase I contractors whose progress is deemed to be satisfactory and where NASA is interested in Phase II continuation. These requests contain new information, a model contract, submission instructions, evaluation and award criteria, and a due date for response. For planning purposes, Phase II proposals will be due approximately one month after Phase I final performance ends.

4.2.1 Evaluation and Selection. The NASA Installations responsible for the Phase I research comprehensively evaluate all Phase II proposals using uniform procedures and the criteria noted in Section 4.2.2. The Installation SBIR Committees then rank the proposals, taking into consideration overall quality, value to NASA, and Installation program balance. The committees then forward their recommendations to the NASA Headquarters SBIR Office. Final selection consideration takes into account additional assessments made by Headquarters Program Offices of overall value to the NASA program.

Final selections are made from the group of proposals recommended for award and are based on Installation priorities, value to NASA, programmatic or schedule requirements, and availability of funds. Under current legislation, special selection priority is given to proposals for which valid non-Federal funding commitments for Phase III activities have been obtained (see Section 4.2.3). Offerors are notified that new legislation may call for greater emphasis on commercial potential. At its discretion and at any time after the proposal has been received, NASA may initiate early negotiations for a Phase II award if the project is urgently needed to support on-going programmatic activities.

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

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

4.2.2.2 Results of Phase I, including the degree to which Phase I objectives were met, the feasibility of the innovation, and whether the Phase I results indicate a Phase II project is appropriate.

4.2.2.3 Future importance and eventual value of the product, process, or technology results to the NASA mission.

4.2.2.4 Capability of the Small Firm. NASA will assess the capability 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.

4.2.2.5 Commercial Potential. NASA will assess indicated potential applications of the research results to non-NASA markets and the offerer's plans to market and commercialize them. Non-Federal funding commitments for Phase III activities should also be discussed. (See the following section.)

4.2.3. Non-Federal Commitments for Phase III Funding. Offerors for Phase II contracts are strongly urged to obtain valid non-Federal capital commitments for Phase III follow-on activities from parties other than the proposing firm. Valid Phase III funding commitments must provide that a specific, substantial amount (usually at least half the Phase II funding request) will be made available to the firm to pursue stated Phase III objectives. They must indicate the source, date, and conditions or contingencies under which the funds will be made available. Alternatively, self-commitments of the same type and magnitude that are required from outside sources can be considered.

Phase III commitments from outside parties must be provided as letters to the proposing firms. Preferably, they should accompany the Phase II proposal, but they may be considered until final Phase II selection decisions have been made by NASA. Mere expressions of technical interest in the outcome of the Phase II research or of potential future financial support by other parties are not valid Phase III commitments and will not be accepted as such by NASA.

4.3 Debriefing of Unsuccessful Offerors

After final Phase I and Phase II selection decisions have been announced, a critique (debriefing) for an unsuccessful offeror may be provided to the offeror's corporate official or their designee only upon written request. Telephone requests for debriefings will not be accepted. Debriefings are not opportunities to reopen selection decisions. They are intended to acquaint the offeror with perceived strengths and weaknesses of the proposal and perhaps to provide suggestions for constructive future action by the offeror.

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

4.3.1 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 its proposal was not selected for award. Late requests will not be honored.

4.3.2 Phase II. To request debriefings on Phase II proposals, offerors must contact the Contracting Officer at the relevant NASA Installation in writing **within 45 days after notification has been mailed to the offeror** that its proposal was not selected for award. Late requests will not be honored.

5.0 Considerations

5.1 Awards

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

In October 1992, NASA expects to announce the selection of approximately 320 proposals for negotiation of fixed-price Phase I contracts with values normally not exceeding $50,000. Following contract negotiations and awards, Phase I contractors will usually have six months to carry out their proposed Phase I programs.

NASA anticipates that during 1993 approximately 50 percent of the Phase I projects resulting from this Solicitation 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 type or cost-type contracts with usual performance periods not exceeding 24 months and funding not exceeding $500,000.

5.2 Final Reports

Six (original plus five) copies of a final report on the Phase I project must be submitted to NASA upon 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 project results through Phase II both for NASA purposes and for commercial purposes 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 assessments 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. The first two payments will be made 30 days after receipt of valid invoices. The final payment will be made 30 days after acceptance of the final report.

5.4 Treatment and Protection of Proposal Information

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

5.4.1 Proprietary Information. It is NASA policy to use information (data) included in proposals for evaluation purposes only 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", as described in the 1988 *SBA Policy Directive*, is applied to the data which constitute trade secrets or other information that is commercial or financial and confidential or privileged, as follows:

"For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to the proposer as a result of or in connection with the submission of this data, the Government shall have the right to duplicate, use or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ______ of this proposal." Pages containing proprietary material shall be marked "Confidential proprietary material."
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 and legend have not been appropriately applied.

The offerer should also note that the above notice has been printed on the proposal cover page so that the offerer can alert NASA to the presence of pages containing proprietary material. **Do not label the entire proposal proprietary.**

5.4.2 Non–NASA Reviewers. In addition to Government personnel, NASA, at its discretion and in accordance with 18-15.413-2 of the NASA FAR Supplement, may utilize 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(s) and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

5.4.3 Release of Proposal Information. By submission of a proposal, the offeror agrees to permit the government to disclose publicly the information contained in Forms 9.A and 9.B of proposals selected for awards. Other proposal information (data) is considered to be the property of the offeror, and NASA will protect it from public disclosure to the extent permitted by law.

5.4.4 Final Disposition of Proposals. The government retains ownership of the copies of proposals accepted for evaluation, and they will not be returned to the offeror. Copies of all evaluated Phase I proposals will be retained for one year after the Phase I selections have been made, after which time unsuccessful proposals may be destroyed.

5.5 Rights in Data Developed Under SBIR Contracts

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

5.5.1 Some data of a general nature are to be furnished to NASA without restriction (i.e., with unlimited rights) and may be published by NASA. These data will normally be limited to the project summary accompanying any periodic progress reports and the final report required to be submitted (see Section 5.2) but, in any event, the requirement for them will be specifically set forth in any contract resulting from this solicitation.

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

5.5.3 Other than as required by Section 5.5.1, rights in technical data including software developed under the terms of any funding agreement shall remain the property of 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. 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 Section 5.5.2 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, non-exclusive, 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 nonexclusive, 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. NASA typically limits the Phase I award amount to $50,000. If included cost sharing should be shown in the summary budget but not included in items labeled "AMOUNT REQUESTED."

5.9 Profit or Fee

Both Phase I and Phase II SBIR contracts may include a reasonable profit or fee.

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 1992 to other Federal agencies, and prior NASA SBIR awards received by the offeror must be identified in the Technical Proposal Parts 10 and 11 as noted in Section 3.3 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 paid 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 individual consultants, but there are cost limits on subcontracting the research and analytical portions of both Phase I and Phase II contracts:

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

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

NOTE: The dollar amounts of research and analytical effort do not include those items listed under "Other Direct Costs" on the budget sheet.

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 contract negotiations.

5.13.1 Standards of Work. Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.

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

5.13.3 Examination of Records. The Comptroller General (or a duly authorized representative) shall have the right to examine any directly pertinent records of the contractor involving transactions related to the contract.

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

5.13.5 Termination for Convenience. The contract may be terminated by the government at any time if it deems termination to be in its best interest, in which case the contractor will be compensated for work performed and for reasonable termination costs.

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

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

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

5.13.9 Affirmative Action for Veterans. The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.

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

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

5.13.12 Covenant Against Contingent Fees. No person or agency has been employed to solicit or secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the contractor for the purpose of securing business.

5.13.13 Gratuities. The contract may be terminated by the government if any gratuities have been offered to any representative of the government to secure the contract.

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

5.14 Additional Information

5.14.1 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.

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

5.14.3 Limitations on Awards. This Solicitation is not an offer by the Government to make any specific number of awards under either Phase I or Phase II. NASA is not responsible for any monies expended by the offeror before award of any contract resulting from this Solicitation. Also, awards under this Program Solicitation 92-1 are contingent upon the availability of funds.

5.14.4 Classified Proposals. NASA will not accept classified proposals.

5.14.5 Unsolicited Proposals. Unsolicited proposals will not be accepted under the SBIR program in either Phase I or Phase II.

6.0 Submission of Proposals

6.1 What to Send

Offerors must submit the following items for each proposal:

6.1.1 One original proposal cover sheet signed in ink and included as a separate page. This is Form 9.A, a red-printed form included in this Solicitation.

6.1.2 One original project summary as a separate sheet. This is Form 9.B, a red-printed form included in this Solicitation.

6.1.3 One check list as a separate sheet. This is Form 9.D, a black-printed form included in this Solicitation.

DO NOT STAPLE THE ABOVE ITEMS TOGETHER: LEAVE SEPARATE.

6.1.4 Five black and white copies of the entire proposal as described in Sections 3.3-3.6 and addenda. Each proposal copy is to be stapled separately.

6.2 Physical Packaging Requirements

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

6.2.2 Packaging. Secure packaging is mandatory. NASA cannot process proposals damaged in transit.

All items (6.1.1 through 6.1.4) 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.

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

6.3 Where to Send Proposals

All proposals that are mailed through the U.S. Postal service by regular or express mail are to be sent to the NASA Headquarters Mail Room addressed as follows:

SBIR Program Manager
Code CR
National Aeronautics and Space Administration
409 3rd Street, SW, Room C900
Washington, DC 20546

Proposals sent via commercial delivery services (e.g. Federal Express) or handcarried should be delivered to the NASA mail substation at:

SBIR Program Manager
Code CR
Receiving and Inspection
National Aeronautics and Space Administration
600 Independence Avenue, SW, Room A16
Washington, DC 20546

The mail substation telephone number (202-453-1163) may be used when required for reference by delivery services. **NASA cannot receive proposals on Saturdays, Sundays, or Federal holidays.**

6.4 Deadline for Proposal Receipt

Deadline for receipt of Phase I proposals at NASA is 4:00 p.m., EDT, July 21, 1992. Offerors are cautioned to be careful of unforseen delays that can cause late arrival of proposals at NASA. NASA assumes no responsibility for evaluating proposals received after the stated deadline. Nevertheless, should it 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. Such acceptances would be made only under unusual and justifiable circumstances and when they would not provide unfair competitive advantages to the offerors.

6.5 Acknowledgement of Proposal Receipt

NASA will acknowledge receipt of proposals by a postal card mailed to the company official who endorsed the proposal cover sheet. If a proposal acknowledgement card is not received from NASA within 30 days following the closing date of this Solicitation, the offeror should call the SBIR inquiry number, 703-271-5672. NASA will not respond to such inquiries made prior to August 21,1992.

6.6 Withdrawal of Proposals

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

7.0 Scientific and Technical Information Sources

7.1 Technical References

To assist offerors in obtaining technical information about the subtopics, most of the Subtopic descriptions include selected references. These documents are in the public domain and are available from the public information sources cited below and from university technical libraries and larger public libraries. **Please do not request any of these reference documents from the SBIR Office or from NASA Installations.**

To help proposers gain access to the documents cited, the references include the document accession numbers or the initials of the agency from which it is available. These are described below.

Citation: AIAA or (Ann-nnnnn)
American Institute of Aeronautics and Astronautics
Attn: Library
555 West 57th Street, 12th floor
New York, NY 10019
Tel: 212-247-6500 ext.231

Citation: CASI or (Nnn-nnnnn) or (Xnn-nnnnn)
NASA Center for AeroSpace Information
PO Box 8757
BWI Airport, MD 21240
Tel: 301-621-0147

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

Citation: EI or ESL
Engineering Societies Library
345 East 47th Street
New York, NY 10017
Tel: 212-705-7611

Citation: INSPEC or IEEE
IEEE Service Center
PO Box 1331
Piscataway, NJ 08855-1331
Tel: 908-981-0060

Citation: NTIS or (PBnn-nnnnn/XAB)
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
General: 703-487-4660
Title ID#: 703-487-4780
Fax: 703-321-8547

Citation: UMI
University Microfilms International
300 North Zeeb Road
Ann Arbor, MI 48106-1346
Tel: 800-521-0600 except AL and MI
Tel: 313-761-4700 ext. 490, 491

Some items have only an identification number with one of the following prefixes.

Citation: ISBN
The International Standard Book Number may be used to order from the publisher or as an identification to library borrowing.

Citation: ISSN
The International Standard Serial Number may be used to identify a journal or periodical in which the article is published.

Citation: LCCN
The Library of Congress Control Number may be used to identify an item available at the Library of Congress.

The accession numbers are also used in the NASA Scientific and Technical Information System. This is NASA's large database that is the foundation of RECON, the online bibliographic search system maintained by NASA's Center for Aerospace Information (CASI), formerly the NASA Scientific and Technical Information Facility. (See citation above.)

Some documents are subject to restricted distribution regulations. If applicable, these restrictions are noted in the reference either in words or with the following acronyms:
EAR: Export Administration Regulations
ITAR: International Traffic in Arms Regulations

Any firm can, for a fee, use the services of one of the NASA Regional Technology Transfer Centers to utilize the NASA database and many others. Full-text paper copies or microfiche of almost all reports and papers in the databases are available.

Technical libraries having access to RECON may request reports directly from CASI. Current NASA contractors may, for a fee, register to use the NASA RECON system. Contact CASI at 301-621-0160.

7.2 Regional Technology Transfer Centers

NASA's network of Regional Technology Transfer Centers (RTTCs), listed below, provides a variety of services to NASA SBIR offerors, including searches of the Scientific and Technical Information System, the database containing many of the references cited in Section 8. RTTCs should be contacted directly to determine whether additional services are available and to discuss fees charged since these vary, depending upon the organization and type of service requested.

Northeast:

Center for Technology Commercialization
Massachusetts Technology Park
100 North Drive
Westborough, MA 01581
Tel: 508-870-0042

Mid-Atlantic:

Mid-Atlantic Technology Applications Center
University of Pittsburgh
823 William Pitt Union
Pittsburgh, PA 15260
Tel: 412-648-7000

Southeast:

Southern Technology Applications Center
University of Florida, College of Engineering
Box 24, One Progress Boulevard
Alachua, FL 32615
Tel: 904-462-3913
800-354-4832 FL only
800-225-0308 outside FL

Mid-West:

Battelle Memorial Institute
Great Lakes Technology Transfer Center
25000 Great Northern Corporate Center, #450
Cleveland, OH 44070-5310
Tel: 216-734-0094

Mid-Continent:

Commercial Technology Services
Texas Engineering Experiment Station
The Texas A&M University System
237 Wisenbaker Engineering Research Center
College Station, TX 77843-3369
Tel: 409-845-0538

Far-West:

Far-West Regional Technology Transfer Center
University of Southern California
3716 South Hope Street, Suite 200
Los Angeles, CA 90007-4344
Tel: 213-743-6132
800-642-2872 CA only
800-872-7477 outside CA

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

Technology Application Center
University of New Mexico
2808 Central, S.E.
Albuquerque, NM 87131
Tel: 505-277-3622

7.3 National Technical Information Service

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

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Tel: 703-487-4600
Fax: 703-321-8647

8.0 Technical Topics and Subtopics

Section 8 contains detailed descriptions of the technical areas (subtopics) within which small businesses are invited to submit proposals.

Each subtopic description in Section 8 outlines the technical problem for which NASA requests proposals for innovative R&D solutions. Most subtopics also include references to documents in the public domain describing the background or status of relevant technologies. Ways to access these references are described in Section 7.

9.0 Forms

The four forms needed to complete a proposal are provided. Three copies each of Form 9.A, Cover Sheet, and Form 9.B, Project Summary, are included since these are printed in red. (If additional copies are needed, contact NASA SBIR by one of the means given in Section 1.5.) Please note the instructions for completing these in Section 3.2.5 and on the reverse sides. Offerors are encouraged to make photocopies of Form 9.C, Summary Budget, and Form 9.D, Checklist, as needed.

Listing of Technical Topics and Subtopics

Technical Topics and Subtopics

01.00 Aeronautical Propulsion and Power

01.01 Internal Fluid Mechanics for Aeropropulsion Systems

Innovative techniques are sought for analyzing flows in aeronautical propulsion systems for low subsonic through hypersonic speeds. Areas of interest include:

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

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

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

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

References:

NASA Conference Publication 10063, Aeropropulsion '91, Sessions 9-12, Internal Fluid Mechanics Research, 1991. NASA-CP-10063

Computational Fluid Dynamics Symposium on Aeropropulsion, NASA, Cleveland, OH, April 24-26, 1990. N91-21062

01.02 Aeropropulsion System Components

Proposals are solicited in two areas: turbine engines, and drive-train technology.

Turbine engines: Innovative improvements are needed for inlets, propellers, and/or fans, compressors, combustors, turbines, nozzles, and recuperators and/or regenerators. Objectives include: greater cycle efficiency; lower gaseous and particulate emissions; reduced coolant penalties using advanced materials; and reduced weight, volume, and aerodynamic drag. Improvements may be investigated using multi-disciplinary analysis methods, experimental methods, or advanced computational fluid dynamic methods.

Drive-train technology: New concepts are solicited which would decrease drive system weight and noise and increase reliability and strength. Areas of interest include: high-temperature gear and bearing materials; transmission health monitoring system; improved gear tooth forms; transmission concepts for high-horsepower gear boxes; and expert systems and optimization methods.

References:

NASA Conference Publication 3049, Aeropropulsion '87, February 1990. N88-15790

NASA Conference Publication 10063, Aeropropulsion '91, March 1991. NASA-CP-10063

01.03 Aeropropulsion System Instrumentation, Sensors, and Controls

In the future, propulsion system components will be exposed to increased thermal and aerodynamic loads. This exposure will require precise measurements of the severe operating environment and engine conditions must be made for control, safety, and health monitoring considerations. To satisfy these requirements, innovative techniques and instrumentation are sought for accurate, minimally intrusive measurement of pressure, temperature, strain, flow, and other parameters. These measures are also needed for verification of design codes, development of advanced aerospace propulsion systems, and operation and control of these systems.

- Strain and temperature measurements on both metal and ceramic surfaces up to 1900°C.
- Gas temperature and pressure measurements, both static and dynamic for up to 1900°C.
- High-temperature electronics and integrated sensors.

- Fiber-optic and integrated-optic sensors and control systems.
- Aerodynamic flow and combustion diagnostic systems.
- Data processing techniques for non-intrusive, whole-field measurement systems.

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

- Control of distributed systems.
- Nonlinear or adaptive real-time control design.
- Reliability enhancement through redundancy management or fault detection.
- Improved component performance through compressor-stall alleviation, combustor-pattern factor control, or other advanced techniques such as integrated system intelligence and high-speed computation for artificial intelligence applications.

References:

NASA Conference Publication 100063, Aeropropulsion '91, Session 5, Instrumentation and Controls Research, March 20-21, 1991. N88-15794

Lorenzo, C. F. and Merrill, W. C. "An Intelligent Control System for Rocket Engines: Need, Vision and Issues," IEEE Control System Magazine, Vol. II, No. 1 (January 1991), 42-46.

01.04 Novel Aeropropulsion Concepts and Analytical Methods

Improving propulsion system performance, weight, bulk, and cost are required for many important future aeronautical vehicles. This is especially true for high-speed accelerators for transatmospheric vehicles and efficient cruise powerplants for supersonic and hypersonic airplanes. This subtopic solicits proposals to identify and analyze possible improved, or new airbreathing propulsion system concepts that would enable major vehicle capability advances. Current advanced propulsion concepts include variable-cycle engines, air-turbo-ramjets, dual-mode (subsonic and/or supersonic combustion) scramjets, and air-augmented rockets. Proposed advanced propulsion systems could utilize conventional fuels, high-density hydrocarbons, slurries, cryogenic methane, or hydrogen. Proposals to enhance the fidelity of first-order propulsion system modeling are also solicited provided they are: (1) analytical rather than empirically based, and (2) are capable of modeling either the performance or weight of advanced/novel components for which no database yet exists.

To qualify, Phase I concept evaluation proposals must: (1) have clear applications to the aero objectives stated above, (2) include technically sound first-order system concept modeling and/or valid comparative evaluations against conventional powerplant baselines or other advanced alternatives to support postulated desirability and feasibility, and (3) suggest realistic, hardware-oriented Phase II R&D continuations directed toward experimental verification of key elements of proposed concepts which are suitable for pursuit by NASA and by the small business in the near future within the scope of the SBIR program. Proposals to enhance first-order modeling fidelity need not satisfy the above conditions.

References:

Fishbach, L. H., et al. "Temperature and Lifetime Effects on the Performance of a Nuclear-Powered Airplane," NASA Technical Memorandum-52432, 1968. N72-70935

Franciscus, Leo C. "The Supersonic Fan Engine - An Advanced Concept in Supersonic Cruise Propulsion," NASA Technical Memorandum-82657, 1981. N81-27094

Eisenberg, Joseph D. "Rotorcraft Convertible Engines for the 1990's," NASA Technical Memorandum-83003, 1982. N83-12091

02.00 Aerodynamics and Acoustics

02.01 Computational Fluid Dynamics

More powerful numerical computation capabilities for predicting fundamental fluid flow phenomena can lead to improved aerodynamic characteristics and configurational optimization for advanced aircraft, missiles, and aerospace vehicles of every type and application. NASA's interest in computational fluid dynamics encompasses the entire spectrum of aerodynamic and aerothermodynamic phenomena that may be encountered by subsonic to hypersonic aircraft and aerospace vehicles. This research would advance understanding of static and dynamic behavior, transient phenomena, maneuvering, stability and control, aerodynamic performance, real-gas effects, heat transfer, and combustion phenomena. Applications include both external and internal flow fields and multiple body interactions.

This subtopic solicits proposals for novel approaches in any of the areas listed below. Only those proposals for innovations that significantly advance the state of the art will be considered for award. Proposals must clearly identify Phase II objectives and expected applications both in NASA programs and any potential commercial markets to which the research results could be directed.

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

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

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

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

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

References:

Sorenson, R. and McCann, K. "A Method for Interactive Specifications of Multiple-Block Topologies," AIAA paper 91-0147, Jan. 1991. A91-19157

Van Dam, C., et al. "Drag Calculation of Wings Using Several Euler Methods," AIAA paper 91-0338, Jan. 1991. A91-19240

Baldwin, B. and Barth, T. "A One-Equation Turbulence Transport Model for High Reynolds Number Wall-Bounded Flows," AIAA paper 91-0610, Jan. 1991. A91-19304

Narain, J. et al. "The Prediction of Viscous Hypersonic Flows About Complex Configurations Using an Upwind Parabolized Navier-Stokes Code," AIAA paper 91-0394, Jan. 1991. A91-21477

02.02 Flow-Physics Modeling and Control

Performance improvements for all classes of aerospace vehicles are dependent, to a large measure, upon improved modeling of transition and turbulence in complex flows. Also required are practical flow control approaches for such phenomena as heat transfer, noise, shock wave drag, flow separation and vortices, as well as transition and turbulence, both free and bound. This subtopic solicits proposals for research on inventive and innovative flow-physics modeling and control concepts applicable to:

- Modeling and/or control of transition and transitional flows across the speed range.

- Control of transition and turbulence-related phenomena such as heat transfer, skin friction, acoustics, and mixing rate.

- Control of complex flow phenomena such as flow separation, vortical flows including drag due to lift, and shock wave drag.

References:

Bushnell, D. M.; and Hefner, J. N.: "Viscous Drag Reduction in Boundary Layers," Progress in Astronautics and Aeronautics, Vol. 123, 1989. A91-12688

Hussaini, M. Y.; and Voigt, R. G.: "Instability and Transition," Vol. I and II, Springer Verlag, 1989. ISBN 0387973230, ISBN 0387973249

Gad-el-Hak, M.; and Bushnell, D. M.: "Status and Outlook of Flow Separation Control," AIAA Paper No. 91-0037, 1991. A91-19110

Hefner, J. N.; and Sabo, F. E., eds.: "Research in Natural Laminar Flow and Laminar-Flow Control," Proceedings of a Symposium held at Langley Research Center, Parts 1-3, Hampton, Virginia, March 1-19, 1987. N90-12539, N90-12519, N90-12503

02.03 Hypersonic Vehicle Aerothermodynamics

Innovative applications of computational and experimental aerothermodynamic technologies are sought which will account for the complex aerothermodynamic phenomena that will impact the design and development of future planetary probes and hypersonic aerospace vehicles such as second-generation shuttle configurations, advanced reentry vehicles, aero-assist orbital transfer vehicles, the National Aerospace Plane, and hypersonic transport aircraft. Phenomena of interest include, equilibrium and finite-rate chemistry, transport properties and multi-component mixing laws, thermal, radiation, gas-surface interactions such as surface catalytic reactions, shock-wave and boundary-layer interactions, and laminar, transitional, and turbulent viscous flows. Technology applications of interest include the extension of computational and experimental methodology to include the above phenomena, grid-generation for complex hypersonic and reentry vehicles, diagnostics for high-enthalpy test facilities, and experiments to validate computational methods, assess non-equilibrium radiation effects about aerospace configurations, and measure physical properties such as phenomenological reaction rates.

References:

Park, Chul: Nonequilibrium Hypersonic Aerothermodynamics. John Wiley and Sons, 1990. A91-14483

Gnoffo, Peter A.: Conservation Equations and Physical Models for Hypersonic Air Flows in Thermal and Chemical Non-equilibrium, NASA TP 2867, Feb. 1989. N89-16115

Allwright, S.: Multiblock Topology Specification and Grid Generation For Complete Aircraft Configurations. AGARD CP 464, p. 11-1, 1989. N90-21986

Miller, C. G.: Langley Hypersonic Aerodynamic/Aerothermodynamic Testing Capabilities-Present and Future. AIAA Paper No. 90-1376, June 1990. A90-38483

02.04 High-Angle-of-Attack and High-Lift Configurational Aerodynamics

The development of experimental and computational methods and data analysis procedures to enhance the basic understanding of low-speed aerodynamics and airframe-control-propulsion interaction phenomena would provide important contributions to high angle-of-attack and high-lift aerodynamic research. Combined improvements in aircraft performance, stability and control, and noise characteristics for future civil and military aircraft would be a significant benefit. The vortex-dominated flow fields require innovative techniques to define the interaction between vortices and boundary layers, shear layers, or solid surfaces. Extensive integration of modern sensor technology and/or sophisticated computer-experiment integration is considered an important part of this area of interest.

This subtopic solicits proposals for 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.
- Integration of airframe, control surfaces, and propulsion system to enhance the performance of all elements which includes reducing noise.
- Interactive aerodynamic design, geometry definition, and graphical flow-field and solution visualization.
- Acoustic and pressure sensing methods.
- Unstructured-grid approaches for practical, three-dimensional, aircraft aerodynamic computations using the Euler and Navier-Stokes equations.

References:

Ng, T., and Malcolm, G. "Aerodynamic Control Using Forebody Blowing and Suction," Eidetics International, Torrance, CA, AIAA-91-0619, Proceedings of AIAA 29th Aerospace Science Meeting, Reno, NV, January 7-10, 1991. A91-19387

Peraire, J., Peiro, J., Formaggia, L., et al. "Finite Element Euler Computations in Three Dimensions," International Journal for Numerical Methods in Engineering, Vol. 26 (1988), 2135-2159. A89-12130

Jameson, A., Baker, T.J., and Weatherill, N.P. "Improvements to the Aircraft Euler Method", AIAA Paper 87-0452, Jan. 1987. A87-22644

Nichols, M.R. "Bibliography on Aerodynamics of Airframe/Engine Integration of High Speed Turbine Powered Aircraft," NASA TM 8184, Nov. 1980, N81-11032

02.05 Unsteady Aerodynamics and Aircraft Dynamics

The drive for increasing agility for combat aircraft emphasizes the growing dominance of unsteady aerodynamics on aircraft dynamics. Successful high agility design requires an understanding of complex, unsteady aerodynamic phenomena, particularly at conditions involving extensive flow separation. It also requires the development of experimental and analytical methods for reliably predicting these effects and their impact on aircraft flight dynamics, and the development of airframe design approaches for obtaining desired characteristics. Research areas of interest include:

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

References:

Nguyen, L. T.: Flight Dynamics Research for Highly Agile Aircraft. SAE-892235

Brandon, J. M.; and Shah, G. H.: Unsteady Aerodynamic Characteristics of a Fighter Model Undergoing Large-Amplitude Pitching Motions at High Angles of Attack . AIAA-90-0309. A90-26933

02.06 Rotorcraft Aerodynamics and Dynamics

Many aspects of rotorcraft aerodynamics and dynamics are not thoroughly understood or adequately modeled. Areas of importance include: aerodynamics of rotor-airframe-tail interactions; rotor-blade air-flow loading analyses; improved rotor system performance; analysis of advanced hub designs and their influence on rotor dynamics; rotorcraft vibration and vibration alleviation; aeroelastic stability; rotor noise; and new rotor concepts for high speed flight.

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

Offerors should emphasize novel concepts and innovative analytical or experimental approaches to the development of any proposed concept. Evidence of substantial prior analytical or experimental basis for the proposed innovation and clear explanations of how any innovation differs from known concepts should be included.

References:

Martin, D.M., Mort, R.W., Young, L.A., et al. "Hub- and Pylon-Fairing Integration for Helicopter Drag Reduction," Proceedings of the 46th American Helicopter Society Annual National Forum, Phoenix, AZ, May 1991. N77-27436

Heffernan, R.M., Yamauchi, G.K., Gaubert, M., et al. "Hub Loads Analysis of the SA349/2 Helicopter," Journal of the American Helicopter Society, Vol. 35, No. 1 (January 1990). A90-23936

Stremel, P.M. "Calculation of Flow about Two-Dimensional Bodies by Means of the Velocity-Vorticity Formulation on a Staggered Grid," 29th Aerospace Sciences Meeting, Reno, NV, January 7-10, 1991. A91-21551

Talbot, P.D. "High Speed Rotorcraft: Comparison of Leading Concepts and Technology Needs," Proceedings of the 46th American Helicopter Society Annual National Forum, Phoenix, AZ, May 1991. AVAIL:AIAA

02.07 Wind Tunnel Design and Experimental Techniques

Improved wind tunnel designs and experimental techniques are required to advance understanding of aerodynamic phenomena. Areas of interest include, but are not limited to the following:

- Pressure-sensitive paint and/or coating systems and software to convert video images to quantitative measurements for applications in conventional and cryogenic wind tunnels operating at total pressures from 1/4 to 9 atmospheres and temperatures down to 100 K.
- Low-amplitude, high-frequency dynamic flowfield disturbance measurements techniques.
- Measurement techniques for determining attachment line characteristics and boundary-layer transition location, including the use of IR detection and imaging systems at temperatures down to 100 K, thin-film sensors, and surface coatings.
- Two-space and three-space dynamic flowfield measurements in reacting and non-reacting flows.
- Hardware and software for the measurement and display of fluid-dynamic parameters for reacting and

non-reacting flows. The measured data may be in the form of captured images of parameters measured in a plane in the flowfield or on the model surface using non-intrusive global techniques.

- Reusable propulsion simulators for dynamic testing of powered models capable of providing inlet and exhaust flow conditions such that mass flow, velocities, and pressure ratios closely match scaled full-scale engine requirements.

- Techniques for measuring molecular level mixing of He into cold air in hyper-velocity (Mach 6) flow. Trace species can be considered. Molecular clustering results in enhanced scattering at these conditions.

- Nozzle micropolishing techniques for quiet high-speed tunnels.

- Novel wind tunnel model construction methods. The methods should include processes that can result in significantly reduced fabrication time and/or complexity.

References:

Gartenberg, E.; and Roberts A. S., Jr.: Twenty-Five Years of Aerodynamic Research with IR Imaging, A Survey." Thermosense XIII, SPIE Paper 1467-59, April 1991. N89-24623

Trolinger, James D.; Craig, James E.; and Assazy, Medhat: 'Non-Intrusive Diagnostics for National Aerospace Plane Testing.' AIAA Paper 88-2051, May 1988. AVAIL:AIAA

McKenzie, Robert L.: 'Progress in Laser-Spectroscopic Techniques for Aerodynamic Measurements -- An Overview.' AIAA Paper 91-0059, January 1991. A91-21351

02.08 Wind Tunnel Instrumentation

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

- Non-interfering or non-intrusive transition monitors

- Flow-field visualization in boundary layers

- Quantitative spectroscopic flow-field diagnostics

- Multidimensional, global measurement of surface and flowfield properties

- Hot-wire and hot-film calibration techniques for supersonic and hypersonic flows

- Miniaturized, heat-flux sensors for high heating rates (< 400 Btu/ft^2-sec)

- Miniaturized pressure sensors for 1-50 psi range for high-temperature environments (up to 1500 K) and frequencies up to 25 kHz

- Static and dynamic calibration of pressure sensors for temperatures up to 1500 K and frequencies up to 25 kHz

- Infrared optical fibers for image relay to the IR imagers in the range 2-5 μm and 8-12 μm

- Non-intrusive measurements of temperature and pressure in thin-skin models

- Miniaturized mass spectrometers for gas species identification and measurements

- Non-intrusive measurement of angle of attack. Skin friction measurement in high-temperature and high-speed environments

- Fast (30 frames/sec) and true transfer schemes for CCD camera images.

References:

C. G. Miller: Refinement of an Alternate Method for Measuring Heating Rates in Hypersonic Wind Tunnels, AIAA Journal; Vol. 23 (1985), 810. A85-32625

R. K. Hanson: Combustion Diagnostics: Planar Flow Field Imaging Techniques. 21st International Symposium on Combustion, Combustion Institute of America (1986), 1677-1691. A90-13241

T. D. Finley: National Transonic Facility Model Altitude Systems, NASA Conference Publication No. 3010 (1987), 371-385. X89-13030

Biesiadny, T. J. et al, 'Aerospace 1991,' Aerospace America: The Year in Review, vol. 29, Dec. 1991, p.11-42, 44-70. A92-17923, ISSN 0740-722X

02.09 Aircraft Noise Prediction and Reduction

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

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

References:

Brooks, et. al. "Reduction of Blade/Vortex Interaction Noise Through Higher Harmonic Pitch Control," J. Am. Hel. Soc., Vol. 35, No. 1 (1990), 86-91. A90-23937

Farassat, et. al. "Advanced Turboprop Noise Prediction Based on Recent Theoretical Results," J. Sound Vib., Vol. 119, No. 1 (1987), 53-79. A88-24303

Seiner, et. al. "Dynamic Pressure Loads Associated with Twin Supersonic Plume Resonance," AIAA J., Vol. 26, No. 8 (1988), 954-960. A89-16111

02.10 Propulsion Noise Reduction

A wide range of future aircraft types must employ low-noise, highly efficient propulsion systems at subsonic, transonic, or supersonic flight speeds. This subtopic solicits proposals for research on innovations for any of the objectives listed below. Advanced design approaches for quieter propulsion systems and components (including associated inlets and nozzles) must be supported by analytical and experimental verification methods.

- Aerodynamic and acoustic analysis and design methods; diagnostic or flow visualization methods, including unsteady flows.
- Reduced noise generation with increased efficiency, greater strength, and lower weight.
- Prediction of the steady and unsteady aerodynamics and acoustics of unducted and ducted propellers (ultra-high bypass ratio fans) at both design and off-design conditions.
- Advanced low-noise propeller configurations which make higher subsonic cruising speeds possible.
- Practical and efficient jet and supersonic-fan source noise reduction concepts for supersonic civil transports that will permit federal and local community noise rules to be met with maximum efficiency.

References:

Groeneweg, J. F. "Aeroacoustics of Advanced Propellers," TM-103137, September 1990. N90-26635

Groeneweg, J. F., and Rice, E. J. "Aircraft Turbofan Noise," Journal of Turbomachinery, Vol. 109 (Jan. 1987), 130-141. A87-31144

Groeneweg, J. F., and Bober, L. J. "NASA Advanced Propeller Research," TM-101361, September 1988. N89-15913

03.00 Aircraft Systems, Subsystems, and Operations

03.01 Aircraft Icing Protection Systems

Improved aircraft icing protection remains an important aviation safety objective. This subtopic solicits proposals for innovative concepts and analysis methods which will lead to highly effective and efficient ice protection systems and techniques for helicopters, general aviation aircraft, commercial transports, and military aircraft. Areas in which innovations are sought include:

- Methods that aid in winter operation safety, particularly in-flight ice protection systems that minimize weight and power consumption, and ground deicing and anti-icing fluids that minimize aerodynamic penalties and maximize holdover times.
- Novel experimental techniques that can be conducted in a realistic icing environment, e.g., methods for flow visualization, cloud droplet characterization, droplet trajectory measurements, ice-accretion geometric characterization, ice-accretion aerodynamic penalties measurement, and icing scaling laws for wind tunnel and flight testing.
- Instrumentation to measure supercooled cloud properties. Special emphasis should be placed on taking into account realistic aircraft icing situations.
- Methods to predict ice accretion on aircraft components and the resultant change in aerodynamic performance.
- Methods to predict aircraft performance and handling characteristics in the icing environment during takeoff, landing, and cruising.

References:

Reinmann, J. J., "NASA's Aircraft Icing Technology Program," in Aeropropulsion 1991, NASA. N91-20120

Zumwalt, G. W., et al, "Electro-Impulse De-Icing Testing Analysis and Design," NASA CR 4175, September 1988. N90-10031

Soeder, R. H. and Andracchio, C. R., "NASA Lewis Icing Research Tunnel User Manual," NASA TM 102319, June 1990. N90-23407

03.02 Aircraft Weather Environment

This subtopic requests innovations that minimize aircraft flight hazards associated with and influenced by weather. This should be accomplished by improving predictability, detection, and avoidance of weather hazards and by providing a data base for design criteria. Hazards that are influenced by weather and considered here are heavy rain, winds, wind shear, turbulence, lightning, and wake turbulence. Innovative improvements are needed in airborne equipment suitable for measuring environmental effects and in algorithms for alerting the pilot and crew of impending changes in weather and flight hazard conditions.

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

Airborne sensors for the detection of low-altitude wind shears.

Airport weather monitoring to determine when wake vortex separation constraints may be relaxed, to determine the influence of weather on the persistence and decay of wake turbulence, and to assess the hazard presented by weather-reduced strength vortices.

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

References:

NASA CP 10050, Airborne Wind Shear Detection and Warning Systems, July 1990. N91-11682, N91-11695

Greene, G. C. "An Approximate Model of Vortex Decay in the Atmosphere," AIAA Journal of Aircraft, Vol. 23, No. 7 (July 1986), 566-573. A86-44889

AGARD CP 470, Flight in Adverse Environmental Conditions, September 1989. N90-15401

03.03 Control Concepts for Fixed Wing Aircraft

Modern vehicle design concepts rely heavily on advanced controls techniques to enhance mission performance and efficiency and for flight envelope expansion. Both aircraft and transatmospheric vehicles flight profiles must be carefully tailored and controlled to avoid limits imposed by aerodynamic heating, structural, and propulsion considerations to achieve a broad range of mission objectives. Interactions between disciplines are at unprecedented levels and the use of numerous control effectors, including thrust-vectoring concepts, requires complex flight control systems. Current and future mission requirements dictate that conventional control system design criteria must be re-examined and redefined. Improved synthesis methods must be developed for highly integrated, multidisciplinary, dynamic systems. Among the key challenges will be the need to provide proper interfaces between the airframe, the guidance and control systems, the pilot, and the exterior situation.

This subtopic solicits proposals for innovative advances to the technologies involved, with emphasis on any of the areas listed below.

- Guidance laws and concepts including trajectory optimization.
- Readily implementable, full-envelope, control-law design algorithms.
- Pilot-vehicle interface techniques.
- Utilization of knowledge-based, expert systems, or neural networks concepts.
- Control system design and aircraft performance metrics.
- Reliable onboard aircraft state estimation.
- System identification and parameter extraction.

References:

McRuer, D., Ashkenas, I., and Graham, G. "Aircraft Dynamics and Automatic Control," Princeton University Press, Princeton, New Jersey, 1973. A74-31219

Blakelock, J.H. "Automatic Control of Aircraft and Missiles," John Wiley & Sons, Inc., New York, 1991.

03.04 Fully Automatic Guidance for Rotorcraft

Under visual flight-rule conditions, nap-of-the-earth (NOE) flight in a conventional helicopter is currently extremely taxing for two pilots. Developing a single-pilot, all-weather NOE capability will require significant automation. A major goal is the development of pilot-centered computer and/or sensor concepts for enhanced NOE flight-control capability. The NOE flight regime requires the helicopter to fly below tree tops whenever possible, following a preplanned nominal trajectory. This subtopic solicits proposals for innovative problem solutions in the following two areas:

Range sensors for local navigation and guidance: The ability to estimate range to objects in the proximity of a moving vehicle is essential to the guidance of a helicopter flying a low altitude. It may be necessary to integrate range information from more than one sensor to acquire range over a large field of view.

Neural networks for rotorcraft guidance and control: Neural networks have been advocated as effective means of solving problems in machine vision and robotics. The two key features of neural networks are adaptability and parallelism. These two properties promise networks that can be trained to make decisions at high speed and in a robust manner to perform range estimation and guidance to assure a safe flight among obstacles.

References:

Cheng, V.H.L. and Sridhar, B. "Considerations for Automated Nap-of-the-Earth Rotorcraft Flight," American Control Conference, Atlanta, GA, June 1988. A88-54083

Cheng, V.H.L. and Sridhar, B. "Integration of Active and Passive Sensors for Obstacle Avoidance," American Control Conference, Pittsburgh, PA, June 1989. A89-54083

Sridhar, B., Cheng, V.H.L., and Phatak, A.V. "Kalman Filter Based Range Estimation for Autonomous Navigation Using Imaging Sensors," 11th IFAC Symposium on Automatic Control in Aerospace, Tsukuba, Japan, July 1989. NP0-22238

03.05 Flight Research Sensors and Instrumentation

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

- Temperature, pressure, density, flow angle, and velocity measurements.

- Turbulence measurements up to Mach 0.8.

- Air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach Number, and air density)

- Boundary-layer flows using visualization.

- Surface acoustics employing optical technology.

- Off-surface flow fields, including vortical and separated flow, suitable for CFD code validation for regions from the surface to 50 feet away from the surface.

- Strain on advanced structures at 1700 °C and above.

- Aerodynamic skin friction on flat and curved surfaces and in the presence of streamwise pressure gradients.

- Structural deflections from Mach 3 to Mach 10 using optical methods.

- Thin-film, pressure-measurement technology to provide static and dynamic measurements for low-speed, transonic, or high-speed applications.

References:

Instrument Society of America, Proceedings of the 35th International Instrumentation Symposium. Orlando, FL, May 1-4, 1989. A89-19651

Instrument Society of America, Proceedings of the 34th International Instrumentation Symposium. Albuquerque, NM, May 2-6, 1988. A89-27651

Instrument Society of America, Proceedings of the 33rd International Instrumentation Symposium. Las Vegas, NY, May 3-8, 1987. A88-33051

03.06 Aircraft Flight Testing Techniques

Improved flight-test data acquisition and analysis methods using onboard and/or ground-based, real-time processing are needed. This subtopic solicits proposals for innovative techniques to obtain any of the following types of information:

- Accurate structural modes.

- Several simultaneous aircraft performance parameters, such as lift and drag at extreme angle-of-attack (greater than 50 degrees) during integrated maneuvers.

- Nonlinear characteristics of aircraft and propulsion systems such as longitudinal and lateral directional aerodynamics and inlet flow at elevated angles-of-attack.

- Local flow visualization and characterization to locate vortex flows and laminar-to-turbulent flow transition in a wide variety of flight conditions.

- Identification of various instability modes affecting boundary-layer transition and separation.

- Laser systems for measuring aircraft inlet-flow characteristics, shock position and strength, and engine-exhaust flow conditions for the purposes of inlet and/or engine control and thrust calculation.

- In-flight spectral analysis using onboard digital signal processing of wide-band measurements such as pressures, acoustics and anemometers.

References:

Kuethe, A.M. and Chow, C.Y. Foundations of Aerodynamics, Wiley, 1986. A77-17545

McCormick, B.W. Aerodynamics, Aeronautics and Flight Mechanics, Wiley, 1979. A79-52571

Nelson, Robert. Flight Stability and Automatic Control, McGraw, 1989. ISBN0070462186

03.07 Hypersonic Flight Systems Technology

Emerging concepts for combined cycle engines, airframe-engine integration, lightweight structures, cryogenic, and high-temperature insulations and subsystems may produce the necessary dry-weight fraction and propulsive and aerodynamic performances needed for aircraft flying at more than 5 times the speed of sound. This subtopic solicits proposals for innovative systems-oriented research to support and enable the use of advanced, high priority hypersonic technologies. (This subtopic does not support vehicle design and performance studies.) Areas of interest include:

- Advanced, efficient, three-dimensional numerical design methods for external and internal vehicle and propulsion flow-path analysis using super workstations.

- System optimization methods applicable to optimizing the configuration, propulsion system, airframe-propulsion integration, aerodynamics, thermal management system, trajectories, and dry weight.

- Vehicle sizing and scaling algorithms, i.e., computer programs.

- Computer-aided design software applicable to the design of hypersonic aircraft at the conceptual level.

- Heat exchangers, reactor, and secondary coolant designs for endothermic fuel systems in hypersonic aircraft.

- Advanced propulsion cycles applicable from Mach 0 to 5 or 25 and accompanying design and integration techniques.

- Advanced heat-rejection radiators, compact, high-performance convective heat exchangers and cooling panels, and cooling jackets that simultaneously employ regenerative and transpiration cooling.

- Durable coatings or insulation systems that can significantly reduce the aerothermal heat load to external/internal surfaces including reduction of heat flux to internal engine surfaces.

References:

Pegg, R. J.; Petley, D. H.; Spitzer, C. R.; Jones, S. C.; Martin, J. G.; and Moses, P. L.: Conceptual Design of a Mach 5 Carrier-Based Aircraft. NASA TM 102634, March 1990.
Limited to U.S. Gov't Agencies & Contractors X90-10345

McClinton, C. R.: CFD Support of NASP Design. AIAA 90-3252. Presented at the AIAA/AHA/ASEE Aircraft Design, Systems, and Operations Conference, Dayton, Ohio, September 17-19, 1990. A90-49120, A91-14472

Pinckney, S. Z. and Walton, J. T.: Program SRGULL: An Advanced Engineering Model for the Prediction of Airframe-Integrated Subsonic/Supersonic Hydrogen Combustion Ramjet Cycle Performance. NASP TM 1120, August 1990. AVAIL:CASI

03.08 Very-High-Altitude Aircraft Technology

This subtopic solicits proposals to enable the development of subsonic aircraft for sustained flight above 100,000 feet altitude. The physical properties of the atmosphere change quickly with altitude beyond 80,000 feet, and atmospheric flight at such extreme altitudes poses significant challenges in all aerospace technologies. NASA currently has no subsonic flight capability above 70,000 feet and is interested in a high subsonic-speed, atmospheric-sampling aircraft, manned or unmanned, capable of at least three hours endurance at altitude with a 1,000 lb. payload.

Specific areas of interest for this subtopic include aerodynamics; propulsion; structures and materials; guidance, control, and navigation; aeroelastic flight dynamics; and other technologies related to flight at extreme altitudes. The results sought are design-oriented solutions to specific problems or design tools. Proposals for studies involving the development of specific design configurations are not of interest unless they are to determine the feasibility of innovative concepts that have not been previously reported in the open literature.

References:

NASA CP 10041, "Global Stratospheric Change: Requirements for a Very-High Altitude Aircraft for Atmospheric Research Workshop," Truckee, CA, July 15-16, 1989. N90-14220

Chambers, Alan, and Reed, R. Dale. "A Very-High Altitude Aircraft for Global Climate Research," The Magazine of the Association for Unmanned Vehicle Systems, Vol. 8, No. 3 (1990), 14-19. AVAIL:ESL

03.09 Aeronautical Human Factors and Flight Management

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

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

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

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

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

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

References:

Boff, K.R. & Lincoln, J.E. Engineering Data Compendium: Human Perception and Performance, Harry G. Armstrong Aerospace Medical Research Facility, Vols I-III (1988).
N88-28630, N88-28631, N88-28632

Degani, A. & Weiner, E.L. Human Factors of Flight-Deck Checklists: The Normal Checklist, NASA Contractor Report 177549, May, 1990. AVAIL:CASI

Elkind, J.I., Card, S.K., Hochberg, J., et al. Human Performance Models for Computer-Aided Engineering, New York: Academic Press, 1990. ISBN0122365305

Irving, S. & Mitchell, C.M. Report on the CHI 90 Workshop on Computer-Human Interaction in Aerospace Systems, SIGCHI Bulletin, Vol. 23 No. 10 (January 1991), 17-23. AVAIL:ESL

Weiner, E.L. & Nagel, D.C. Human Factors in Aviation. New York, Academic Press, 1988. A89-34431

03.10 Testing and Verification of Flight-Critical Systems

Accurate and reliable methods for reducing the time required to validate critical systems are needed for design and modification of modern aircraft. The validation of critical systems in modern aircraft is becoming more complex. Efforts to improve the efficiency of testing critical systems have made significant strides in recent years, but the increased complexity of the systems continues to increase the amount of testing required for integrating system changes. This subtopic solicits proposals for innovations which are expected to yield tools or methods to accomplish some of the objectives listed below that are applicable to the design and modification of modern aircraft flight safety critical systems.

- Identify with a high degree of confidence the areas of hardware, software, functions, flight envelope, overall aircraft response, etc. that are affected by a particular change and reduce the testing required by ensuring that performance of the system and/or aircraft in specific areas has not been affected by a change to the system.

- Limit and identify the possible effects a hardware or software component has on the aircraft performance.

- Provide capability to perform aircraft systems sensitivity analysis when using variable performance system and/or subsystem components.

- Provide a higher degree of automation in the areas of test definition, test performance and analysis of test results.

- Produce overview functional diagrams from detailed system descriptions or low-level component models.

- Provide accurate, on-line documentation for complex, highly integrated systems that allows documentation to be organized by each system engineer to best suit the particular application.

References:

Sitz, Joel R. and Vernon, Todd H. "Flight Control System Design Factors for Applying Automated Testing Techniques," NASA TM 4240, 1990.

Chacon, Vince, Pahle, et al. "Validation of the F-18 High Alpha Research Vehicle Flight Control and Avionics Systems Modifications," NASA TM 101723, 1990. N90-28542

Mackall, Dale and Allen, James G. "A Knowledge-Based System Design/Information Tools for Aircraft Flight Control Systems," NASA TM 101704, 1989. A90-10491, N90-13990

03.11 Aerospace Vehicle Flight-Characteristics Simulation

More rapid, accurate, and reliable methods for predicting flight characteristics of advanced aerospace vehicles are needed for design, for interpreting flight-test results, and for ensuring safety during flight envelope expansion. In particular, accurate predictions of aeroelastic and aero-servo-elastic stability parameters involving interactions among numerous system characteristics, e.g., structures, aerodynamics, and control systems, are essential.

This subtopic solicits proposals for novel, innovative, multidisciplinary, non-linear systems simulation techniques for advanced aerospace vehicles. Projects are expected to yield improved design tools to accomplish some of the objectives listed below, which are applicable to designs of advanced vehicles including the National Aerospace Plane.

- Prediction of pressure and thermal load distributions on the aerospacecraft surfaces, or similar distributions due to propulsive forces, by employing accurate CFD techniques.

- Effective numerical algorithms for multi-disciplinary systems-response analysis with possible adaptive grid-generation at selected time steps.

- Automated three-dimensional mesh-generation techniques.

- Use of high-performance computing machines, including parallel processors for integrated system analysis and pilot-in-the-loop simulations.

- Use of high-performance computer graphics for out-the-window displays with texture and level of detail varied to provide depth perception.

References:

Gupta, K.K., Brenner, M.J., and Voelker, L.S. "Integrated Aeroservoelastic Analysis Capability with X-29A Comparisons," AIAA Journal of Aircraft, Vol. 26, No. 1 (January 1989), 84-90. A89-24311

04.00 Materials and Structures

04.01 Coatings on Fibers for Ceramic and Intermetallic Composites

Coatings on continuous fiber reinforcements are needed in order to assure optimum structural and environmental performance of advanced intermetallic and ceramic matrix composites. These composite systems offer high technical payoff in terms of weight savings and performance for a variety of propulsion and power systems for aerospace and terrestrial applications. Since life and durability of these composite materials are strongly controlled by the nature and stability of the fiber-matrix interaction, this subtopic is soliciting proposals for innovative approaches in the processing, evaluation, and testing of fiber coatings. Of particular concern are coatings that reduce or eliminate problems associated with interfacial reaction, CTE-mismatch between fiber and matrix, and fiber environmental degradation. In particular for ceramic composites coatings that offer better performance than the current graphite and boron nitride coatings are solicited. In the processing area, innovative cost-effective production approaches are required for multifunctional and structurally graded coatings that address these property needs. Finally in the evaluation and testing areas, there is a strong need to characterize the thermophysical and thermostructural properties of fiber coatings, especially with regard to internal stresses that can develop during coating and composite processing and during composite service.

References:

Everrett, R. K., Skowrorek, C. J., Pattnaik, A., Hahn, T. and Krause, D., "Diffusion Barriers and Compliant Layers for Fibers in Titanium Aluminide Matrices", 13th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 18-21, 1989, p.557-567. X90-10253 Limited by ITAR

Misra, A. K., "Theoretical Analysis of Compatibility of Several Reinforcement Materials with NiAl and FeAl Matrices", 13th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 18-21, 1989, p.207-225. X90-10231 Limited by ITAR

Larkin, D. J., Interrante, L. V. and Bose, A., "Application of Chemical Vapor Deposited Yttria for the Protection of Silicon Carbide Fibers in a SiC/Ni$_3$Al Composites", Journal of Materials Research, Vol. 5, No. 11, 1990, p.2706-2717. ISSN 0884-2914

04.02 Processing of High-Temperature Composites

A deterrent to the widespread use of high temperature composites in aeropropulsion and commercial applications is low and/or variable properties due to flawed microstructures. This is particularly true for intermetallic composites and ceramic composites. The nature of the flawed microstructures varies widely; e.g., pores, cracks, undesirable phases, inhomogeneities in grain-size, phase distribution and/or fiber distribution, damaged fibers, reacted fibers, uncontrolled fiber-matrix interface quality, and contaminated surfaces. It is important that methods be developed to improve consolidation processing control such that these flawed microstructural features can be eliminated or minimized.

This subtopic solicits proposals for new, imaginative, and innovative approaches to composite consolidation and/or subsequent processing techniques to produce intermetallic and ceramic matrix composites with improved properties, quality, and homogeneity.

References:

Ceramic Engineering and Science Proceedings, Parts 1 and 2, American Ceramic Society, July-August, 1991.

Buckley, J. D., ed., 14th Conference on Metal Matrix, Carbon and Ceramic Matrix Composites, Parts 1 and 2, Cocoa Beach, FL, Jan. 17-19, 1990. Part 1: X91-10103, NASA-CP-3097-PT-1 Part 2: X91-10125, NASA-CP-3097-PT-2 Limited by ITAR

04.03 Computational Structural Methods for Aeropropulsion

Computer simulation of the complex structural interactions that occur within the hostile, thermomechanical loading environment of aerospace propulsion machinery is an extremely demanding computational problem. Many analyses, particularly complete propulsion system simulations, may result in extreme demands on computer resources, or may require drastic simplifications of the analysis model. Advances in computer science and technology, such as multiprocessor computer architectures, are providing new capabilities that will not only relieve some of these problems, but will allow costly experiments to be replaced with numerical simulation. Additionally, these advances will provide opportunities to accelerate time-intensive simulations, achieve multivariable optimization, and perform realistic probabilistic designs.

This subtopic solicits proposals for novel, innovative techniques that exploit emerging computing hardware architectural concepts, or convert existing capabilities to use these new computer systems, in achieving any of the following objectives:

- Improved aeropropulsion structural and dynamic analyses, and advanced methods for analysis and design optimization. Analysis of large interconnected multi-component systems.

- Determination of the applicability of particular computer architectures for solving specific aeropropulsion structural analysis and optimization problems; the ability of new methods and computer hardware such as neural net technology to replace the need for many re-analyses.

- Exploitation of new machine architectures to solve problems in aeropropulsion system structures that often have cyclical symmetry, nonlinear response, and are subjected to high temperatures, operate with high-speed rotations, and exhibit fluid-structure coupled response.

- Portable programming environments for parallel processors which handle machine-dependent aspects of their architectures. Algorithms that are developed under these environments should be equally applicable to other parallel machines with only minor changes to the code to obtain peak computing performance. Appropriate tools such as facilities for interactive debugging and time profiling of code are needed for these portable environments as well.

References:

Lawrence, C. and Kiraly, L. J. Structural Dynamics Branch Research and Accomplishments for FY89, NASA Technical Memorandum 102488, July 1990. N90-26373

Standley, H. M. A Very High Level Language for Large-Grained Data Flow, 1987 Computer Science Conference (proceedings), St. Louis, MO, February 17-19, 1987. 90-70739

Janetzke, D.C. and Murthy, D.V. Efficient Computation of Aerodynamic Influence Coefficients for Aeroelastic Analysis on a Transputer Network, NASA Technical Memorandum 103671. AVAIL:CASI

04.04 Computational Methods for Aeropropulsion Materials Processing

As materials become more complex, their performance depends to a greater extent on processing. New materials and processes are required and are under development for the manufacture of metal, ceramic, and polymer-matrix composites or their component fibers for aeropropulsion applications. Understanding and controlling these processes can be improved by numerical simulation and process optimization techniques.

This subtopic solicits proposals for innovative applications of the numerical modeling of complex fabrication processes used in the manufacture of advanced composite materials for aeropropulsion. Examples of these processes include plasma-spray deposition, directional solidification, infiltration, physical and chemical vapor deposition, pyrolysis, and many others. Of particular interest is the development of simulation capabilities that will elucidate the interaction of transport phenomena during processing (e.g., fluid, heat, and mass transport) and microstructure development. That is, we seek advanced computerized simulations that will provide cause and effect relationships among transport phenomena (fundamental process parameters) and the resulting microstructural features of the fabricated composites. Other capabilities may be directed toward process optimization methodologies based upon either statistical or deterministic process models. These may include expert systems or similar approaches together with process modeling capabilities. Materials processing models that could be incorporated into standard available transport codes are especially encouraged.

References:

Young, G. W. and Chait, A., "Surface Tension Driven Heat Mass, and Momentum Transport in a Float Zone," J. Crystal Growth, Vol. 106 (1990), 445-466. ISSN 022-0248, IEEE A91011862

Pines, V., Zlatkowski, M., and Chait, A., "Time Development of a Perturbed Spherical Nucleus in a Pure Supercooled Liquid. Part II: Nonlinear Development," Physical Review, A. 42, No. 10 (1990), 6137-6150. A91-16105

Gokoglu, S., Kuczmarski, M., Veitch, L., et al. A Numerical and Experimental Analysis of Reactor Performance and Deposition Rates for CVD on Monofilaments, Proceedings of the 11th International CVD Conference, Seattle, 1990, The ElectroChemical Society. N91-14500

04.05 Cyclic Oxidation Behavior of Materials for Aeropropulsion

Resistance to oxidation for prolonged times at elevated temperatures places a severe demand on the requirements of materials in both advanced aeropropulsion and commercial applications. Further, our ability to measure and predict material performance under these conditions needs great improvement. The usual approaches to this problem have been to evaluate materials under isothermal conditions, i.e., long time continuous exposure to high temperatures. However, in reality, most service conditions are of a cyclic nature, i.e., varying temperatures with time such as in start-up and shut-down and accelerate and decelerate cycles. This cyclic exposure subjects material/coating systems to severe thermal stresses that can crack or spall protective coatings and/or surface scales. Cyclic oxidation is difficult to evaluate in a quantitative manner due to the large number and range of variables, e.g., time-temperature cycle frequency, amplitude, and shape.

This subtopic seeks innovative approaches to the measurement and prediction of material performance under cyclic oxidation conditions appropriate for advanced gas turbine engines. Innovative approaches to experimental verification of existing behavior prediction models and/or of new models are sought. Experimental efforts should be devoted to advanced materials such as ceramics and/or intermetallics. Monolithics and/or composites may be considered as well as coated and uncoated conditions.

References:

Lowell, C. E., Barrett, C. A., Palmer, R. V., Auping, J. V. and Probst, H. B., "COSP: A Computer Model of Cyclic Oxidation", Oxidation of Metals, Vol. 36, Nos. 1 and 2, 1991, pp. 81-112. ISSN 0030-770X

Probst, H. B. and Lowell, C. E., "Computer Simulation of Cyclic Oxidation", Journal of Metals, Vol. 49, No. 10, Oct 1988, p.18-21. A89-29295, ISSN 0148-6608

04.06 Adaptive Control Techniques for Fabricating and Testing Metallic Materials

Real-time measurements, feedback, and/or control techniques are required to optimize fabrication practices and testing information for high temperature metallic materials. These materials include metal matrix composites for airframe structural applications. The development of new critical materials could be enhanced and accelerated with the application of reliable sensors, instrumentation, and control systems integrated into fabrication and testing procedures. Innovative approaches to process control and testing instrumentation are sought in the following areas:

Metal powder and metal matrix composite consolidation; temperature, pressure force on work part, platen motion, change in volume or shape or work part.

Thermal spray metal deposition; spray parameters, deposited material temperature, thickness, substrate temperature.

High temperature materials testing; test specimen temperature, non-intrusive techniques for measuring strains, strain rates, deflections of materials under load at temperatures up to 1800°F, furnace energy input parameters, environmental parameters such as pressure, humidity, chemistry.

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

References:

Bird, R. K. and Brewer, W. D., "Fabrication and characterization of SCS-6/Ti-1100 Composites", 15th Conference on Metal Matrix, Carbon, and Ceramic Matrix Composites, Cocoa Beach, FL, January 1991. X92-10156 Limited by ITAR

Singleton, O. R. and Royster, D. M., "Laboratory Produced P/M Aluminum 2XXX + Zr Sheet," Journal of Metals, vol. 40, Nov. 1988., p. 40-43. A89-20976, ISSN 0148-6608

Kennedy, J. R. et al, "Effect of Thermal Exposure, Forming, and Welding on High-Temperature, Dispersion-Strengthened Aluminum Alloy: Al-8Fe-1V-2Si. Final report, May 1989-June 1991. NASA-CR-187575 N91-32200

04.07 Oxidation-Resistant, Carbon-Carbon Composites for Aerostructures

Innovations are needed in the area of thin (<0.10 inch), oxidation-resistant, carbon-carbon composites for use as airframe thermal protection material or for hot structural applications on advanced hypersonic vehicles. The service environment of primary concern encompasses the temperature range from 550°C to 1650°C and the pressure range from one atmosphere in air to vacuum. Specific areas in which innovations are needed are:

Thin, oxidation-protective coatings having a good match in coefficient of thermal expansion to the carbon-carbon substrate should also be strongly adherent to the substrate.

Durable, moisture-resistant, protective glassy sealants and overcoat glazes which are not degraded by ground-level humidity conditions of 80°F and 95 percent relative humidity.

Molecular-level matrix inhibitors affording effective substrate oxidation protection in the event of oxygen penetration of the primary oxidation barrier coating.

References:

Maahs, H. G., ed. "Oxidation-Resistant Carbon-Carbon Composites for Hypersonic Vehicle Applications," Proceedings of the Workshop Held at NASA Langley Research Center, Hampton, VA, Sept. 15-16, 1987. NASA CP-2501, 1988. X88-10334

Maahs, H. G. "Carbon-Carbon Composites: Emerging Materials for Hypersonic Flight," The World and I, (June 1989), 300-307. N90-26080

04.08 Nondestructive Evaluation of Material Properties

Innovations are solicited for characterizing material properties using nondestructive evaluation (NDE) techniques. Traditionally, NDE has been a final check-out procedure for quality assurance. 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 and structures; reduced costs in developing and maintaining aerospace systems; and means to make informed decisions for safe and economic life extension of aging systems.

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

References:

Madaras, E. I., Winfree, W. P., Smith, B. T. Heyman, J. S., "Detection of Bondline Delaminations in Multilayer Structures with Lossy Components, Proceedings of IEEE Ultrasonics Symposium, 1987. N88-21256

Heyman, J. S., "NDE Research for Aging Aircraft Integrity," Proceedings of IEEE Ultrasonics Symposium, Honolulu, HI, December 4-7, 1991. AVAIL:AIAA

Nath, S., Shim, Y. K., Lord, W., "Boundary Integral and Finite Element Simulation of Electromagnetic NDE Phenomena," Review of Progress in QNDE, Vol. 9A, edited by D. O. Thompson and D. E. Chomenti, pp. 303 (1990). ISBN 0070462186

04.09 Alloys for Space Propulsion Systems

Alloys used in conventional liquid propulsion systems frequently require protective coatings, weld overlays, and usage limitations to combat environmental effects (oxygen compatibility and hydrogen embrittlement). Innovative approaches are sought for materials and coatings for implementing advanced propulsion concepts in the following areas:

- Models to predict environmental effects that include thermodynamic and metallurgical techniques to be employed as precursors to mechanical testing.
- Thermal processing and mechanical schedules to optimize resistance to environmental effects.
- Non-intrusive coating methods for damage-resistant materials that are amenable to complex geometries.
- Porous refractory materials are also sought for beamed-energy propulsion systems such as solar-thermal and solar-electric propulsion designed for transplanetary conditions.
- Mathematical modeling of pore structure as a precursor to thruster design for high specific impulse and high thrust.
- Iridium-coated rhenium (Ir/Re) chambers for next-generation rocket engines.
- Advanced materials for temperatures in excess of 2200°C for use with highly energetic propellants. Proposals should focus on high-temperature, highly oxidation resistant materials and fabrication processes for application to advanced rocket engines.

References:

G. M. Jenkins, The Systems Approach, Systems Behavior, ed. J. Beishon and G. Peters, Open University Press, 1972.

Lackey, W.J., Stinton, D.P., Cerny, G.A., et al. "Ceramic Coatings for Heat Engine Materials - Status and Future Needs," ORNL-Technical Memorandum-8959, Dec. 1984. N85-29053

Shoji, J.M., Perry, F.J., Lim, D.P., and Pard, A.G., "Windowed Porous Material Absorption Concept - A New Solar Thermal Propulsion Concept", 1986 JANNAF Propulsion Meeting, Vol. 1, p. 119-126. N87-26098

04.10 Lubricants for Aeronautics and Space Applications

Advanced aeronautics and space missions and service requirements place stringent demands on lubrication for surfaces and mechanical components. Innovative, new concepts for both liquid and solid lubricants for dependable, long-life service under strenuous operational environments are sought in the following areas; with emphasis on development, testing and processing:

Long-life, dry-film lubricants and self-lubricating composites for applications requiring long-term survival in space environments without degradation of lubricating properties. Of special interest are mechanism lubricants for use in long-duration low earth orbit (up to 30 years in Space Station Freedom, for example). These lubricants should emphasize resistance to degradation under exposure to atomic oxygen, which is known to cause rapid degradation of most organic materials and dry film lubricants having organic binders.

Liquid lubricants for long-term space applications that exhibit low creep, low volatility, and stability under all exposures.

Wide-temperature solid-lubricant materials capable of operating to 800°C to 1000°C for advanced aeronautics and space applications.

Liquid lubricants for advanced, gas turbine engine applications having bulk oxidation stabilities from 330°C to 400°C.

References:

Zaretsky, E.V. 'Liquid Lubrication in Space,' Tribology Int., Vol. 23, No. 2 (April 1990), 75-93. N90-28063

Roberts, E.W. 'Thin Solid Lubricant Films in Space,' Tribology/Int., Vol. 23, No. 2 (April 1990), 95-104. EI 881004257

Jones, W.R., Jr., et al. "The Preparation of New Perfluoroether Fluids Exhibiting Excellent Thermal-Oxidative Stabilities," I&EC Research, Vol. 27 (1988),1497-1502. N86-25475

Visentine, J.T. and Whitaker, A.F., NASA TM-100351, Material Selection Guidelines to Limit Atomic Oxygen Effects on Spacecraft Surfaces. X89-10321

04.11 High-Performance Polymers for Aircraft Applications

This subtopic solicits proposals for innovations in high performance, high temperature polymers for structural and functional aerospace applications. Emphasis should be on synthesis and development of high performance, high temperature polymers which display exceptional properties as films, coatings, and adhesives. These polymers should also be easily processed and cost-effective.

Films and Coatings: High performance polymers are being developed for long-term (60,000 to 120,000 hours), high temperature (150°C to 350°C) performance. Innovations are sought for novel materials than can perform in aircraft that experience temperatures in the 200°C range or in the hostile environments of space (radiation, atomic oxygen, etc.). New/improved chemistry or new formulations of state-of-the-art polymers are needed to meet requirements such as high temperature performance, toughness, easy processability, and environmental durability.

High-Performance Adhesives: High performance adhesives are being developed for long-term (60 K to 120 K hours), high temperature (150°C to 230°C) supersonic performance. Innovations are sought for the high performance polymers required to bond metal to metal, metal to composite, composite to composite, films to various substrates for use under high-speed aero environmental conditions.

References:

Lee, S. M., ed. International Encyclopedia of Composites. New York, VCH Publishers, NY, 1990. ISBN 0895732904

04.12 Composite Materials for Aircraft and Space Applications

This subtopic solicits proposals for innovations in polymeric based matrix composite materials that offer significant structural weight savings and enhanced performance in airframe and spacecraft structures. Emphasis should be on development of new products and product forms.

Aircraft Structures: High-performance composites are being developed with high structural efficiency and reduced costs for airframe structural applications on subsonic and supersonic aircraft. Innovations are sought in the following specific areas: textile preforms, low-cost fabrication technology, automated process control for composite fabrication, low-cost tooling for various fabrication methods such as thermoforming, lightweight core materials for high-temperature sandwich construction, polymer based matrices, and reinforcement fibers from organic or inorganic precursors.

Spacecraft Materials: Ultra-high-performance composites will be utilized in future spacecraft. Innovations are needed in the following areas: lightweight core materials for precision sandwich space structures such as reflectors and optical benches, ultrahigh performance composites, fabrication technology for high precision structural subelements, concepts for "smart materials" to provide on-orbit control of space structures.

References:

Lubin, George. Handbook of Composites. New York, Van Nostrand Reinhold Company, NY, 1982. A82-42651

Lee, S. M., ed. International Encyclopedia of Composites. New York, VCH Publishers, NY, 1990. ISBN 0895732904

04.13 Adaptive, Smart Aerospace Structural Components and Materials

The integration of adaptive, intelligent and smart materials in structural components for aerospace applications are a significant challenge for future missions. Known smart, intelligent and adaptive materials include, but are not limited to, piezoelectric ceramics and polymers, electro-rheological fluids, magnetostrictive materials, and shape-memory alloys and polymers. Structural concepts of interest are those which can produce predictable changes in geometry and/or mechanical properties in response to a controlled command. An adaptive, smart and intelligent system contains an actuator, sensor and processor. Improvements are needed in compactness, toughness, load capability, motion and frequency bandwidth, reduced driving power, and simplicity of operation for the intended applications.

Spacecraft applications include instrument pointing, tracking and/or isolation, launch load alleviation, antenna shaping and/or reshaping, vibration suppression or damping of platform jitter, thermal deformation compensation, and thermal snap of solar arrays. Operating environments include vacuum, large temperature changes, cosmic radiation, low available power, and dynamic disturbances from attitude control systems and/or multiple tracking payloads.

Aircraft applications include motion control of winglets and wing leading and trailing edges, control of wing surface for flutter suppression, engine vibration reduction and acoustic noise reduction for improved passenger comfort. Aircraft operating environments are atmospheric with wide dynamic pressure and climatic variations.

References:

Proceedings of the AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Long Beach, CA, April 2-4, 1990. AIAA Conference Publication CP-902, Part IV-Structural Dynamics II, 18 Papers on Adaptive Structures, pp 2221-2380. A90-29409

04.14 Space Structure Dimensional Stability

The objective of this subtopic is to identify new and novel materials that will provide structures operating in a space environment with increased dimensional stability. Ultra-high dimensional stability is required for elements of active systems that are used to maintain the relative vertex positions of retro-reflectors, triangulation bases, Ronchi rulings, and sensor mounts. Several proposed NASA interferometric missions have material property requirements of: a coefficient of thermal expansion (CTE) less than 10^{-8}/K; temporal stability (strain) better than 0.1 part-per-billion (ppb) per day; and radiation stability (strain) such that the part does not change its size more than 0.1 ppb when exposed to 1 rad of ionizing radiation. All of these properties are to be maintained for a 10-year mission life. During a mission, these materials may be exposed to as much as 10^8 rad. Specific areas of innovation sought include:

- Non-contact metrological techniques with angstrom and sub-angstrom accuracy.
- Multi-axial systems for the measurement of long term dimensional stability of optical and structural materials.
- Novel materials with improved dimensional stability.

References:

Dolgin, B. P., Moacanin, J., O'Donnell, T., "Theoretical Limits of Dimensional Stability for Space Structures," SPIE Proc. 1533, pp. 229-239 (1991). Presented at the SPIE's Dimensional Stability II conference of the 36 Annual International SPIE Symposium, July 1991.

Coulter, D., Dolgin, B. P., Rainen, R., O'Donnell, T., "Materials Technology for SIRTF," Presented at the Infrared Technology XVII conference of the 36 Annual International SPIE Symposium, July 1991.

Johnson, S.W., and Wetzel, J.P., eds., "Engineering, Construction, and Operations in Space II," Proceedings of Space 90, Albuquerque, NM, Apr. 22-26, 1990. American Society of Civil Engineers. A91-27576

04.15 Active Truss Strut for Interferometric Applications

Large, high-precision structural systems, once deployed in space these systems will have to maintain very high dimensional stability, on the order of nanometers over tenths of meters. One way of meeting these stringent requirements is by developing active structural systems. The implementation of such a system will require the integration of high precision sensing and actuation devices into the structure. An example of would be an active structural member such as a truss member that would sense relative deformation along its length, both statically and dynamically, and then exert a corrective force.

Innovative designs are solicited for an active truss strut member that could be used in interferometric applications in space. Typical requirements are: travel for coarse adjustment ±1 cm, vernier adjustment capability of ±100 microns, force level ±500 newtons, relative displacement measurement accuracy to 1 nanometer, force measurement accuracy to 0.1 newton, and a length of about 30 cm. The design should minimize power, voltage, mass, and hysteretic effects and maximize repeatability under static and dynamic loading in the frequency range from 0 to 100 Hz. The static position of the active member must be maintained and must withstand the static load without the application of power. The member must retain its structural integrity in the event of a mechanical or electronic failure of the actuation mechanism.

References:

Fanson, J.L., Blackwood, G.H., and Chu, C.C., "Active Member Control of Precision Structures," AIAA Paper No. 89-1329. Proceedings of the 30th Structures, Structural Dynamics and Materials Conference, Mobile, AL, April 3-5, 1989. AIAA Paper 89-1329. A89-30806

Anderson, E.H., Moore, D.M., Fanson, J.L., and Ealey ,M.A., "Development of an Active Truss Element for Control of Precision Structures," Optical Engineering, Vol. 29, No. 11, November 1990, pp. 133-1341. A91-15172, ISSN 0091-3286

Takahara, K., Kuwao, F., Shigehara, M., Katoh, T., Motohashi, S., and Natori, M., "Piezo Linear Actuators for Adaptive Truss Structures," Proceedings of the 1989 ASME Winter Annual Meeting, San Francisco, CA, December 10-15, 1989. ASME Publication Adaptive Structures, AD-Volume 15. pp. 83-88. A91-38835

04.16 Spacecraft Structures and Mechanisms for Manned Spacecraft

Innovative technology advances are sought to enable or improve the design, development, and in-space assembly of structures and mechanisms for future manned space missions. Vehicle designs are expected to include structural concepts that are light weight, require minimum crew assembly time, are easily repairable on-orbit and that can readily withstand the severe environments (including meteoroid and debris hazards). This subtopic solicits design innovations including, but not limited to, the following:

- Lightweight structural concepts for manned spacecraft for planetary missions.
- Lightweight structural concepts for planetary surface systems including assembly and construction concepts.
- Structural concepts for thermal protection systems for planetary entry vehicles.
- Concepts for devices to enable the deployment, assembly and in situ placement of structural components for manned planetary spacecraft and surface systems.

References:

NASA Conference Publication 3034-PT-1, Computational Methods for Structural Mechanics and Dynamics, Part 1, 12. N89-24638

NASA TP-2893, Practices in Adequate Structural Design, 6. N89-18504

NASA SP-7046(20), Technology for Large Space Systems: A Bibliography with Indexes (supplement 20), 6. N89-26037

04.17 Space Mechanical Components

Mechanical devices, robotic manipulation, and moving parts in general are vital to current and future space missions. Failures or degradation of basic mechanical components, such as bearings, gears, and seals, can compromise mechanism system performance or interrupt spacecraft operation. Problems often stem from limitations inherent to the components themselves, as well as from system performance requirements and the rigors imposed by space. Innovations in mechanical component concepts, designs, and technology are sought to solve various mechanism shortcomings. Advanced components, all of which require long life, high performance, and improved reliability, include:

Bearings, seals, traction drives, speed reducers, cryogenic-compatible devices, and other components which reduce vibration and/or expand the operating envelopes of rotating space machinery.

Bearing and actuator design concepts to reduce torque ripple and increase bandwidth of high-precision (e.g., pointing) mechanisms.

Basic mechanical components (i.e., **bearings, actuators, drives)** which can be integrated into equipment or vehicles designed for lunar/martian surface operation. Required characteristics include robustness, low or zero maintenance, efficiency, and tolerance to the environment.

Inherently clean (no outgassing, absorption, or particle generation) components for use in non-contaminating mechanisms.

Mechanical components which, at the component level, have inherent redundancy or imbedded self-diagnostics.

New test capabilities and analysis tools for rapid, representative, and verifiable accelerated testing of long-life designs.

Mechanisms for providing long-term, in-service lubrication (but not the lubricants themselves) or relubrication of mechanical components.

References:

Loewenthal, S. L. and Schuller, F. T.: "Feasibility Study of a Discrete Bearing/Roller Drive Rotary Joint for the Space Station," NASA TM-88800, July 1986. N80-30206

Steinetz, B. M., Rohn, D. A., and Anderson, W. J.: "Evaluation of a High Torque Backlash-Free Roller Actuator," 20th Aerospace Mechanisms Symposium, NASA CP-2423 (revised), 1986, pp.205-230. N87-16336

04.18 Special Purpose Materials for Space Applications

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

Marking inks having good chemical abrasion resistance.
Thread-locking compounds with a range of shear strengths.
Urethanes, silicones and epoxies cured by use of UV light and resistant to chemical attack and abrasion.
O-ring and gasket materials having low shrinkage when cooled to 100°C, for use in high vacuum and pressurized systems.
Epoxy adhesives for bonding metals and composites, for use above 250°C.
Laminated printed circuit-board materials with tailored coefficient of thermal expansion to alleviate thermal fatigue of soldered joints.
Thermally conductive, flat black paint for thermal control, for use in the range -100°C to -196°C.

References:

Griffin, Michael D. and French, James R. 'Space Vehicle Design,' AIAA Series, Washington, DC. AVAIL:AIAA

'Fracture Control Safety Policy and Requirements for Payloads Using the Space Transportation System,' published by NASA, NHB 1700.7B. AVAIL:CASI

04.19 Materials to Withstand Space Environmental Effects

Spacecraft materials of the future must be stable when exposed to the combined environmental effects of space for extended periods of time, in some instances exceeding 30 years. The combined environment that can significantly degrade materials includes vacuum, thermal cycling, solar ultraviolet electromagnetic radiation, high energy protons and electrons, micrometeoroids, and, in low earth orbit, neutral atomic oxygen and orbital debris. Innovative materials must be developed to meet this challenge.

Atomic oxygen protective coatings for spacecraft materials that are stable in the combined space environment, low offgasing, non-flammable, and non-toxic.

Thermal control coatings that are stable when exposed to the synergistic effect of the natural space environment; including spacecraft induced contamination.

Materials and instrumentation for micrometeoroid and/or debris protection, impact detection, and damage evaluation.

References:

Teichman, L.A. and Stein, B.A. eds. 'Space Environmental Effects on Materials Workshop,' NASA Conf., Hampton, VA, Pub. 3035, 1988. N89-23528

Allcock, H.R. 'Inorganic Polymers,' Scientific American, Vol. 230, No. 3 (1974), 66. AVAIL:AIAA

Miller, E.R. ed. NASA Technical Memorandum 86461, 'Induced Environment Contamination Monitor, Preliminary Results from the Spacelab 1 Flight,' MSFC, Aug. 1984. N84-33461

Leger, L. J., 'Oxygen Atom Reaction with Shuttle Material at Orbital Altitudes, NASA TM-58246, May 1986. A83-16503

04.20 An Analytical Tool for Inflatable Antenna Structures

A new class of space structures, referred to as inflatable, deployable space structures, is currently under development for numerous antenna applications. Such structures have great potential for providing low cost, light weight, and high deployment reliability as compared to the conventional mechanical deployable concepts. Since these structures consist of pressurized membranes, specialized analytical tools are required for the characterization of their static and dynamic behavior on orbit.

The development of a general purpose tool for the analysis of inflatable antenna structures is solicited. The goal of such a tool is the prediction of structural behavior; that is, static and dynamic responses of an off-axis parabolic antenna. The structural model has to account for such variables as nonlinear material properties of the membrane, geometric nonlinearities, internal pressure and local stiffening effects. Responses are to be calculated due to arbitrary static, thermal and dynamic loading conditions.

References:

Thomas, M. and Friese, G. J. 'Pressurized Antennas for Space Radars', Proceedings of the AIAA Conference on Sensor Systems for the 80's, December 1980, pp. 65-71. A81-13361

Grossman, G., 'Analysis of Rim Supports for Off-Axis Inflatable Reflectors, Parts I and II, 'ASCE Journal of Aerospace Engineering, Vol. 4, No. 1, January 1991, pp. 47-77. A91-20972, ISSN 0893-1321

Nieboer, J.J., Wismans, J., and de Coo, J.A., 'Airbag Modelling Techniques', SAE Paper No. 902322, 1990 SAE Abstracts, pp. 1855-1869.

Hoffman, R., Ulrich, D., Protard, J. B., Wester, H., Jaehn, N., and Scharnhorst, T., 'Finite Element Analysis of Occupant

Restraint System with PAM-CRASH," SAE Paper No. 902315, 1990 SAE Abstract, pp. 1901-1912.

04.21 Castable Aluminum and Magnesium Matrix Composites

Graphite-magnesium and graphite-aluminum are valuable metal matrix composite (MMC) materials for space structural components such as mechanical joints and connecting mechanisms. These typical MMC materials provide very high specific strength and stiffness properties with a near zero coefficient of thermal expansion. They also have excellent resistance for long term exposure to space environment MMC products are still, however, prohibitively expensive for most applications. This problem has recently driven the MMC component development toward various inexpensive casting processes when compared with MMC components produced by traditional methods 'such as powder metallurgy, thermal-arc plasma spray, and diffusion bonding. This subtopic solicits innovations directed at the following:

Castable aluminum and magnesium composite methods in which typical defect-free MMC components can be cast with near-net-shape dimensional tolerance and provide high production rate capabilities at low cost and with less labor. These MMC mechanical components will be made of continuous, chopped or particulate graphite reinforcement infiltrated either with aluminum or magnesium metal matrix. Castable MMC methods must be able to produce very complex, shaped, structural components.

Graphite fiber preform and foam development for the above castable MMC methods so that very complex-shaped, fibrous preform and foam can be achieved. These fibrous preforms can be made from chopped and/or continuous graphite fibers in which fiber volume fraction and the controlled fiber orientation are essential design factors.

References:

P. Rohatgi, "Advances in Cast MMC's," Advanced Materials Processes, 2/90, p. 39. AVAIL:AIAA

D. Hammond, "Castable Composites Target New Applications," Modern Casting, 9/90, p. 27. A91019304

Zhang Zhu, "A Literature Survey on Fabrication Methods of Cast Reinforced Metal Composites," Cast Reinforced Metal Composites, Proceedings of the International Symposium on Advances in Cast Reinforced Metal Composites, Chicago, IL, Sept. 26-30, 1988, p.93-99. A89-33166

R. Sample, R. Bhagat, M. Amateau, "High Pressure Squeeze Casting of Unidirectional Graphite Fiber Reinforced Aluminum Matrix Composites," Journal of Composite Materials, Vol. 23,10/89, p. 1021. A90-13123

04.22 Joining Polymeric and Metallic Composite Components

The structural materials employed in the space environment have to be assembled in space with means that are strong, resistant to the space environment and compatible with the selected structural materials. This places many restraints on the type of fasteners that are employed. The fastening process should be one that is readily accomplished in space by astronauts and adaptable to the environmental conditions. Numerous types of fastenings are available including: clamps and bolts, welding and brazing, and adhesive bonding. In this subtopic, proposals are requested for innovations in adhesive bonding systems.

These adhesive bonding systems must have the following characteristics when being applied and in subsequent service. The system has to be capable of fastening aluminum and magnesium base composites to polymeric base (epoxy matrices) composites with a tensile and or shear strength that at least matches the weakest of the two sections formed. The joint should be capable of withstanding the thermal cycling of the components (-100°C to +120°C) with the corresponding changes in the length of the formed section from thermal expansion and contraction. The adhesive has to be capable of being applied during assembly over the above temperature range in a high vacuum atmosphere. The joint adhesive has to be resistant to long time (30 years) exposure to the space environment including atomic oxygen, ultraviolet and solar radiation and thermal cycling.

References:

Thompson, D.F. and Babel, H.W. "Material Applications on the Space Station - Key Issues and the Approach to Their Solution." Sampe Quarterly (October 1989) pp. 27-33.

Beland, S. "Joining Thermoplastic Composites in High Performance Thermoplastic Resins and Their Composites." Noyes Data Corp. 1990.

Keough, B. "Evaluation of adhesives used on LDEF." Proc. Of LDEF Materials Workshop, NASA Langley Research Center, November 1991, in press.

04.23 Thermal Protection Materials and Systems

Future atmospheric entry vehicles such as aerobraking orbital transfer, manned and unmanned planetary entry (lunar and Mars vehicles), and transatmospheric vehicles will require reusable thermal protection materials and ablative and/or reflective thermal protection materials systems that are more durable and lower in weight than those currently available. This subtopic solicits innovative concepts for new high- and low-density, rigid and flexible, ceramic materials and systems having extremely good thermal-shock resistance and temperature capability in the range from 1000°C to 2500°C.

Among the possible materials are Si_3N_4, SiC, BN, Al_2O_3, and other refractory carbides, nitrides, and borides. Possible forms are fiber-fiber composites, fiber-matrix composites, foams, and various woven forms developed into thermal protection system components for flexible thermal barriers, gap fillers, and high temperature structural composites for application to future entry vehicles.

Ablative materials using non-catalytic and radiation-reflecting technologies are required for planetary entry and return missions. For environmental durability, innovations are required to provide long life, water proofing, and increased toughness. This applies to both materials and techniques for future composite thermal protection materials as well as the state-of-the-art shuttle orbiter. New minimum-weight, load-bearing, and non-structural thermal protection systems using new components and processing methods are of interest.

References:

Chiu, S.A. and Pitts, W.C. "Reusable Surface Insulations for Reentry Spacecraft," Paper AIAA-91-0696, 29th Aerospace Sciences Meeting, Reno, NV, January, 1991. A91-21589

Stewart, D.A. and Leiser, D.B. "Thermal Stability of Ceramic Coated Thermal Protection Materials in a Simulated High-Speed Earth Entry," Ceram. Engr. & Sci. Proc., No. 8 (1988), 1199-1206. A89-19479, ISSN 0196-6219

Leiser, D.B., Churchward, R., Katvala, V. "Advanced Porous Coating for Low Density Ceramic Insulation Materials," J. Am. Ceram. Soc., Vol. 72, No. 6 (1989), 1003-1010. AVAIL:ESL

Rasky, D.J., Bull, J.D. and Tran, H.K. "Ablation Response of Advanced Refractory Composites," Proceedings of the 15th Annual Conference on Composites, Materials and Structures, Restricted Session, Advanced Ceramics Association, Cocoa Beach, FL, January, 1991. AVAIL:ESL

04.24 Vacuum Plasma Spray Forming

Innovative means of in-process sensing and observation during vacuum plasma spraying (VPS) of coatings and structures are needed to more closely monitor the process, thus providing better control of VPS operation. Challenges to conventional sensing techniques include vacuum compatibility, intense radiated heat and light, powder overspray, and RF interference from plasma arc equipment. Specific areas of innovation include:

- Accurate part temperature before, during, and after spraying.
- Means of observing the powder pattern as it enters the plasma and is deposited onto the substrate.
- Means of measuring thickness of the sprayed deposit as well as its texture (roughness, waves, etc.).
- Equipment or methods for reducing or eliminating the oversprayed or undeposited powder.

References:

Holmes, R. R., "Vacuum Plasma Coatings for Turbine Blades," Advanced High Pressure O_2H_2 Technology, 1984, p.74-82. N85-26869

McKechnie, T. N. and Holmes, R. R., "Vacuum Application of Thermal Barrier Plasma Coatings," Advanced Earth-to-Orbit Propulsion Technology 1988, Vol.1, p.692-702. N90-28653

McKechnie, T. N. and Wooten, J. R., "Vacuum Plasma Sprayed NARloy Z," Advanced Earth-to-Orbit Propulsion Technology 1990, Vol. 1, p.251-261. X91-10304 Limited by ITAR

04.25 Bonding Techniques for High-Temperature Components

Devices constructed using a mixture of steel, aluminum, ceramic and graphite components are envisioned that are mechanically strong, vacuum tight, and able to withstand both high-temperatures and chemically reactive environments without leaks or fractures. Permanent, low-resistance metal-graphite joints able to withstand high temperatures and high current loads would greatly simplify the construction and durability of compact, high-temperature graphite furnaces. These furnaces are needed for the development of Space Station experiments in the Gas-Grain Simulation Facility. Similarly, graphite-steel or ceramic-steel welded reaction tubes would provide the high-temperature stability of graphite or ceramic components with the ease of construction of off-the-shelf stainless steel vacuum hardware. Such an arrangement would eliminate vulnerable rubber o-rings and multiple seals in favor of a single welded joint. Innovation techniques are sought that would allow any of the following:

- Bonding of ceramic parts to graphite and graphite and ceramic parts to stainless steel, aluminum, titanium or other metals.
- Bonding of very dissimilar metals such as molybdenum-aluminum, titanium-aluminum, graphites, ceramics, and metals of all types.
- Construction of high-temperature, vacuum hardware from ceramic-graphite-steel components.
- Construction of low-resistance, graphite-metal joints capable of operation at temperatures in excess of 1000°C.
- Systems to measure structural surface strains, including thermal strains.

References:

Twentyman, M. E., Hancock, P., "High-Temperature Metallizing of Alumina" from Surfaces and Interfaces in Ceramic and Ceramic-Metal System, J. Park and A. Evans (eds.) (Plenum Press, New York, 1981), pp. 535-546. ISBN 0-30-640726-4

Donnelly, R. G., and Slaughter, G. M., "The Brazing of Graphite" in Welding Journal 41 (1962) reprinted in the Source Book on Brazing and Brazing Technology, ASM Int., Materials Park, OH (1980), pp. 308-314. ISBN 0-87-170099-9

04.26 Low-Temperature Extrusion Material With Ceramic Reinforcement

Space-based materials processing and industries that support solid freeform fabrication (SFF) would benefit from the capability to produce components with improved strength and thermal characteristics. A materials system which has the properties of a ceramic and is able to implement SFF manufacturing techniques, such as fused deposition modeling, would be able to add to the current growth of applications for direct "component from computer" manufacturing. Current solid freeform fabrication systems use such polymers as nylon-like material for their high strength material for extrusion. An innovative approach is required to incorporate ceramic powders or ceramic precursors into the extrusion. This subtopic solicits innovative proposals in the following areas:

Polymer ceramic matrix composites capable of being extruded through a small diameter extruder, and having a low and reproducible shrinkage coefficient. The goal is to produce net shape components with strength or thermal characteristics approaching those of a ceramic.

Polymer-ceramic and ceramic systems capable of undergoing extrusion for which there is a microwave drying process leading to very low overall shrinkage coefficients.

References:

J.L. Beaman, H. L. Marcus, D.L. Bourell, and J.W. Barlow, Solid Freeform Fabrication Symposium Proceedings, August 1990.

N.K. Vail and J.W. Barlow "Microencapsulation of Finely Divided Ceramic Powders" J.L.Beaman, H. L.Marcus, D.L.Bourell, and J.W.Barlow eds. Solid Freeform Fabrication Symposium Proceedings, August 1990.

S. Kennerknecht, and D. Sifford, "Pattern Making", Incast, March 1991, Volume 4, No. 3.

04.27 Welding Technology

Innovative means for controlling welds and improving properties of weldments are needed to achieve lower cost, lighter weight and more reliable aerospace components and assemblies. Materials of interest are high strength steels, nickel-based alloys, Al-Li alloys, etc. Areas in which innovations are desired include: physically based mathematical models of weld phenomena such as penetration , shielding, cutting and defect formation, etc., and models comparing the relation of weld strength to weld structure to provide tools for weld and weld process development. Innovative methodologies should be created for:

- Modifying materials to improve weldability without degrading other desired material properties.
- Simulation of robotic welding processes using graphic displays and actual weld databases.
- Simplified programming of robots with multiple and redundant axes of motion to improve operations and reduce weld programming time.
- Improving sensors and methods for determining and controlling the performance and accuracy of robots and manipulators used in welding, including position, velocity and acceleration.
- On-orbit joining and repairs.
- Modifying and improving weldability of normally unweldable materials utilizing the vacuum GTAW process.
- Processing and verifying weld-seam, video-imagery technologies (e.g. neural networks, enhanced algorithms, etc.) for weld-seam tracking.

References:

Brosilow, R. "Space Shuttle Flies on Computer Welds," Welding Design and Fabrication, Description of Welding System Architecture for NASA Welds, (August 1989). AVAIL:ESL

Nunes, A.C., Jr., Bayless, E.O., Jr., Jones, C. S., III, et al. "Variable Polarity Plasma Arc Welding on the Space Shuttle External Tank," Welding Journal, Description of the VPPA Welding System developed at NASA-MSFC, Vol. 63, No. 9 (June 1984), 27-35. A84-48541

Lancaster, J.F., ed. The Physics of Welding, 2nd Ed., International Institute of Welding. Review of the Current Understanding of the Physical Basis of the Welding Process, Pergamon Press, 1986. A80-28749

"Major Repair of Structures in an Orbital Environment." Report No. SA-ROS-4 Grumman Aerospace Corporation. NASA-MSFC

Contract No. NAS8-36436, June 1987. Review of Background Considerations for Space Welding. N90-70123

04.28 High Temperature Superconductors

Innovations are desired in high-temperature, superconductive materials for remote sensing and magnetic levitation.

Sensor electronics: Proposals are solicited for large-area, thin or thick superconductive films deposited on rigid, low-thermal-loss substrates for application as sensor and detector electronic leads for systems operating under cryogenic conditions.

Magnetic levitation: Materials capable of producing a high levitative force are required for application as magnetic bearings, positioning devices, and vibration dampers. Innovations are also sought in forming techniques for production of bulk, superconductive ceramics into coils, cables, and cavities. Techniques for property enhancement should be combined, if possible, with forming techniques, incorporating flux pinning sites, and inducing preferred orientation.

References:

Romanofsky, R.R. and Sokoloski, M.M., Prospects and Progress of High Tc Superconductivity for Space Applications, NASA-CP-3100, April 1990.

04.29 In Situ Materials Processing and Utilization

Manned activities in space will require or be enhanced by utilization of in situ lunar materials as sources of propellants, shielding, volatile gases, metals and ceramics, or other construction materials. Proposals are solicited for innovative techniques and processes which may be carried out either on the lunar surface or in Earth orbit. Proposed methods and equipment must consider reaction thermodynamics, reaction rates, engineering requirements, and system characteristics. Only those innovations whose development can be pursued on Earth in the near future will be considered, and system studies and conventional engineering designs will not be acceptable. Specific areas of interest include:

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

- Highly automated equipment, sized for the lunar or Earth-orbital environments, to extract and move lunar materials to processing facilities and to concentrate and size feedstock for efficient processing.

- Simplified, self-contained systems that can process metallic or ceramic material into 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 direct applications of this research may not exist for many years, Phase I proposals must lead to realistic, near-term Phase II objectives that will contribute significantly to NASA commercial research programs and directly or indirectly provide expectations of non-NASA commercial spinoff processes or products.

References:

Mendell, W.W., Editor "Lunar Bases and Space Activities of the 21st Century" (1985), Lunar and Planetary Institute, Houston, 865. A86-30113

Johnson S.W., and Wetzel, J.P., eds. "Engineering, Construction, and Operations in Space II," Proceedings of Space 90 (1990), American Society of Civil Engineers, New York, NY 10017-2398, 1585.

04.30 Nondestructive Monitoring of Composite Structures

The innovation desired is a capability for real-time health monitoring of composite structures. The system should be capable of indicating discontinuities, impact damage initiation and growth, as well as providing information about the degradation of material properties. Sensors can be either embedded or attached to the monitored structure. The system should perform either continuous or periodic interrogation and reporting on structural integrity. This system is intended to reduce the amount of nondestructive evaluation (NDE) needed for periodically deployed structures or to report on the structural integrity of deep space vehicles and optical systems. The system should interface to a computer through standard forms of computer communication.

References:

Lesko, J. J., Carman, G. P., Fogg, B. R., Miller III, W. V., Vengsarkar, A. M., Reifsnider, K. L., Claus, R. O., "Embedded Fabry-Perot fiber optic strain sensors in the macromodel composites," Optical Engineering, vol. 31, no. 1, January 1992. ISSN 0091-3286

Takat, K., "Fiber Sensors Take Wing in Smart-Skin Applications," "Smart-skin fiber sensors offer real-time monitoring of the structural health of tomorrow's aircraft," Photonics Spectra, p. 88, April 1991. ISSN 0731-1230

Claus, R. O., "Fiber Sensors As Nerves for 'Smart Materials'," Photonics Spectra, p. 75, April 1991. ISSN 0731-1230

05.00 Teleoperators and Robotics

05.01 Mission Support Flight Robotics

Long duration orbital experiments and missions require telerobotic systems adaptive support onboard and external to the spacecraft. Internal robotics will be contained in laboratory-rack sized volumes. Innovative concepts and techniques are needed to conduct telescience effectively. Areas of required innovation include:

Telepresence interface for a small robotic arm within a Space Station experiment rack. This will allow for experiment monitoring and modifying of robot and experiment instruction sets.

Low-cost intelligent video camera for monitoring experiments and facilities. It should accommodate black and white and color cameras, built in graphics, be controlled from manual stations, and be capable of computer control. Possible motion tracking of blinking infrared targets would be useful.

Acquisition and tracking of objects for recognition and three-dimensional perception in cluttered environment, passive markers, and proximity sensing for collision detection and avoidance.

Robotic control algorithms to control flexible arms joining two very large payloads floating in space with minimum stabilization and disturbance on the system. Algorithms for guidance of the arm's payload from a remote sensor in a different reference frame; control algorithms for distributed architectures including smart-joint controllers and remote operator stations.

Control of remote systems through shared, automated and manual methods; remote recovery or path alteration via high-level operator control; real-time, realistic interactive graphic simulations of remote task with time delay effects; and user-friendly, intelligent visual parameters. Efficient, integrated real-time operator presentation of multiple sensors including real-time, three-dimensional audio tracking of targets.

Miniature video cameras: non-interfering, proper spectrum, cool adaptable for micro-G; lighting and guides to illuminate and record very small specimens.

Anthropomorphic input devices and end effectors to include sensors and how information is returned and used.

References:

"Physical and Digital Simulations for Space Robotics", Elaine Hinman, Gary Workman, International Robots and Vision Automation Show and Conference, October, 1991.

05.02 Supervised Autonomous Intelligent Robotic Systems for Manned Space Missions

NASA is interested in innovative space robotic systems that can perform tedious, time-consuming tasks autonomously to free the cognitive and dexterous skills of the crew for research and exploration in the space environment. Such systems must minimize the need for ground controllers guiding robots through intricate activities and avoid the resultant problems involved in communicating over the long distances of space. Also, such systems should provide enhanced safety for humans in space by performing dangerous tasks and provide rescue capability such as the EVA Retriever. The focus of this subtopic is on the development of both software and hardware, including innovative CASE-like tools for the development and integration of autonomous system modules, and methods for the validation of dynamics control strategies in robotic testbeds. Additionally, projects are sought that develop innovative architectural designs for supervised autonomous robotics and the supporting technology for systems modules including:

- Greater mobility and capacity for manipulation.
- Fault-tolerant systems and mechanisms.
- Real-time collision avoidance with attached payloads in cluttered environments.
- Space certifiable miniature servomotors.
- Human-robot two-way interfaces including voice and enhancing human understanding.
- Visual and non-visual sensing.
- Computer vision.
- Perception.
- Environmental modeling.
- Reasoning including planning.
- Control, including dynamical control via distributed processing chips.

References:

IEEE Transactions on Systems, Man, and Cybernetics November/December 1989, Volume 19, Number 6, "Special Issue on Machine Vision". AVAIL:AIAA

IEEE Transactions on Systems, Man, and Cybernetics November/December 1990, Volume 20, Number 6, "Special Issue on Mobile Robotics". AVAIL:AIAA

05.03 Intelligent Robotic Operations

The subtopic has the goal of enabling robotic activities at remote sites in space. Innovations in all of man-assisted or supervised autonomous robotic systems and advanced computer technology tasks are sought:

Mobile and/or crawling minirobots weighing less than 20 kg that are self-contained, semi-autonomous, and that can navigate rough surfaces, climb non-magnetic, smooth space structures, deploy instruments, and retrieve samples in low or zero gravity. They must operate hours at a time without intervention.

Astronaut assistance aboard the Space Station Freedom. Self-contained robots would learn and reproduce repetitive tasks taught by the astronaut. This requires multiple-degree-of-freedom, adaptive stabilizers with force-torque-momentum compensation that balances actions by the astronaut.

Reconfigurable, modular, real-time systems software for manipulator control applications. This VME-processor-based software should be UNIX compatible with interfaces for multiple sensors, manipulators, and real-time processor subsystems. It should also provide extensive utilities to ease online configuration and use of the system for experimental and applications-oriented tasks.

Automated inspection, monitoring, detection, and warning systems based on single or fused sensory capabilities for detection of cracks, defects, leaks and changes in structures and instruments. This could include voice actuated mechanisms, real-time, on-board image difference detection; object tracking; predictive, advisory, and control systems and modelling; and high speed intelligent storage and retrieval of multimedia data and imagery.

Rendezvous, docking, and capture in space with autonomous, smart mechanisms. This could include planning and scheduling tools, smart skin sensors, intelligent integrative proximity operation tools, distributive cooperating intelligent systems, maneuvering aids, and advanced compliant methods.

References:

Proceedings of the Workshop on Space Telerobotics", Vol. 1 to 3, NASA Jet Propulsion Laboratory, Editor: G. Rodriguez, 1987 and 1989. N89-26541

"Generic Extravehicular (EVA) and Telerobot Task Primitives for Analysis, Design and Integration" JPL Publication 90-10, J. H. Smith and Michael Drews. N91-13876

"The Space Station Assembly Phase: Flight Telerobotic Servicer Feasibility", Vol. 1 and 2, September 1987. JPL Publication 87-42. N88-20352 NASA-CR-182690

05.04 Neural Networks and Fuzzy Logic for Robotic Systems

Innovations are required for intelligent space robotic and teleoperators systems. These systems will use neural networks and other knowledge-based structures to achieve goals through the interaction between modifiable subgoals and a dynamic model of the environment and the intelligent system itself. The innovations proposed must be justified from a space operations perspective. The impact of system effects such as communication time delay must be considered. Proposals are solicited in the following areas:

- Intelligent systems for process control functions for automated science instruments, planetary rovers, spacecraft attitude control, navigation, rendezvous and docking and space assembly, maintenance, repair and servicing.
- Neural network learning algorithms for unsupervised and supervised identification of rigid and flexible multibody dynamics in zero-gravity environments, motion and contact planning with non-holonomic constraints, execution and monitoring and error recovery, and intelligent teleoperation.
- Neural networks for feature extraction, sensor fusion, and associative memory for space image processing, communication, pattern recognition, autonomous rendezvous, docking and capture mechanisms.
- Fuzzy logic algorithms for autonomous spacecraft and space robot control, intelligent teleoperation, execution monitoring and error recovery, and rapid prototyping.
- Real-time control implementation on redundant robots and spacecraft prototypes; real-time, ground-based simulation of spacecraft and space robot operations; and ground-based visualization software for execution monitoring.

References:

Narendra, K. S. and Parthasarathy, K., "Identification and Control of Dynamical Systems Using Neural Networks", IEEE Trans. Neural Networks, 1 (1), 1990, pp. 1-27
A90-34466 ISSN 1045-9227

"Neural Networks for Control" Miller, W.T., Sutton. R.S. and Werbos, P.J., Bradfor Book, MIT Press, Cambridge, MA, 1991.
ISBN 0-26-213261-3

"Neural Networks and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence", Kosko, B., Prentice Hall, Englewood Cliffs, N.J., 1991.1 ISBN 0-13-611435-0

05.05 Space Robotic Mechanisms

This subtopic solicits novel concepts for:

Transponders which will permit multiple signals to be passed back and forth across a continuously rotating joint. These transponder pairs must be non-contact, permit a high data rate, be EMI resistant, be simple and compact and suitable for use in outer space. This technology should also be considered as a basis for a replacement for ordinary electrical and or fiber optic connectors. In this application, the portion of the transponder which is exposed to outer space should be designed such that insertion and separation forces are minimal and precision alignment and protective covers are not required.

High-fidelity controller for zero-gravity, off-loading device. A concept for a device which will physically permit a six degree-of-freedom space robot to be tested and exercised on earth in an end-to-end configuration under what amounts to near zero gravity conditions.

Cableless Power and signal transfer across the robot wrist joint.

Fastening systems for payloads.

References:

Vranish, J. M. and Sharifi, Mohammed. "NASA/GSFC Split-Rail Parallel Gripper," European Space Symposium Conference, Toulouse, France, September 1989. N90-24328

Vranish, J. M. "Advanced Robotic Mechanisms," NASA Technology 2000 Conference Proceedings, Washington, DC, November 1990. AVAIL:CASI

05.06 Robotic Surrogates for Human Grasping and Manipulation

Humans and robots must be capable of interacting with future space hardware. The human interaction could be either in situ or via remote control of a robot. The robot must be capable of autonomous operation, teleoperation, or a combination of the two. The robot might be substituted for a human (e.g. in hazardous operations) or operate in conjunction with a human as an assistant. Dexterous robotic grasping and manipulation capability must be developed to achieve this capability. Innovations are required in the following areas:

- Human-scale, robotic hand designs for human-type grasping and manipulation.
- Human-scale robotic arm designs for grasping and manipulating objects by using the exterior surfaces of the arms, much like large fingers.
- Human-scale integrated arm, wrist, and hand designs for human-type grasping and manipulation.
- Object sensing, adaptive grasping, manipulation, or stable grasp recognition functions, as well as integration of sensors with a robotic arm, wrist, and hand to provide these functions.
- Tactile, slip, force, and torque sensing for a human-scale robotic arm and hand.
- Intelligent systems that exhibit higher order human-like grasping and manipulation behaviors such as active, haptic (touch) exploration and estimation based on sensory feedback, adaptive vision-hand coordination, and learning-based arm and hand controls.
- Devices or systems that use a human arm, wrist, and hand as a master controller with bilateral control and sensing features. Easy donning, doffing, and portability are highly desirable features.
- Devices or systems to provide intuitive tactile, force, and torque feedback to a human operator's arm and hand.

References:

IEEE International Conference on Robotics and Automation, 7th, Proceedings, Vol. 1-3, Sacramento, CA, April 9-11, 1991.
A92-21520

05.07 Telerobotic Displays, Non-Visual Sensing, and Controls

Small, lightweight devices for mapping three-dimensional surfaces using active video and active laser or microwave sensing. NASA has developed a laser-based system which can produce fast, accurate, range and intensity images. Alternative methods of obtaining three-dimansional imaging data and methods to process the range images or data to obtain geometric descriptions of objects viewed are sought.

- Director-type visual display techniques for use with path-planning systems that provide natural cues for real-time teleoperator trajectory control.

- Unique methods for attachment to and mobility along truss structures while carrying modest payloads. Applications include external surface inspection and transport of small dexterous arms as well as inspecting and servicing large, smooth, curved structures such as aerobrakes or reflectors.

- Small, low-power sensing systems that can operate in vacuum, do not generate EMI, and can be mounted in end effectors or on external surfaces for proximity detection, tactile sensing, and force and torque sensing.

- Methods or mechanisms for canceling or compensating for unwanted micro-G level vibrations and accelerations from manipulator mechanisms for use in on-orbit experimental apparatus and laboratory logistics systems.

References:

Lay, Richard W.: "Laser-Based Robotic Sensor Kicks Up Speed, Accuracy." Electronic Engineering Times, November 18, 1985. ISSN 0192-1541

Will, Ralph W.; and Rhodes, Marvin D.: "Automated Construction of Large Space Structures." Presented at the SPIE Symposium on Advances in Intelligent Systems, Boston, MA, November 4-9, 1990. A91013919

06.00 Computer Sciences and Applications

06.01 Computational Advances for Aerospace Applications

New concepts are solicited to improve and enhance computational techniques for solving large-scale scientific and engineering problems in many aerospace disciplines. Improvements include increased computational speed (operational rates on the order of billions of floating point operations per second on arrays of several million elements), graphics, and all aspects of data handling including storage and long-haul communications. Proposals may address any of the following areas:

Parallel processing: Methods and software for exploiting parallel processing and for easing the task of developing efficient FORTRAN-based programs for parallel processing computers while retaining the efficiency of programs transferred from one architectural design to another; also methods for predicting resulting system performance prior to system construction. Architectures of interest include multiple instruction-stream multiple data-stream (MMD), systolic arrays, data flow, demand driven and reduction machines.

Data management: Software and hardware systems to manage, structure, and handle large scientific and engineering computation databases, including systems to facilitate the preparation of data input (particularly complex grid systems) and the analysis of results interactively, using graphic engineering workstations networked to supercomputers; new or enhanced data storage and data compression techniques.

Graphics: Computer graphics concepts, capable of implementation in software and hardware for visualizing complex computational results, to bring new understanding to the physical phenomena being modeled, with emphasis on displaying and recording (e.g, video, multimedia, etc.) of several physical quantities varying over three dimensions and time. For example, enhanced display of internal flow structures, depth perception; quantitative comparison of numerical and experimental fluid flow data; solid modeling of aerospace configurations for computer animations, grid generation, and digital image processing techniques applicable to surface, tracer, and optical flow visualization methods; and high-speed but cost-effective image processing techniques suitable for analysis and synthesis of fluid dynamics data.

References:

Cheng, Doreen Y. "A Survey of Parallel Programming Tools," NASA Ames Research Paper, January 23, 1991. AVAIL:CASI

Supercomputing '91 Proceedings, Albuquerque, NM, sponsored by IEEE Computer Society Technical Committees on Supercomputing Applications and Computer Architecture and ACM Sigarch (November 18-22, 1991). ISBN 0818620560, ISBN 0897914120

Yan, Wen-Jei. Handbook of Flow Visualization. Ann Arbor, Hemisphere Publishing Corporation, 1989. ISBN 0891166696

Peterson, Victor L., et. al., "Supercomputer Requirements for Selected Disciplines Important to Aerospace," Proceedings of the IEEE, Vol. 77 (July 1989), No. 7. A89-53152

06.02 Software Support Systems for Unmanned Missions

The engineering of large-scale computer systems to support increasingly complex unmanned spacecraft missions requires new approaches for managing the correspondingly complex design and operation of the control and data handling systems. Innovations are needed, therefore, in the development, verification, sustaining engineering, and operation of large-scale software systems, for example:

- Management of the software engineering process.
- Software development productivity including alternative software paradigms, for example, development by reuse, iconic programming.
- Software performance, quality, and reliability in critical spacecraft ground systems, including fault-tolerant and distributed systems.
- Support for human operators in spacecraft control and data processing environments through use of improved human-computer interaction techniques and artificial intelligence.

References:

Ichikawa, T. and Hirakawa, M. "Iconic Programming: Where to Go?" IEEE Software, (Nov 1990), 63-68. IEEC 91017480

"Intelligent Systems" section, Space operations Application and Research (SOAR) Workshop Abstracts, Lyndon B. Johnson Space Center, JSC-24438, June 1990. AVAIL:CASI

06.03 Reliable Software Development

Innovative approaches are sought for developing and verifying highly reliable software for safety-critical aerospace applications. These approaches 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.

References:

Proceedings of AIAA Computers in Aerospace VII Conference, American Institute of Aeronautics and Astronautics, Monterey, CA, October 3-5, 1989. A90-10476

IEEE/AIAA/NASA Digital Avionics Systems Conference, 9th, Proceedings, Virginia Beach, VA October 15-18, 1990, IEEE Catalog No. 90CH2929-8. A91-54576

Proceedings of the Fourth International Workshop on Real-Time Ada Issues, ACM Ada Letters, Vol. X (1990), No. 9. AVAIL:ESL

Voigt S. and Smith K. Proceedings of TRI-Ada '90, Baltimore, MD, December 3-5, 1990. Software Reuse Issues, NASA CP3057, 1989. N90-14789

06.04 Knowledge-Based Systems for Aerospace Applications

Knowledge acquisition, representation, and utilization are the key elements for the effective development and implementation of advanced software systems for spaceborne, airborne, and earth-based applications. At the current time skilled knowledge engineers are needed to translate the experts'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 inefficient when interacting with unreliable data or in multiple technical domains. Knowledge engineering technology is needed in areas such as:

Knowledge-based systems with emphasis on: knowledge acquisition, representation, verification and validation, and maintenance for real-time systems and/or distributed cooperating systems.

Integration of data bases and knowledge bases.

Machine learning for automated data analysis and automatic improvement of problem-solving systems.

Hierarchical control architectures for distributed knowledge-based systems.

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

Human-machine interfaces capable of displaying integrated dynamic system relationships that are understandable in a flexible and natural manner and show what is desired and the reason for the request.

References:

Berenji, H. R., Chen, Y. Y., Lee, C. C., et al. "A Hierarchical Approach to Designing Approximate Reasoning-Based Controllers for Dynamic Physical Systems. Proc.," 6th Conf. on Uncertainty in Artificial Intelligence, 362-369, 1990. AVAIL:ESL

Boy, G. A., and Mathe, N. "Operator Assistant Systems: An Experimental Approach Using a Telerobotics Application," IJCAI Workshop on Integrated Human-Machine Intelligence in Aerospace Systems, Detroit MI, August 21, 1989; and in Internat'l Jour. Intell. Systems, Special Issue on Knowledge Acquisition, 1991. ISSN 0094-243X

Colombano, S. P., Young, L. R., Haymann-Haber, G., et al. "An Expert System to Advise Astronauts During Experiments," 40th Congress Internat'l Astronautical Federation, Oct., 1989. A90-13266

Lansky, A.L. "Localized Representation and Planning; in Readings in Planning," Morgan Haufmann Publ., San Mateo, CA, 670-674, (1990). N90-26373

06.05 Software Systems for Mission Planning and Flight Control

Innovative concepts are needed to improve pre-flight and real-time mission planning techniques for on-board and ground control support of manned flight operations. Areas of particular interest include:

- Fuzzy logic in the support of flight control and pattern recognition
- Intelligent computer-aided training (ICAT) and virtual reality systems to support training development.
- Planning and scheduling tools including genetic algorithms.
- Failure detection technology including artificial neural systems.
- Human-machine interfaces including speech recognition and synthesis.

Innovative approaches that improve utilization of these technologies or that open new areas of application are of significant importance. These may be in the form of building tools to facilitate the advancement of the technology and/or construction of demonstrations which illustrate the potential uses of the technology.

References:

Rufat, Watts, Carey, et al. "Distributed Cooperative Systems for Advanced Automation:Tradeoffs," In the Proceedings of the IEEE conference on Systems, Man, and Cybernetics, Los Angeles, CA, November 1990. A87-50632

Lea, R. N. "Automated Space Vehicle Control for Rendezvous Proximity Operations", Telematics and Informatics, Vol 5 (1988), No 3., 179-185. N88-30335

Villarreal, J. and Robert Shelton, R. "A Space Time Neural Network", Second International Conference on Neural Networks and Fuzzy Logic, Houston, TX, 1990. AVAIL:ESL

Loftin, R. B., et.al. "An Intelligent System for Training Space Shuttle Flight Controllers in Satellite Deployment Procedures, Machine-Mediated Learning," Vol. 3 (1989), 41. A89-21802, N88-30331

06.06 Optical Processing Technology

NASA has an on-going need for novel processing architectures to address mission-related problems in which speed, weight, and power consumption are critical issues. Specific application areas include robotic vision, autonomous lander guidance, and spectral data analysis. Optical processing technology shows promise in such areas by taking advantage of the speed and inherent parallel nature of light to perform computations more quickly and with less power than can be accomplished with traditional digital electronics. A major bottleneck, however, is due to the limitations of commercially available spatial light modulators (SLM's). Processing architectures which use to their fullest the advantages of photonics over electronics require spatial light modulators which combine high-resolution, high-speed updatability, and high-contrast phase and/or amplitude modulation. Currently available SLM devices offer some of these features, but are often the result of a trade-off between resolution and speed.

This subtopic solicits improvements in spatial light modulator devices for use in optical processing architectures, specifically in the area of combining high-resolution and high-contrast with high-speed updatability. Multi-level phase or amplitude modulation is desirable, but not necessary. Both electrically and optically addressed devices should be considered. The result of a Phase II effort would be a working device prototype which can demonstrate the desired characteristics, leading to a commercially available device in Phase III.

References:

Warde, C. and Fisher A.D. "Spatial Light Modulators: Applications and Functional Capabilities in Optical Signal Processing," Academic Press, San Diego, (1987) 477-523.
A90-26837, N90-11804

06.07 Modeling Methods for Model-Based Reasoning Systems

Mathematical models of system components are used for simulators that predict system behavior to various stimuli. Recent efforts to monitor, diagnose, and control real-time systems by applying model-based reasoning techniques to component models of the target systems have experienced similar success. Innovative modeling methods and machine-learning approaches are sought to:

- Increase the fidelity of component models,
- Reduce the effort to build system-wide parameters which describe the behavior of the system in its entirety,
- Synthesize effective approximate models capable of reasoning at multiple levels of abstraction where the component model breaks down due to complexity or uncertainty, and
- Automate the maintenance of model bases by adjusting component and system parameters during real-time operation through adaptive learning techniques.

References:

Davis, R., "Diagnostic Reasoning based on Structure and Behavior", D. G. Bobrow, ed., Qualitative Reasoning about Physical Systems, MIT Press Cambridge, MA 1985.
Paper: ISBN 0-26-252100-8, Hard cover: ISBN 0-26-202218-4

E. A. Scarl, J. R. Jamieson and C. I. Delaune, "Diagnosis and Sensor Validation through Knowledge of Structure and Function", IEEE - Transactions on Systems, Man and Cybemetics SMC-17 (3), pp. 360-368 (May/June 1987). A87-48494

C. L. Belton-Parrish and S. Enand, "KATE - A Model-based Diagnostic and Control Shell", Intelligent Diagnostic System, Eds. K. F. Martin, J. H. Williams and D. T. Pham, IFS/Springer-Verlag, to be published in Fall 1992. AVAIL:AIAA

Compilation of Publications (1987-1990) on "Automated Knowledge Generation", Department of Computer Engineering, University of Central Florida, Orlando, FL, NASA Grant #NAG10-0042. AVAIL:CASI

07.00 Information Systems and Data Handling

07.01 Focal-Plane Image Processing

Focal-plane image processing is concerned with high resolution (spatial and spectral) imaging, video, and vision-based robotics. The goal is to exploit unique ways to improve image resolution and compression, to extract and identify relevant information, and to reduce electronics mass and power requirements. Typical approaches may include integrated sensor-array imaging and coding; charge-domain or on-array processing; pyramid, parallel, or neural network processing; multi-resolution signal decomposition (e.g., wavelet representation); feature extraction and recognition; "smart" sensing; and knowledge-based control. Phase I results should establish or support the feasibility of the proposed concept and the improved performance that its Phase II development could provide to NASA space applications:

Planetary exploration and space physics. Requirements are for high resolution (spatial and spectral) imaging under severe mass, power, and communication constraints.

Microgravity research. Many experiments require high resolution (up to 10^7 pixels/frame) and/or high frame rates (up to 1000 frames/second).

Space Station video and extra-vehicular activities (manned or robotic). Requirements are for high quality video data compression.

Earth observation systems. Requirements are for knowledge-based fusion of a variety of sensors.

References:

"Expert Imaging System for Data Compression," F. O. Huck, NASA TM 104044. AVAIL:CASI

"Rover Imaging Systems for the Mars Rover/Sample Return Mission," F. O. Huck, NASA TM 104043. AVAIL:CASI

07.02 Computational Applications Software for Massively Parallel Computing Systems

NASA has a growing need for high-rate, ground-based computer systems to perform multidisciplinary numerical modeling of physical systems as well as to perform analysis of large volumes of acquired data and model data. Many of these applications have been execute rapidly on massively parallel computing architectures that offer the potential of scalability to teraFLOPS performance in the 1990s and cost-performance ratios significantly better than conventional vector supercomputers. Large-scale, massively parallel systems are now available commercially including Thinking Machine's CM-200, the MasPar's MP-1, and the Intel Gamma.

Extensive availability of applications software packages are needed for the commercial massively parallel systems in order for users to accomplish productive work in a rapid fashion. Packages desired are similar to those currently found on large-scale vector processors and include:

- Computational fluid dynamics;
- Sensor data analysis algorithms;
- Graphics generation and data visualization;
- Image processing and pattern recognition;
- Mathematics and statistics algorithms;
- Database management;
- Artificial intelligence as an aid to data analysis;
- Optimization problem algorithms;
- Image restoration techniques (characterized by spatial and spectral varying point-spread functions).

References:

JaJa, J. ed. "Proceedings of the Third Symposium on the Frontiers of Massively Parallel Computation," IEEE Computer Society Press, Order Number 2053, 1990. IEEG(PON)-2053

07.03 Information Processing Technology and Integrated Data Systems

High-performance, fault-tolerant, distributed information data systems are needed for advanced aerospace missions. These data systems must provide data communication bandwidths and processing services well above what are 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. Also, these data systems may carry real-time data; therefore, both delays and variability of delay must be kept to a minimum for correct operation. Innovations are sought in both the areas of distributed systems and hardware implementation for meeting future high performance data system needs. Suggested areas for innovation are:

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

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

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

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

High performance processors and computers as elements of distributed systems.

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

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

References:

Husain, A., et. al.: Optical Processing For Future Computer Networks, SPIE Optical Engineering, Vol. 25, No. 1, January, 1986. A86-21973

NASA Efforts to Develop and Deploy Advanced Spacecraft Computers, General Accounting Office Report GAO/IMTEC-89-17, March, 1989. N90-25582

Shull, T.; and Rinsland, P.: Spaceflight Optical Disk Recorder Development, Paper AIAA-90-5031, Proceeding of the AIAA/NASA Second International Symposium on Space Information Systems, Pasadena CA, September 17-19, 1990. A91-14958

07.04 Heterogeneous Distributed Data Management

Due to the diversity of computers, operating systems, management systems, network protocols, etc., NASA space scientists have to learn many different access methods in order to obtain data. The heterogeneity of the data centers makes multi-mission research almost impossible. A step towards solving this problem would be developing software systems that would provide uniform access to objects of different types in different formats over heterogeneous distributed computing systems. For some classes of objects e.g., manuscripts and graphics, the software should be considered as complementary to existing initiatives and formats. Such object types (and sample formats) include:

- Databases (FITS, Ingres, Oracle, IM/DM, etc.).
- Manuscripts (SGML, LaTex, Word Perfect, Troff, etc.).
- Spectra/spreadsheets (CDF, EXOSAT, Lotus, Excel, etc.).
- Images (FITS, TIFF, IRAF, etc.).
- Graphics (GMF, PIC, Post Script, etc.).
- Software Tools (Ada, C, Fortran, etc.).
- Expert systems (ART, R1, OPS5, etc.).

References:

Jacobs, Barry, E. "Distributed Access View Integrated Database (DAVID) System," Proceedings of Technology 2000 Conference, Office of Commercial Programs, National Aeronautics and Space Administration, Washington, DC 20546. AVAIL:CASI

07.05 Onboard Data Reduction

Increasing volumes of data are being generated on board spacecraft due to higher data rates and volumes from instruments which are increasing in complexity and sophistication. Limited bandwidth for transmission of the data to the ground leads to requirements for onboard data reduction. Enhanced onboard data reduction techniques and architectures are required to maximize the amount of useful data which can be transmitted from the spacecraft to the ground. Current capabilities in these areas limit the amount of effective data reduction which can be done on board the spacecraft. This subtopic seeks new and/or enhanced data reduction capabilities for future spacecraft. Suggested areas of innovation include the following:

New data compression algorithms which will yield high-ratio data compression while maintaining the fidelity of raw data.

Efficient architectures for onboard processing utilizing advanced data reduction and compression algorithms.

References:

Rice, R. F., "Channel Coding and Data Compression system Considerations for Efficient Communication of Planetary Imaging Data," JPL Technical Memorandum 33-695, Jet Propulsion Laboratory, Pasadena, CA, September 1, 1974. NASA-CR-140181, N74-34598

Rice, R. F., Pen-Shu, Y. and Miller W., "Algorithms for a Very High Speed Universal Noiseless Coding Module", JPL Publication 91-1, Jet Propulsion Laboratory, Pasadena, CA, February 15, 1991. AVAIL:JPL

07.06 High-Performance Computing and Communication

While the High-Performance Computing and Communication (HPCC) program deals with "inter-computer" communications, it is also important to deal with "inter-human" communication, in particular, among the many HPPCC program participants. A prime example of "inter-human" communication would be an information exchange facility in which the types of information shared include software, data, research results, corporate resources, etc. The objective of the High Performance Computing and Communications Distributed Information System project is to provide such a mechanism. In accordance, NASA is looking for technologies in the following areas:

- **Software Repositories.** Software repositories are used to maintain software components intended for reuse. Technologies of interest are software repository management systems, user-access tools for heterogeneous distributed software repository systems, and tools for managing software standards.

- **Data Repositories.** Data repositories are used to maintain databases and data sets. Technologies of interest are data repository management systems, user access tools to heterogeneous distributed data repository systems, and tools for managing data standards.

- **Bibliographic Repositories.** Bibliographic repositories are used to maintain on-line literature such as journals and documentation. Technologies of interest are bibliographic repository management systems, user access tools to heterogeneous distributed bibliographic repository systems, and tools for managing bibliographic standards.

References:

Grand Challenges: High Performance Computing and Communications. A report by the Committee on Physical, Mathematical and Engineering Sciences, Federal Coordinating Council for Science, Engineering and Technology, Office of Science and Technology Policy, to Supplement the President's Fiscal Year 1992 Budget and to Supplement the President's Fiscal Year 1993 Budget.

08.00 Instrumentation and Sensors

08.01 Topographic Measurements from Space

High-resolution topographic mapping of the Earth and Lunar surfaces from spacecraft requires major improvements in space-based laser altimeter sensors. Technological goals include increase in electrical efficiency, sensor lifetime, and ruggedness along with reduced weight. 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 planetary surface. The technology challenges of space-based laser altimetry include:

- A diode-pumped, Q-switched, solid-state laser transmitter that produces a minimum of 20 millijoules pulse energy in the wavelength region of 700 nm to 950nm with 10 percent or greater electrical-to-optical efficiency.

- A low-voltage laser Q-switch that is free from optical damage at laser intensities of 400 Megawatts per square centimeter for use with miniature diode-pumped solid-state lasers.

- A device, such as a CCD star camera or fiber-optic gyro, to measure pointing angles of the laser altimeter transmitter to sub-milliradian accuracy.

References:

Zuber M. T., et al. "The Mars Observer Laser Altimeter Investigation." Journal of Geophysical Research, in press, 1992. ISSN 0272-7528

Shannon, D. C. and Wallace R. W. "High-Power Nd:YAG Laser End Pumped by a cw, 10mmxl μm Aperture, 10-W Laser-Diode Bar.", Optics Letters, Vol. 16, No. 5 (1991), 318-320. A91-28393 ISSN 0146-9592

Bufton, J.L., "Laser Altimetry Measurements From Aircraft & Spacecraft," Proceedings IEEE, Vol.77, No.3 (1989), 463-477.

08.02 Airborne, Remote, Turbulent-Air Motion Measurements

The ability to measure turbulence in the daytime convective planetary boundary layer from an airborne platform has existed for several years. The accuracy of these measurements is, in many cases, limited by the errors in the air velocity measurements. Current measurement techniques are typically limited by:

- Measurements of ambient air flow made in relatively close proximity to the aircraft and therefore influenced by the flow around the aircraft

- A total "system calibration" that is not based on physical constants

- An inability to make reliable measurements in clouds and in precipitation

- Mechanical resonances of the aircraft which may have a detrimental influence on the data quality

Innovations are needed to design, build, and test a remote, air-motion sensing system that can overcome these limitations. Measurements of the three components of the ambient wind field relative to the aircraft must be made far enough in front of the aircraft (approximate speed of 100 m/s) so that the measurements are not affected by the airflow around the body, but are close enough (e.g., ~10 m) so that correlations with data from in situ sensors located along the fuselage are retained. The proposed system must demonstrate a precision of +/- 0.05 m/s for a mean ambient wind of ~1 m/s and have a horizontal resolution of less than 10m in order to capture the turbulence levels of importance in the daytime, convective, planetary, boundary layer.

References:

Keeler, R.J. et al, "An Airborne Laser Air Motion Sensing System, Part I: Concept and Preliminary Experiment," Journal of Atmospheric and Oceanic Technology, Vol. 4, March 1987, p.113-127. A87-45732, ISSN 0739-0572

Vaughan and A.A. Woodfield, 1987: "An Airborne Laser Air Motion Sensing System. Part I: Concept and Preliminary Experiment." J. Atmos. Ocean. Tech., 4, 113-127.

Kristensen, L., and Lenschow, D., "An Airborne Laser Air Motion Sensing System, Part II: Criteria and Measurement possibilities," Journal of Atmospheric and Oceanic Technolgy, vol. 4, March 1987, p.128-138. A87-45733, ISSN 0739-0572

Schwiesow, R.L., Cupp, R. E., Post, M. J. and Calfee, R. F., "Coherent Differential Doppler Measurements of Transverse Velocity at a Remote Point--Laser Atmospheric Aerosol Detection," Applied Optics, Vol. 16, May 1977, p. 1145-1150. A77-31208

08.03 Instrumentation for Aerosol and Cloud Studies

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.

Attributes of new concepts might include reduced weight and power, greater reliability, greater resolution, and other significant figures of merit not currently achievable.

References:

Woods, D. C., R. L. Chuan, W. R. Cofer, III, et al., "Aerosol Characterization in Smoke Plumes from a Wetlands Fire," Global Biomass Burning: Atmospheric, Climatic, and Biospheric Implications, Joel S. Levine, ed. MIT Press, 1991. ISBN 0-26-212159-X

Kent, G. S., L. R. Poole, M. P. McCormick, et al., Optical Backscatter Characteristics of Arctic Polar Stratospheric Clouds, Geophys, Res. Lett., 17, No. 4, 377, 1990. A90-28480

08.04 Climate Observations From Space

Satellite and supporting in situ observations of precipitation rates, cloud cover, and broadband radiation at the surface and top of the atmosphere are needed to satisfy global-scale climate monitoring requirements. This subtopic solicits the following innovative methods and techniques.

- Improved direct and indirect techniques for measuring rainfall at the surface, e.g., rain gauge technology for direct measurements and active (radar) and passive microwave technology for indirect measurements of precipitation.

- Improved techniques for interpreting and assimilating rainfall data from weather radar and conventional observations. Includes innovative remote sensing algorithms and statistical techniques for applications to "ground-truth" measurements needed to validate satellite estimates of rainfall.

- Methods for global monitoring of spectral and broadband Earth radiation, surface radiation-budget, and radiation characteristics of clouds using both space platforms and ground-based observations.

References:

Hai, L., M. Xin, and C. Wei. 1985: Ground-Based Remote Sensing of LWC in Cloud and Rainfall By A Combined Dual Wavelength Radar-Radiometer System, Adv. Atmos. Sxi., 2, 93-103. A85-40884

King, M.D.L.F. Radke, and P.V. Hobbs. 1990: Determination of the Spectral Absorption of Solar Radiation By Marine Stratocumulus Clouds from Airborne Measurements Within Clouds. J.Atmos. Sci.,47,894-907. ISSN 0022-4928

Rosenfeld, D., D. Atlas, and D. A. Short. 1990: The Estimation of Convective Rainfall By Area Integrals, 2, The Height Area Rainfall Threshold (HART) Method. Jour. Geophys. Res., 95, 2161-2176. A90-26572, ISSN 0148-0227

Thiele, O. W. 1988: Validating Space Observations of Rainfall. Contributed paper. Tropical Rainfall Measurements. A Deepak Publishing, 528. ISBN 0-93-719414

08.05 Tunable Solid-State Lasers, Detectors, and LIDAR for Orbiting Platforms

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 through the IR, is required to conduct scientific experiments to measure atmospheric aerosols; molecular species, i.e., carbon monoxide, methane, carbon dioxide, nitrogen, and water vapor; and meteorological parameters. Additionally, high energy lasers are needed to create a plasma on a planetary surface to determine the surface elemental composition. Such a system requires a multi-joule, Q-switched, short-pulsed laser operating at high efficiency. More specifically, innovations are sought in the following areas:

- Laser-diode arrays in the 0.76-to-0.81 μm or the 1.4-to-2.1 μm spectral ranges for optical pumping of solid-state materials.

- Non-linear optical materials to efficiently double, triple, or quadruple the frequency of near infrared wavelengths, 0.7 to 1.1 μm, or to produce efficient optical parameter oscillators in the mid-IR, 2.5-to-5.5 μm, spectral region.

- High-speed and/or high-quantum-efficiency detectors with low noise properties and operating in the 0.9-to-5.5 μm region. Room temperature operation is preferred.

- A multi-joule, Q-switched diode pumped Nd laser system operating at 1 Hz and an efficiency of 0.15 or greater. Beam quality of the system should be less than 15 times diffraction limit.

- Novel tunable, solid-state laser materials, especially solid-state lasers compatible with laser diode pumping. Lasing between 0.7 μm and 1.1 μm and 1.5-to-2.1 μm is of particular interest.

- Continuous-wave solid-state laser devices compatible with laser diode pumping. In general, single- frequency, continuous-wave devices with a power output of 10 to 100 mW are sought. Wavelength stability and linewidth of these devices should be less than 15 MHz and preferably less than 1.0 MHz. A means of actively stabilizing these devices is preferred.

- Pulsed, solid-state laser devices compatible with laser diode pumping. In general, pulsed lasers operating on a single mode and producing in excess of 0.1 J/pulse at a 10 Hz pulse repetition frequency are sought. Spectral purity of the pulsed lasers should be in excess of 0.99 and preferably higher than 0.999.

- Narrow-band spectral filters having a high spectral resolution, from 10^5 to as high as 2.10^6, and a high peak transmission, greater than 0.5. Filters in the range of 0.7-to-1.1 μm and 1.5-to-5.5 μm with the lower resolution are sought while a filter at 1.06 μm with the higher resolution is sought. Stability of the filter should be a fraction of its spectral bandwidth.

References:

Couch, Lana and Hudson, Wayne. "Global Change Technology Initiative, Technical Overview." NASA Headquarters, Office of Aeronautics, Exploration Technology, Code RS, Washington, DC, May, 1990. NASA Code RS

Allario, Frank. "Progress in Solid-State Lasers for Spaceborne Lidars." Laser and Optical Remote Sensing: Instrumentation and Techniques, North Falmouth, MA, September 28, October 1, 1987. N90-70967

Barnes, N. P. "Remote Sensing Using Solid-State Lasers, Progress and Projections." Optical Remote Sensing of the Atmosphere, Incline Village, NV, February 12-15, 1990. A88-19659

08.06 Earth Observing Sensor Development For Geostationary Orbit

Innovations are desired for the development of a new generation of instrumentation for earth observation to be flown on the Geostationary Earth Observatory (GEO). The multi-sensor, multidisciplinary specifications of GEO will require significant improvements in spatial and spectral resolution relative to instruments that are presently flown on operational geostationary satellites. To meet the overall goals of NASA's Mission to Planet Earth, innovations for GEO are required in:

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

Visible and infrared imaging devices with high resolution, visible and infrared imaging devices including advanced spectral separation techniques and high performance, focal-plane arrays with onboard calibration.

Optical systems that are thermally stable, large aperture (up to 1 meter diameter), and high resolution.

References:

Jedlovec, G., Wilson, G., Dodge, J. "Status Report: NASA's Plans for an Earth Science Geostationary Platform," NASA/MSFC SSL Preprint Series No. 89-109, February 1989. AVAIL:CASI

Harris, L., Johnston, G., et al. "Earth Orbiting Technologies for Understanding Global Change," 40th Congress of the International Astronautical Federation, Oct. 7-12, 1989. A90-13241

Koczor, R. J., "The GEO Platform," Space Programs and Technologies Conference, Huntsville, AL, Sept. 25, 1990. AIAA Paper No. 90-3639. A91-10065

Davis, "On-orbit Location Options for Earth Science Geostationary Platforms," Paper No. 90-3856, AIAA Space Programs and Technologies Conference, Sept. 26, 1990. A91-10201

08.07 Airborne Stratospheric Science Studies

NASA requires innovations in the methods used to make measurements from airborne platforms flying in the stratosphere, and to support those measurements with analyses and models. Innovations are sought in platforms as well as in measurement techniques. Measurements of interest include both remote measurements of the Earth's surface and remote and in situ measurements of the stratosphere from NASA's stratospheric platform aircraft (ER-2). Remote measurements of the surface include the identity and condition of ecosystems on land and in water, and their relationship to other geophysical variables. Stratospheric composition includes the identity and concentration of gaseous species, as well as the number, size, shape, and composition distributions of aerosol and cloud particles. Innovations needed include:

- Increased speed, sensitivity, accuracy, specificity, space-time coverage and applicability (i.e., range of measured constituents or parameters).

- Advanced detector, source, pointing/tracking, and miniaturization technology as well as improved sensor survival for long periods in harsh environments.

- Self-diagnosis techniques that provide a continuous measure of data quality and instrument health. Real-time adjustments in sensor operation to compensate for instrument degradation or changes in sensed properties.

- Data processing techniques that increase the usefulness of raw data in answering specific questions of current concern.

- Contributions to analysis and modeling the chemistry and dynamics of species measured from the ER-2, and future very-high-altitude, science-platform aircraft.

References:

Chan, K. R., Scott, S. G., Bui, T. P., Bowen, S. W., and Day, J. "Temperature and Horizontal Wind Measurements on the ER-2 Aircraft during the 1987 Airborne Antarctic Ozone Experiment." Journal of Geophysical Research 94 (1989): 11,573-11,587. A89-53912

Loewenstein, M., Podolske, J. R., and Strahan, S. E. "ATLAS Instrument Characterization: Accuracy of the AASE and AAOE Nitrous Oxide Data Sets." Geophysical Research Letters. 17 (1990): 481-484. A90-28506

Matson, P. A., Vitousek, P. M., and Livingston, G. P. "Nitrous Oxide Flux from Amazonian Ecosystems: Soil Fertility and Disturbance Effects." Bulletin-The Ecological Society of America 70.2 (1989): 194. N77-27436

Pueschel, R. F., Snetsinger, K. G., Hamill, P., Goodman, J., and McCormick, P.M. "Nitric Acid in Polar Stratospheric Clouds: Similar Temperature Thresholds of Nitric Acid Condensation and Cloud Formation." Geophysical Research Letters. 17 (1990): 429-432. A90-28493

08.08 Tunable Optical Filter for Remote Sensing Applications

NASA seeks tunable, optical filters for use in a wide range of remote sensing applications. The visible (0.3 to 1.1 μm) and near-IR wavelength ranges (1.1 to 3.0 μm) are of primary importance, but longer wavelength regions (3 to 5 and 7 to 14 μm) are also of interest. The attributes of a tunable optical filter fall into two categories. The first concerns the calibration characteristics, including stability, out-of-band rejection, uniformity, optical quality, and polarization extinction ratio. The second concerns the applicability, including wavelength range, bandwidth, transmission, throughput, field-of-view, response time, power requirements, size, weight, and cost.

Optical tunable filters provide an alternative to more traditional means of spectral selection such as gratings and prisms. They include, but are not limited to acousto-optical tunable filters (OATF), liquid-crystal tunable filters (LCTF), and ferroelectric liquid-crystal devices. Each of these devices will have unique advantages and disadvantages. It is important that these unique characteristics of these devices be well understood and their specific technical challenges are addressed. For example, reduction of RF power in the IR range for AOTFs and increase in the transmission efficiency and tuning speed of LCTFs.

References:

Chang, I.C., "Acousto-Optic Tunable Filters," Optical Engineering, Vol. 20, No. 6, p. 824-829, Nov.-Dec., 1981. A82-18003, ISSN 0091-3286

Masterson,m H. J., Sharp, G. D., and Johnson, K. M., "Ferroelectric Liquid-Crystal Tunable Filter," Optics Letters, Vol. 14, No. 22, p. 1249, 1989. ISSN 01465-9592

Jacobs, "Liquid Crystal Laser Optics: Design, Fabrication, and Performance," J. Opt. Soc. Am. B, Vol. 5, No. 9 (1988), 1962-1977 (1988). INSPEC A89001076, INSPEC B89002865

Wu, "Design of a Liquid Crystal Based Tunable Electro-optic Filter," Appl. Opt., Vol. 28, No. 1 (1989), 48-52 (1989). AVAIL:AIAA

08.09 Sensor Readout Electronics

Advancements in sensor readout electronics are required to enable and enhance a number of NASA missions utilizing imaging and spectroscopic detector arrays. These areas of advancement include:

- Low-noise, low-power devices and circuits for cryogenic temperatures (0.1 K to 80 K). Silicon CMOS devices and circuits operating with low noise below 8 K, devices and circuits in advanced materials such as GaAs for 0.1 K - 8 K operation, and ultra-low noise discrete transistors, such as Ge JFETs, at all cryogenic temperatures.

- Circuits operating with sub-electron r.m.s. read noise for detector arrays; structures for CCD output amplifiers with sub-electron read noise circuits for sub-electron read noise in X-Y switched FET readout electronics; circuits suitable for large arrays which can detect and count single photo-electrons.

- Advanced techniques for thermal compartmentalization and isolation of electronics in cryogenic dewars, such as multi-temperature, multi-stage packaging to reduce dewar thermal loads and IR photonic leaks; low-power, high-resolution (e.g. 10 mW, 50 kHz, 16 bit) A/D converters for cryogenic operation with focal planes.

- Techniques for optical transmission of data (and perhaps power) between warm electronics and cryogenic focal-planes. Such links must dissipate very low power on the focal plane.

- Advanced readout architectures for event-driven readout of large detector arrays to enable efficient readout under sparse illumination conditions; circuit techniques and prototype readout multiplexers for such readout.

References:

Fossum, E. R., Report of the Sensor Readout Electronics Panel in Workshop Proceedings: Sensor Systems for Space Astrophysics in the 21st Century (Astrotech 21), pp. 58-67, Pasadena, CA, JPL Pub. 92-94, Vol. 2.

Fossum, E. R., "Future Directions in Focal-Plane Signal Processing for Space-Borne Scientific Imagers," in Proc. SPIE Vol. 1541, Infrared Sensors: Detectors, Electronics, and Signal Processing, pp. 62-67, 1991.

Proc. SPIE Vol. 1684, Infrared Readout Electronics, Fossum, E. R., ed., expected to be available summer 1992.

08.10 Detectors and Detector Arrays

Detectors and detector arrays for space astronomy, astrophysics, geophysics, and atmospheric studies at varying wavelengths require the following innovations:

- Composite, cryogenic, or room-temperature IR bolometers, including using diamond (optional) films coated with metal for absorbing incident radiation, with attached semiconductor or superconductor thermometers for measuring the temperature change.

- Cryogenically cooled, junction-field-effect transistors (JFETs)(2-4K) with low-noise at low-audio frequencies (10Hz) and low-power dissipation.

- Low-noise multiplexers for reduced heating of dewars at 2 K for detectors and sensors.

- Low-noise, low-power amplifiers with voltage gain and a complete line of electronic parts suitable for operation at 2 K to support cryogenic detectors.

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

- Three-dimensional (energy, x, y) detector arrays for UV and visible.

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

- High-quantum-efficiency, near-infrared, and UV photocathodes.

- Charge-coupled device (CCD) array improvements.

- Spaceborne sensor for the direct measurement of magnetospheric currents in space.

- Array detectors for UV cameras, visible blind, high dynamic range.

- High-efficiency, far-infrared dichroic and bandpass filters and wideband beamsplitters for Michelson interferometer.

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

- Improved passive radiative coolers for 25-60 K operation in deep space.

- Superconducting quantum interference devices (SQUIDs) designed for low-noise readout of cryogenic detectors.

- Stable, non-mechanical , cryogenic (2-4 K) beam chopper or interrupter for use at far-infrared wavelengths (0.01 to 1 cm).

- Solid-state X-ray detectors that have sub-keV energy resolution when operated at or near room temperature and that are hermetically sealed for space flight.

References:

Jacoby, G. ed. "CCD's and Astronomy," Astronomical Society of the Pacific, Conference Series; Vol. 8; published 1990.

Anon. "Charged Coupled Devices and Solid-State Optical Sensors No. 2," SPIE Electronic Imaging and Science Technology Conference, San Jose, CA, Vol. 1147.

Cheryl Dole et. al. "Generation Lifetime Damage Factor, Its Variance in Silicon," IEE Transactions on Nuclear Science, Vol. 36, No. 6 1872.

Ahmed, I., Betts, R. R., Happ, T., Henderson, D. J., Wolfs, F. L. H., and Wuosmaa, A. H., "Nuclear Spectroscopy with Si PIN Diode Detectors at Room Temperature," Nuclear Inst. and Methods, A299, 201, 1990.

08.11 Technology for Infrared Astronomical Applications

Innovative concepts and techniques are needed to support spaceborne infrared astronomical telescope projects. This includes development of sensing instrumentation for both ground and flight (airborne and space) test. Means are needed to achieve ultimate performance in low-background instruments:

- Improved sensitivity of discrete IR detectors and integrated IR-detector-array electronics operating at cryogenic temperatures;
- Means to reduce device noise, dark current, and susceptibility to particle radiation and to provide high uniformity and high radiometric accuracy;
- Detector arrays and concepts for detector materials with cutoff wavelengths between 2.5 and 1000 μm;
- Advanced multiplexer architecture, interconnect technology, and monolithic structures.
- Area-array focal planes operating with cutoff wavelengths longer than 14 microns and temperatures between 35 K and 80 K.
- Bolometric arrays operating at He^3 temperature.
- Detector, multiplexer, and analog signal processing structures providing two-dimensional spatial imaging in Fourier transform spectrometers.
- Methods to count individual IR photon events, either directly or via up conversion.
- Novel techniques in long-wavelength (>20 microns) IR filter design and manufacture.
- High-quality, low-cost fabrication techniques for optics capable of diffraction-limited performance down to 1 micron. Included are both small optics for instrument applications, and large (>1 m) mirrors.
- Novel techniques are needed for in situ evaluation of image characteristics and maintenance of image quality in IR telescopes.

References:

Proceeding of the SPIE Conference Cryogenic Optical Systems and Instruments III, Session on Stratosperic Observatory for Infrared Astronomy (SOFIA). Proc SPIE 973, PP.147-216. N90-21313

Bailey G. C., Niblack C. A., Wimmers J. T. "Recent Developments on a 128 x 128 Indium Antimonide/FET Switch Hybrid Imager for Low-Background Application," NASA Doc. 686-11. A88-12692

McCreight, C.R., "Proceedings of the Third Infrared Detector Technology Workshop," Moffett Field, CA, Feb. 7-9, 1989. NASA TM 102209. N90-21313

08.12 Submillimeter Antennas, Radiometers, and Spectrometers

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

- Antenna systems with aperture diameters up to 4 meters and RMS surface accuracies of $<\lambda/50$; multiple beams with scan angles of many beamwidths.
- Low-noise submillimeter radiometers, with $T_{REC} < 20$ hv/k, over the frequency range 350-3000 GHz, with 71 five-year lifetimes.
- Solid-state, phase-locked, submillimeter local oscillators up to 3000 GHz with output power greater than 100 microwatts. These local oscillators should have dc power requirements less than 20 Watts, be small and lightweight, and have 71 five-year lifetimes.
- Multichannel spectrometers to simultaneously analyze IF signal bandwidths up to 10 GHz with a frequency resolution of ≤1 MHz, small size, lightweight, and low dc power (< 10 mW per channel), along with high stability and lifetimes greater than five years.

References:

Frerking, M.A. "Submillimeter (Terahertz) Receiver Technology Conference, Proceedings Introduction," Int. J. IR & MM Waves 8, 10, 1211-1214 (Oct. 1987).

Waters, J.W. "Microwave Limb-Sounding of Earth's Upper Atmosphere," Atmospheric Research, Vol. 29, Elsevier Science Pub., Amsterdam, (1989), 391-410. A90-34026

Frerking, M. A. "Development of Components for Submillimeter Wave Heterodyne Radiometers at JPL," Proc. 29th Liege Int'l. Astrophysical Colloquium from Ground-Based to Space-Borne Sub-mm Astronomy, Liege, Belgium, 3-5 July 1990, ESA SP-314 (Dec. 1990). N91-22017

08.13 Instrumentation for Exobiology

Exobiology seeks to understand the origin and evolution of life and life-related processes and materials throughout the universe. This requires a large and specialized cadre of analytical instruments and systems for flight experiments in low Earth orbit and on planetary missions. These instruments and systems must be highly accurate and precise while performing meaningful analyses on very small samples containing biologically important elements and their molecules. Those instruments are further required to be highly miniaturized and extremely efficient in their use of spacecraft resources requiring innovative concepts and approaches. Examples include the following:

- Miniaturized gas chromatograph subsystems including innovative detectors, columns, sampling devices, and sample treatment devices (e.g., pyrolyzers, DTA, DSC) to detect and quantify rapidly volatile and organic compounds at parts-per-billion levels.
- Miniaturized highly rugged electrochemical devices to measure O_2 at parts-per-million levels in planetary atmospheres.
- Miniaturized, infrared, diode laser spectrometer and subsystems, including diode lasers capable of operating at high temperatures, (>200 K), for molecular spectrometry of gases in the range of 2-to-5 microns to measure biogenic molecules, e.g., C and N isotopes in CO_2 and NO_x precision of 0.1 percent 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 for the production, collection, levitation, observation, and analysis of 0.1-100 micron aerosol particles inside an environmentally controlled chamber in microgravity.

References:

Wood, J. and Chang, S., eds. "The Cosmic History of the Biogenic Elements and Compounds," NASA SP-476, 1985. N85-28562

Miller, J.B. and Clark, B.C. "Feasibility Study for Gas-Grain Simulation Facility," NASA CR-177468, 1987. N88-13954

DeFrees, D., Brownlee, D., Tarter, J., et al. "Exobiology in Earth Orbit," NASA SP-500, 1989. N91-14725

Klein, H.P. Report of the Committee on Planetary Biology and Chemical Evolution, "The Search for Life's Orgins," National Academy Press, 1990. ISBN 0309042461

08.14 Oceanographic Sensors

Advanced ocean color (visible/near IR) and IR satellite sensor missions (SeaWiFS and MODIS) require innovative technology to support calibration, atmospheric correction and in-water algorithm development, and validation of derived products. Innovations are needed in the following areas:

- Expendable, optical, drifting buoys to measure surface upwelled radiance and downwelled irradiance at satellite vis-near IR sensor bands to provide accurate estimates of water-leaving radiance for comparison with satellite data. Aircraft deployment, >4 month lifetime, calibration, anti-foulant approach, and satellite data collection should be considered.
- Turn-key aircraft instrument systems for measurements of ocean reflectances, laser and solar stimulated fluorescence, and optical scattering. Flight on private aircraft, calibration, navigation, and on-board analysis should be considered.
- Moored or towed instruments for estimation of near-surface or depth profiles of apparent, and/or inherent optical properties in narrow bands from 400 nm to 900 nm necessary for derivation of bio-optical state.
- In-situ instruments for measurement of pCO_2 and other parameters required for measuring biogenic gas exchange across the air-ocean interface.
- Field calibration systems for monitoring absolute spectral calibration and stability of in-situ radiometers and irradiance sensors on board research vessels. Highly stabilized, self-calibrating technology, with ability to assure knowledge of drift and stability to 0.5 percent over two months in comparison with more complete calibrations at shore facilities, and capability of interfacing with shipboard instrumentation data systems via standard communication protocols are required.
- A probe for measuring the real and imaginary parts of the dielectric constant of snow, sea ice, and water is needed to interpret satellite active and passive microwave data. The probe has to be portable and suitable for field work in the polar regions and match current satellite frequencies for data transmission.

References:

Esaias, W. E. "Instrumentation for Ocean Optical Remote Sensing," 1990 Proceedings of Technology 2000 Conference, Office of Commercial Programs, NASA, Washington D.C. AVAIL:CASI

Mueller, J. and R. Austin. 'Proceedings of NASA/GSFC SeaWiFS Workshop on Ocean Optical and Other Measurements for SeaWiFS Radiometric Validation and Bio-optical Algorithm Development". Draft available form SeaWiFS Project Office, Code 970.2 Greenbelt, Md. 20771.

G. Feldman, W. Esaias, C. McClain, J. Elrod, N. Maynard, Dendres, N. During, C.Ng, R. Evans, J. Brown, Swalsh, G. Podesta, M. Carle. Ocean Color: Availability of the Global Data Set. EOS Trans. AGU June 6, 1989. A91-17354

08.15 Optical Components for Earth-Orbiting Spacecraft

Innovations are needed in optical components and systems for Earth-orbiting spacecraft/platforms:

- Testing apparatus, methods, and analytical modelling to evaluate the effects and removal of spacecraft contamination on critical surfaces.
- Concepts and designs for optical coating in space.
- Optical coatings for use in the extreme ultraviolet to far IR spectral region that provide wide and narrow band filters, beamsplitters, polarizers and reflectors.
- Telescope baffle blackening agents for use in space at wavelengths from the soft x-ray to millimeter wave regions.
- Heat rejection filters for the removal of unwanted visible or thermal radiation from near-IR telescopes, especially high-magnification systems having intensity of 0.5 w/cm^2 or greater.
- Fourier transform spectrometer for the 120 nm to 400 nm.
- Spectral filters deposited directly onto visible and infrared detector arrays.
- Measurement of the materials refractive index of temperature from 4 K to 273 K with accuracy of one in 10^4.
- Computer algorithms for design, tolerance measurement and/or optical performance evaluation of space flight optics.
- Techniques for producing low-scatter coatings and fabricating conventional and grazing incidence mirrors with low-scatter surfaces for the x-ray/UV spectral region.
- 15 μm to 50 μm IR beamsplitters, polarizers, and filters with high in-band transmittance and good out-of-band blocking, for use at cryogenic temperatures.
- Compact, rugged, vacuum-UV continuum and line radiation sources for space simulation and flight applications.
- A vacuum-compatible optical monitoring system to monitor and/or control layer thicknesses of the order of 10 nm or less for use in producing multilayer coatings of EUV and soft x-ray regions.
- Methods for several picometer astrometric accuracy of measurement of linear distances on the order of several meters.
- Improved technologies for producing high efficiency, low-scatter diffraction gratings and/or holographic optical elements for visible to soft x-ray spectroscopy.
- Holographic optical elements for enhancing the performance of Fabry-Perot interferometers.

References:

Osantowski, John F. and Fleetwood, C.F. 'Contamination of Grazing Incidence EUV Mirrors-An Assessment,' Proceedings SPIE, Vol. 830 (1987), 306. A88-49842

Wright, Geraldine and Bryan, Jowen. 'Proposed Method of Producing Large Optical Mirrors: Single Point Diamond Crushing Followed by Polishing With a Small Tool,' Opt. Eng., Vol. 25 (1986), 1021. A87-18504

Gull T. R, Herzig, Howard, Osantowski, J.F., et al. 'Low Earth Orbit Environmental Effects on Osmium and Related Thin Film Coatings,' Appl. Opt., Vol. 24 (1985), 2660. A85-45262

Keski-Kuha, R.A.M., Osantowski, J.F., Toft, A.R., Partlow, W.D. 'Grazing Incidence Reflectance of SiC films Produced by Plasma-Assisted Chemical Vapor Deposition,' Appl. Opt., Vol. 27 (1988), 1499.

08.16 Innovative Optics Technology

Innovative optical materials, coatings, devices, characterization instruments and design tools are needed to support the development of advanced instrumentation for planetary sciences and astrophysics. Examples include:

- Technology for coating and cleaning of optical surfaces in space, including techniques to characterize and improve performance in the presence of optical contamination.

- Techniques and tools for design, tolerance definition and evaluation of space flight optics, including precision testing of tilted, decentered aspheric surfaces of very low focal ratio.

- Low scatter materials, components, metrology systems, characterization techniques and concepts for instruments affected adversely by narrow angle-scattering such as coronagraphs and dispersive spectrometers. Innovations in diffraction gratings, diffraction masks, active image control and thin films are of particular interest.

- Techniques and instrumentation for test, characterization and certification of micro-precision optical components such as Ronchi rulings to an accuracy of 1 nanometer average line shape.

- Ultra-low mass mirror and mirror segment substrates and face sheet materials for use in cryogenic infrared and sub-millimeter (1-700 micrometers wavelength) reflectors, including surface metrology methods.

- Advanced coatings for thermal infrared (9-11 micrometer wavelength) beam splitter applications with pulsed lasers.

- Conventional and grazing incidence mirrors for wavelengths above 5 nanometers.

References:

Chrisp, M. P. "The PMIRR Optical System for Mars Observer," SPIE Proceedings, Vol. 810 (1987), 44-51. A88-35959

Breckinridge, J. B., Kuper, T. G. and Shack, R. V. "Space Telescope Low-scattered Light Camera: A Model," Optical Engineering, Vol. 23 (1984), 816-820. A83-32026

Meinel, A. B. and Meinel, M. P. "Optical Testing of Off-axis Parabolic Segments Without Auxiliary Optical Elements," SPIE Proceedings, Vol. 28 (1989), 71-75. A89-24697

08.17 Collimators for High-Energy Radiation

Innovations are required in the fabrication of X-ray, gamma-ray, and neutron collimators that have the precision necessary to achieve arcsecond or sub-arcsecond imaging in solar physics and astrophysics when used in stationary multi-trip arrays or as rotating modulation collimators. The collimators will be used to obtain images of complex sources with dimensions that could be as large as 3 to 5 arcminutes. The following collimators are needed:

- Collimators capable of $\geq$ 90 percent modulation of X-rays in the energy range from as low as 1 keV to as high as 100 keV with slit widths as small as 10 microns and diameters as large as 10 cm.

- Collimators capable of $\geq$ 90 percent modulation of X-rays and gamma-rays to energies as high as 20 MeV with slit widths as small as 20 microns and diameters as large as 10 cm.

- Collimators capable of $\geq$ 90 percent modulation of gamma rays to 200 MeV and neutrons to 500 MeV with slit widths as small as 100 microns and diameters as large as 10 cm.

- Fresnel-zone, plate collimators capable of $\geq$ 90 percent modulation of X-rays from as low as 1 keV to as high as 100 keV for use in non-rotating imaging. Slit dimensions should range from 10 microns to 1 cm with an overall diameter as large as 10 cm.

References:

Crannel, C. J. et al. "A Balloon-Borne Payload for Imaging Hard X Rays and Gamma Rays from Solar Flares," in proc. AIAA Int. Balloon Tech. Conf. (AIAA-91-3653), Albuquerque, NM, Oct. 8-10, 1991. AIAA Paper 91-3653. A92-11002

Dennis, B. R., et al. "The Fourier Imaging X-ray Spectrometer (FIXS) for the Argentinian, Scout-launched Satelite de Aplicaciones Cientificas 1 (SAC-1)," proc. Max '91 Workshop #1 NASA/GSFC, 1988.

Hudson, H. S., et al. "Hard X-Ray and Gamma-Ray Imaging Spectroscopy for in the Next Solar Maximum," SPIE Vol. 1344, EUV, X-Ray, and Gamma-Ray Instrumentation for Astronomy, pp. 492-503, 1990. A92-20272

Mertz, L. "Ancestry of Indirect Techniques for X-Ray Imaging," SPIE Vol. 1159, EUV, X-Ray, and Gamma Ray Instrumentation for Astronomy and Atomic Physics, pp. 14-16, 1989. A90-50253

08.18 Single-Mode, Room-Temperature, Mid-Infrared Semiconductor Lasers

Single-mode, tunable semiconductor lasers with radiation in the mid-infrared (2-5 μm)region of the spectrum are needed for applications of LIDAR and remote sensing. New materials growth techniques and device packaging and processing are required.

III-V and II-VI Laser Materials. The alloy GaInAsSb, lattice-matched to GaSb, is of potential importance to the wavelength band of interest because it offers the possibility of adjusting the composition of the active layer. Techniques are sought for the growth and processing of GaInAsSb epitaxial structures into semiconductor diode lasers, and for the demonstration of growing double-heterostructure InGaAsSb leading to the development and delivery of CW single-spatial-mode lasers and feasibility demonstration of single-longitudinal-mode diode lasers, e.g., distributed feedback lasers, in the ~2.0-2.5 μm wavelength region.

Wide-Band Continuously Tunable Single-Mode External Cavity Technology. Conventional diode lasers require an external cavity to ensure single-mode oscillation. Convectional external cavity technology permits only narrow ranges of continuous tunability. New approaches are sought for cavities to insure continuous tunability over the gain curve over a diode and to readily accept diodes with gains covering the 0.6-5 μm band. Proposals are requested that will demonstrate the external cavity technology leading to construction and delivery of the cavity and associated hardware and a demonstration of tunability over the 0.9-1.1 μm range.

References:

Lang, R. and Kobayashi, K., "External Optical Feedback Effects on Semiconductor Injection Laser Properties," IEEE J. Quantum Elect., QE-16 (1980), pp. 347-355. A80-28749

"GaInAsSb/A1GaAsSb Injection Lasers for Remote Sensing Applications," S. Forouhar, J. Cody, and J. Katz, SPIE vol. 1062, Laser Applications in Meteorology and Atmospheric Remote Sensing, pp. 16-20, 1989.

Forouhar, S., Cody, J. and Katz, J., "GaInAsSb/AlGaAsSb Injection Lasers for Remote Sensing Applications," SPIE vol. 1062, Laser Applications in Meteorology and Earth and Atmospheric Remote Sensing, pp. 16-20, 1989. A90-31988

08.19 Analytical Instrumentation for Planetary Atmospheres Research

Innovations are sought for improved operating characteristics of gas chromatograph-mass spectrometer systems used for atmospheric composition measurements of planetary atmospheres. The detection and measurement of atmospheric constituents on future entry probes and flyby missions will require increased performance characteristics to fully meet the measurement goals of the experiment. Instruments sought include:

- Miniaturized, rugged, and reliable gas chromatograph columns that provide fast elution times, high sample capacities, and reliable and repeatable operations after extended (several years) cruise times.
- Improved fabrication and mounting techniques for the quadruple analyzer section. The results should produce a higher precision, lighter weight, and more rugged quadruple rod analyzer section.
- Miniaturized, lightweight, and rugged wide range vacuum pump, such as a turbomolecular pump, capable of producing pressures of 10^{-9} mbar or lower and venting directly to an ambient pressure as high as 10 mbar.
- Longer life, improved stability, rugged and lighter weight, high current and/or pulse counting, positive and negative secondary electron multipliers.

References:

H. B. Niemann, J. R. Booth, J. E. Cooley, R. E. Hartle, W. T. Kasprzak, N. W. Spencer, S. H. Way, D. M. Hunten, and G. R. Carignan. "Pioneer Venus Orbiter Neutral Gas Mass Spectrometer Experiment," IEEE Transactions on Geoscience Electronics and Remote Sensing, GE-18, 60, 1980. A80-30840

H. B. Niemann, D. N. Harpold, S. K. Atreya, D. M. Hunten, T. C. Owen. "Galileo Probe Mass Spectrometer," accepted for publication in Space Science Review, Spring 1992. ISSN 0038-6308

08.20 Optoelectronics for Space Science and Engineering

Optoelectronic devices are useful for a number of applications in space science and engineering due to advantages in size, weight and immunity from electrical interference. Innovative optoelectronic devices and instruments are needed in the following areas:

- Optical gyroscopes -- low noise (noise less than 0.1 percent of measurement rate) optoelectronic inertial rotation sensors (10^{-4} to 10^{2} times the earth rotation rate) using linear and nonlinear fiber optics, ring lasers and ring resonators.
- Fiber optic sensors for on-board spacecraft pressure and temperature sensing and aircraft atmospheric sensing.
- High bandwidth (GHz), high-gain, high-sensitivity (sub-nW) detectors at the 980, 1047 and 1060 nm wavelengths.
- Optical pre-amplifiers (e.g. fiber optic and semiconductor) for high-bandwidth, high-gain, high-sensitivity (sub-nW) IR detectors particularly at the 980, 1047 and 1060 nm wavelengths.
- Optoelectronic integrated circuits for space science (e.g. atmospheric and stellar spectroscopy applications).
- Organic and inorganic, multiple, quantum-well-structured devices for lasers, detectors and for optical modulation.

References:

R. A. Bergh, H. C. Lefevre, and H. J. Shaw. "An Overview of Fiber Optic Gyroscopes," Journal of Lightwave Technology, April 1984. A84-33044

M. A. Krainak. "Optoelectronics Research for Space Communications Programs at the Goddard Space Flight Center," 1991 IEEE Military Communications Conference Proceedings, Paper 47.4, 1991.

"Optoelectronic Materials, Devices, Packaging and Interconnects," SPIE Proceedings, Volume 836, August 1987. A89-10339

J. A. Arnaud. "Enhancement of Optical Receiver Sensitivities By Amplification of the Carrier," IEEE Journal of Quantum Electronics QE-4 (11), 1968.

08.21 Infrared Point Spectrometer for Rover Missions

NASA is actively involved in the development of small rovers for missions to Mars and the Moon. A reflectance-type near-infrared and/or a passive-emission mid-infrared point spectrometer could be used on such rover missions to study the mineralogy of surficial rocks and soils. This is a request for an innovative instrument(s) that can be integrated onto small rovers operating on Earth as prototypes for future space missions and that meet the following general constraints:

- Physical dimensions: $\leq$ 15 cm x 15 cm x 15 cm
- Operating power: $\leq$ 1 Watt; if cooler is needed, $\leq$ 5 Watts; Weight: $\leq$ 400 grams; Wavelength ranges: near-IR: 0.9 to 2.5 µm; spectral resolution $\approx$ 15 nm; mid-IR: 7 to 14 µm; spectral resolution $\approx$ 8 cm^{-1}
- Signal-to-noise ratio: $\geq$ 200:1 for a rock with 90 percent emissivity at 325 K (average lunar) or at 280 K (warm Mars) for the mid-IR and 20 percent reflectance for the near-IR (Moon or Mars).

References:

Bartholomew, M.J., et al. (1989) Infrared Spectroscopy (2.3-20 µm) for the Geological Interpretation of Remotely-Sensed Multispectral Thermal Infrared Data, Int. Jour. Remote Sensing, V.10, p.529-544. ISSN 0143-1161

Pieters, C.M. (1983) Strength of Mineral Absorption Features in the Transmitted Component of Near-Infrared Reflected Light: First Results from RELAB, Jour. Geophys. Res., V.88, p.9534-9544.

A84-13122

08.22 Multichannel Visible-Wavelength CCD Imaging System

NASA utilizes visible-wavelength imaging systems for various space programs and for ground-based telescopes as well. Technology for acquiring images within five or more spectral bands in the visible range simultaneously is sought for astronomical study of time-dependent phenomena and for certain planetary fly-by missions. One approach to meeting the requirement for simultaneity would be to utilize dichroic mirrors placed along an optical axis, each of which would deflect a specific band toward a CCD detector while transmitting the remainder of the beam to other mirror/detector sets. Image registration is important. Secondary filtering ahead of the individual detectors might be required for further bandwidth limiting. Approaches other than that mentioned should also be considered.

References:

Kingslake, R. (editor) Applied Optics and Optical Engineering, Volume 1, Academic Press, New York and London, 1965. ISBN 0-12-408601-2

Melles Griot, Optics Guide, 1990.

08.23 Measuring Electronic Density-of-States of Metals and Alloys

The electronic structure of a metal is of importance in understanding the physical properties of the metal and its alloying behavior. Physical properties of metals such as hydrogen embrittlement and oxygen environmental compatibility impose restrictions on the use of many advanced alloys in NASA rocket propulsion systems. Significant progress has been made in recent years in both theoretical and experimental investigation of the electron energy bands of semiconductors and superconductors. However, an accurate experimental method for determining the detailed structure of the electron density-of-states (DOS) for metals and alloys is still lacking. Innovative instruments with the following performance requirements are needed:

- Precise measurement of the electronic density-of-states (DOS) at the Fermi energy level for metals and alloys. The temperature range for this DOS measurement is between 100 to 800K.
- Measurement of DOS at the Fermi energy level for each microstructural phase in a typical multi-phase metallic alloy; DOS measurement at or near the microstructural grain boundary. The apparatus can measure the DOS values at or near the sample's surface and also its bulk measurement.

- DOS measurements at the Fermi energy level for pure metallic elements shall be compared with the existing low-temperature, electronic, specific-heat data for instrumentation performance verification and calibration.

References:

Schroder, K., Electronic, Magnetic, and Thermal Properties of Solid Materials, Marcel Dekker, Inc., New York, 1978.
ISBN 0-82-477024-4

Fabian, D.J., Watson, L.M., Band Structure Spectroscopy of Metals and Alloys, Academic Press, London and New York, 1973.

08.24 Calibration Systems for Non-Invasive Sensors

This subtopic solicits proposals for innovative techniques and instrumentation systems for calibrating non-invasive sensors. Requirements include high levels of automation and integration between components or instruments via common interface such as IEEE-488, ease of repeatability for procedures, automatic report generation, traceable calibration sources, and implementation of techniques to enhance automation and repeatability. Specific areas to be addressed include:

- Traceable visible and infrared sources
- Measurement of instantaneous field of view
- Measurement of field of view
- Measurement of the modulation transfer function
- System noise analysis
- Measurement of detector sensitivity and linearity
- Comparison between internal and external calibration sources
- Performance of all measurements on pixel, line, channel and system basis
- Measurement repeatability

References:

Jaggi, S. "Adaptive Technique For Removal of Coherent Noise From Infrared Scanner Data," Proceedings of the 23rd Conference on Science and Systems, Princeton University, Princeton, NJ, March 22, 1990. AVAIL:ESL

Young, Eric. "Misalignment Tolerances For an Imaging System With a Segmented Primary Mirror," Optical Engineering, Vol. 28, No. 9 (Sept. 1989). A89-54198

Oh, Sung Jun, Hall, E. L. "Calibration of an Omnidirectional Vision Navigation System Using an Industrial Robot," Optical Engineering, Vol. 28, No. 9 (Sept. 1989). AVAIL:AIAA

Hsien-Che Lee. "Review of Image-blur Models in a Photographic System Using the Principles of Optics," Optical Engieering, Vol. 29, No. 5 (May 1990). AVAIL:AIAA

Meeks, G. R. and Palluconi, F. D., "Thermal Infrared Multispectral Scanner (TIMS): An Investigator's Guide to TIMS Data," June 1985. JPL Publication 85-32. NASA-CR-175875
N85-28286

08.25 Measuring HCl in Solid Rocket Motor Exhaust Plumes

Sensors for purposes of real-time monitoring of HCl in solid rocket motor plumes are needed. The device should be capable of detecting concentrations below 1 ppm (specifically 240 ug/m^3) throughout the three-dimensional volume of the plume. Utilization of novel and innovative technologies is necessary. The instrument package is envisioned to contain elements such as the HCl monitor, an ambient air thermometer, and a data logging device. Similarly, the system should be calibrated with relative ease, thereby facilitating field calibration if necessary.

References:

Hoke, S. H. and V. R. Rivera. 1988. A Near Real-Time HCl Monitor, p.431-434, 1988 JANNAF Safety and Environmental Protection Subcommittee Meeting.

Stanton, A. C. and J. A. Silver, 1987. A Diode Laser Sensor for Measurement of Hydrogen Chloride Gas. TLSP. Final Technical Report, 12 Aug. 1987 - 12 Jan. 1988. Southwest Sciences, Inc., Santa Fe, NM.

American Public Health Association, et al. "Standard Methods for the Examination of Water and Wastewater." 1989.
ISBN 0-87-553161-X

"Disinfection - Water and Wastewater," J. Donald Johnson, ed., Ann Arbor Science Publishers, Ann Arbor.
ISBN 0-25-040042-1

08.26 Micro Deposition Sensors

Several electric propulsion thrusters, notably arcjets and ion thrusters, are scheduled for deployment in the next few years. Among the remaining concerns about their use in a high-vacuum space environment is the erosion of electrode material due to sputtering by high energy propellant ions. In particular, there is concern that this sputtered material (typically, tungsten or molybdenum) may be deposited on solar panels, resulting in loss of electrical power. Thus, an accurate assessment of such erosion deposits is needed. However, the upcoming deployments of these devices are primarily of an experimental nature, with operation times much shorter than eventual commercial mission times. Thus, only minute deposits of sputtered material are expected.

To quantify such small deposits, NASA needs an innovative micro-deposition sensor that would enable monitoring of erosion deposits at a number of locations on the spacecraft, with sensitivities of better than one nanogram of deposited material per square centimeter per minute. Furthermore, detectors and their accompanying electronics and power supply must be light-weight, low-cost, space-qualifiable, and may not give rise to electrical interference with data acquisition systems and communications. Finally, the influence of temperature variations of the probes must be negligible or accountable.

References:

J.N. Zemel, "Microfabricated Nonoptical Chemical Sensors," Rev. Sci. Instrum. 61 (6), June 1990, 1579 (1990). INSPEC A90120397 INSPEC B90065248

D.A. Wallace and S.A. Wallace, "Realistic Performance Specifications For Flight Quartz Crystal Microbalance Instruments For Contamination Measurements on Spacecraft," AIAA paper 88-2727, Proceedings of the Thermophysics, Plasmadynamics and Lasers Conference, San Antonio, TX, June 27-29, 1988. A88-43766

H. Wohltjen, "Mechanism Of Operation And Design Considerations For Surface Acoustic Wave Device Vapour Sensors," Sensors and Actuators, Vol.5, 307 (1984).

08.27 III-V Semiconductor Growth Technology

Integrated photonic and optoelectronic devices are required for remote sensing, communications, and spectroscopy in the spectral region from 0.5-3 µm. Many of these devices, e.g., resonant cavity structures such as vertical cavity lasers and resonant cavity photodetectors, require extremely precise control over the layer thicknesses and composition to a degree not met by current growth techniques.

Innovative techniques are sought to achieve high growth rates and precise control over layer thickness and stoichiometry in III-V compound semiconductors while maintaining good optical and electronic properties. Possible approaches might include in-situ ellipsometry, Raman spectroscopy, or other in situ techniques combined with conventional metalorganic chemical vapor phase deposition (MOCVD), or novel reactor designs such as atomic layer epitaxy. Other approaches may also be considered. The approach proposed should be capable of providing good optoelectronic (e.g., laser-quality) material in the InGaAsP and A1GaAs alloy families and of controlling the thickness to 1-2 monolayers over layered structures as thick as 10-20 µm at growth temperatures as high as 800°C.

Phase I should demonstrate the feasibility of a system designed for the InGaAsP alloy compounds. Phase II would design and construct the growth chamber and monitor instrumentation, demonstrate growth of a test structure (e.g., a 99 percent reflectivity multilayer InGaAsP mirror and/or a vertical cavity laser structure at 1.3 or 1.55 µm) and deliver the system for installation into an existing MOCVD system.

References:

Jewell, J. L., Harbison, J. P., Schere, A., Lee, Y. YH., Florez, L. T., "Vertical-Cavity Surface-Emitting Lasers: Design, Growth, Fabrication, Characterization," IEEE J. Quantum Electron, Vol. 27, pp. 1332-1346, 1991. A91-52063, ISSN 0018-9197

Koshiono, K., Unlu, M.S., Chyi, J. I., Reed, J., Arsenault, L., Morkoc, H., "Resonant Cavity Enhanced Photodetectors," IEEE, J. Quantum Electron, Vol. 27, pp. 2025-2034, 1991. A91-54489, ISSN 0018-9197

Capuder, K., P.E. Norris, H. Shen, Z. Hang, and F.H. Pollack, "In Situ OMVPE Process Sensing of GaAs and A1GaAs by Photoreflectance," Journal of Electronic Materials, Vol. 19, No. 4, 1990, pp 295-298.

08.28 Measuring Degradation of Structural Materials in the Space Environment

The assessment of the damage being inflicted on materials in space during flight provides valuable information to the materials and structural engineers designing space equipment. The need is for non-intrusive equipment that does not interfere with the effects of the environment on the specimens being tested and that is capable of measuring the effects of atomic oxygen, ultraviolet radiation, solar radiation, thermal cycling, and high vacuum. Proposals are requested in the following areas for in-space use:

- Profilometer to measure surface damage to polymeric and metallic composites.
- Camera to determine mass-loss and selective attack of UV-radiation and atomic oxygen.
- Acoustic emission sensors to monitor structures for damage due to thermal cycling and impacts of micrometeorites and debris in space.
- Scanning electron microscope for detailed study of surface damage.
- X-ray dispersive analysis instrument to determine chemical changes to exposed surfaces.

References:

Thompson, D.F. and Babel, H.W. "Materials Applications on the Space Station: Key Issues and the Approach to Their Solution." Sampe Quarterly (October 1989) pp. 27-33.

Tompkins, S.S., Bowles, D.E. et. al. "Response of Composite Materials to the Space Station Orbit Environment." Space Station Symposium, Williamsburg, Virginia. (April 1988) pp. 21-22. (AIAA/NASA)

Leger, L.G., Santos-Mason, B, Visentine, J.T., et al. "Review of LEO Flight Experiments," Proceedings on the NASA Workshop on Atomic Oxygen Effects, November, 1986, p.6. N87-26173

Gregory, J.C. "Interaction of Hyperthermal Atoms on Surfaces in Orbit: The University of Alabama Experiment, "Proceedings of the NASA Workshop on Atomic Oxygen Effects, November, 1986, p.31. N87-26177

09.00 Spacecraft Systems and Subsystems

09.01 Spacecraft Attitude Determination and Control

NASA is involved in ground-based determination of spacecraft attitude, in flight calibration and alignment of attitude sensors, and studies of spacecraft attitude dynamics and control. Continued emphasis will be on performing these functions using generalized and efficient algorithms operating in a near-real-time environment on PC workstations. Innovations are sought for new attitude determination and attitude sensor processing approaches, and algorithms and procedures for in-flight sensor calibration and alignment.

- Generalization of attitude determination techniques and filters which might be implemented in multi-mission support software.
- Specification, algorithm development, and implementation of PC software tools to aid in flight dynamics analysis.
- Computationally efficient methods for comprehensive in-flight sensor alignment and calibration, possibly as part of the attitude determination process.
- Improved environmental models in order to enhance attitude sensor measurements and spacecraft dynamic simulation.
- New techniques for near-real-time, multi-star identification and other methods for improved attitude sensor measurement processing.

References:

Wertz. Spacecraft Attitude Determination and Control. Reidel Publishing Company, 1978. A79-29500

NASA Conference Publication 3011, Flight Mechanics/Estimation Theory Symposium 1988. N89-15934

NASA Conference Publication 3050, Flight Mechanics/Estimation Theory Symposium 1989. AVAIL:CASI

NASA Conference Publication 3102, Flight Mechanics/Estimation Theory Symposium 1990. NASA-CP-3102, N91-17073

09.02 Spacecraft Controls Analysis

Future unmanned spacecraft, payload pointing systems, and instrument control systems will demand complex, multivariable control laws to meet their challenging stability and performance specifications. In addition, control-structure dynamic interaction will become an even greater concern as more and more demands are imposed on the control system. Robust, control system analysis software algorithms and interactive, user-friendly interface innovations are sought to support the control system design process of the future in the following areas:

- Robust algorithms for multivariable control system design.
- Interactive, user-friendly techniques for displaying and developing a physical understanding/intuition of the multivariable control system design.
- Structural mode significance and interactive capabilities for structural model order reduction.
- Robust classical design algorithms including frequency-response, root-locus, and time-response capabilities for large order (up to 150th order) systems.
- Interactive, user-friendly control system input techniques.
- Robust system identification methods including frequency-response and time-response methods.

References:

F. H. Bauer, J. P. Downing, and C. J. Thorpe. "Structural Mode Significance Using INCA," AIAA Guidance, Navigation and Control Conference Paper 90-3346, August 1990. A90-47606

F. H. Bauer, J. P. Downing, and C. J. Thorpe. "New Multivariable Capabilities of the INCA Program," 3rd Annual Conference on Aerospace Computational Control, August 1989. N90-23049

J. P. Downing, F. H. Bauer and C. J. Thorpe. "ASTEC-Controls Analysis for Personal Computers," 3rd Annual Conference on Aerospace Computational Control, August 1989. N90-23052

F. H. Bauer and J. P. Downing. "Control System Design and Analysis using the Interactive Control Analysis (INCA) Program," AIAA Guidance, Navigation and Control Conference Paper 87-2517, August 1987. A87-50522

09.03 Guidance, Navigation, and Control of Space Transportation Systems

Future space transportation systems include heavy lift launch vehicles, transatmospheric vehicles, and interplanetary spacecraft that will need advanced techniques for guidance, navigation, and control. GN&C must be developed. These are 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 environmental uncertainties encountered by a spacecraft during atmosphere maneuvers.
- Algorithmic or computational advances which can significantly improve the ability to solve complex optimization problems on board a flight computer.

References:

Cramer, E., Bradt, J., and J. Hardtla, "An Ascent Guidance Algorithm to Use On-Board LIDAR Wind Measurements," Proc. ACC, San Diego, CA, June, 1990. A90-38610

Caglayan, A., and S. Allen, "A Neural Net Approach to Space Vehicle Guidance," Proc. ACC, San Diego, CA, June, 1990. AVAIL:ESL

Mease, K., and M. VanBuren, "Aerospace Plane Guidance Using Geometric Optimal Control Theory," Proc. ACC, San Diego, CA, June, 1990. A89-24697

09.04 Guidance and Control for Spacecraft

High-precision guidance and control will continue to be key elements of future space systems in the face of onboard disturbances, system uncertainties and configurational changes. In particular, spaceborne telescopes and planetary imaging systems will need controlled devices which make efficient use of bandwidths constrained by plant uncertainty and sensor noise while meeting stringent stability and pointing requirements. A number of future spacecraft will also be required to maneuver autonomously, accurately, and reliably through the atmosphere. With the increasing complexity of space systems, there exists a critical need for advanced control methods and computational tools to gain confidence in the performance of a spacecraft under varying configurations.

This subtopic solicits innovative concepts to advance the technologies involved, with emphasis on the following areas:

Spacecraft Guidance and Control Systems: Innovations in the control of spacecraft articulating elements in linear and nonlinear regimes, on-orbit multivariable system identification for robust control, adaptive and fuzzy control of systems undergoing structural and environmental changes, real time control for autonomous rendezvous, docking, landing, aeromaneuvering and aerobraking of planetary and other spacecraft.

Spaceborne Observatory Control: Innovations in space- and lunar-based optical metrology sensors, disturbance isolation, and control to provide optical stability to a fraction of a wavelength; precision sensors and actuators for segmented reflector alignment and phasing and wavefront control, as well as integration of components and evaluation of end-to-end performance of entire system; optical position sensors with nanometer accuracies; and design of retroreflector targets for purposes of metrology.

Computational Control: Advances in flexible, multi-body, dynamic system, real-time simulations capable of handling several hundred state variables by the use of new processing techniques, spatial algebra techniques, numerically robust control algorithms and factorizations.

References:

Bayard, D. S. et al., "Automated on-Orbit Frequency Domain Identification for Large Space Structures," Automatica Vol. 27 (1991), 931. A92-16068, ISSN 0005-1098

Lurie, B. J., "Multiloop Balanced Bridge Feedback in Application to Precision Pointing," International Journal of Control, Vol. 51 (1990), No. 4. A90-31114, ISSN 0020-7179

Reasenberg, R, D., et al. "Microarcsecond Optical Astrometry: An Instrument and its Astrophysical Applications," The Astronomical Journal, Vol. 96 (1988), 1731-1745. A89-14423, ISSN 0004-6256

09.05 Control of Large Space Structures

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

References:

Swanson, A. D., "Fourth NASA/DOD Controls-Structures Interaction Technology Conference," proceedings, Orlando, FL Nov. 5-7, 1990. U. S. Air Force Report No. WL-TR-91-3013. N91-30148

Taylor, L. W., "Fourth NASA Workshop on Computational Control of Flexible Aerospace Systems, parts 1-2," Williamsburg, VA, July 11-13, 1990. Part 1: N91-22307, NASA-CP-10065-PT-1 Part 2: N91-22331, NASA-CP-10065-PT-2

Balakrishnan, A. V. (Editor): The Proceedings of the NASA-UCLA Workshop on Computational Techniques in Identification and Control of Flexible Flight Structures. Optimization Software, Inc. Publication Division, New York, November 2-4, 1989. ISBN 0-911575-59-6. ISBN 0911575596

09.06 Unobtrusive Sensors and Effectors for Large Space Structure Control

A major challenge in the development of control systems for light-weight, highly flexible space structures is to reduce the controller-to-experiment mass ratio. The primary mass of the control system is given by the weight of the sensor and effector used to control the structure. The objective of the proposed research is to develop unobtrusive sensor and effector technology that naturally leads to innovations in the areas of new materials, devices, and techniques for passive and active damping of structural members. Innovative approaches are needed to develop self-sensing devices capable for being used as both a sensor and effector. Potential applications require that actuator technology be developed to operate in the range of 15 kHz to 20 kHz, while the resolution for sensors is on the order of microns.

References:

Dosch, Jeffrey J., Inman, Daniel J., and Garcia, Ephrahim, "A Self-sensing Piezoelectric Actuator for Collocated Control," Mechanical Systems Laboratory, Department of Mechanical and Aerospace Engineering, State University of New York at Buffalo, Buffalo, New York.

Bailey, T. and Hubbard, J. E., "Distributed Piezoelectric Polymer Active Control of a Cantilever Beam," AIAA Journal of Guidance Control and Dynamics, 1985.

09.07 Spaceflight Data Systems

Innovations are required in the following areas of technology for spaceflight data systems:

Radiation Hard Memory. Innovations are sought for technology development leading to space-qualifiable, radiation-hard memory. High-density memory with low-weight, low-power, and ruggedness are important considerations including magnetic memory technologies.

Distributed Temperature Sensing. Innovations are sought on methods and technologies to measure temperatures of the spacecraft structure without using discrete thermistors for every point measured. Low weight, low power and ruggedness are important considerations.

Expert System. A standard database and expert system for the selection of electrical parts and components for spacecraft is desired. Innovative hardware and software techniques are sought to allow a designer to apply specifications of a device to this system which would recommend acceptable part devices. Topics to be addressed include: circuit types, thermal characteristics, device geometry, radiation characteristics, power consumption, mechanical packaging, and performance criteria.

High-Speed Communication Networks. The trend for small spacecraft of the 90's has been to adopt standard, serial-interface bus-oriented architectures. The bound for extensibility of this bus architecture has been the data rates achievable with current technology. Methods are sought to achieve high-speed, onboard reliable communications.

Flight Software Architecture. Flight software is difficult to develop and expensive to test. Innovative methods are sought for reducing the cost and risk of flight software development. This can include software architectural, development environment, test, and simulations solutions.

Mission Operations Analysis for the 90's. The expansion of onboard systems' capacity, flexibility, and autonomy leads to alternatives in spacecraft design that drastically impact traditional operational concepts. Innovative methods are sought for reducing mission operations life-cycle costs without compromising mission success.

References:

"Small Explorer Data System," Description Document, Revision 1, Available from Code 730, GSFC, November 22, 1990. A91-14985

"Second International Symposium for Space Information System," AIAA, September 17-19, 1990. AVAIL:AIAA

"Government Computing Meeting, March 14-16, Available from Colonel Will Stackhouse, Under Secretary of the Air Force, High Technology Acquisition, 1989. A88-35023

09.08 Thermal Control for Unmanned Spacecraft

Future unmanned spacecraft will operate at higher power levels, have many more load centers at dispersed locations, require longer transport distances, and require tighter temperature control than current space systems. Areas of innovation include the following:

Fluid systems technology:

- Measurement techniques for multi-phase fluid behavior in a micro-or partial-gravity environment;
- Low-temperature (60-250 K) heat pipes;
- Sensor interfaces;
- Modular, self-contained heat pumps to allow equipment to operate at a temperature different from a central thermal bus;
- Long-life, no-maintenance thermal components;
- Self diagnostic repair and correction subsystems;
- Design tools for two-phase thermal systems that are based on fundamental principals;

Special thermal system capabilities:

- Utilization of low-to-medium-temperature waste heat for auxiliary cooling or other purposes;
- Integration of thermal and power systems to minimize total weight.

Thermal analysis programs:

Thermal analysis computer programs are needed which take full advantage of the recent advances in personal computers and can successfully interface with the NASA standard programs such as TRASYS, SINDA85, and SSPTA. Areas of interest include:

- Calculation of radiant interchange factors including specular as well as diffuse reflections;
- Generation of geometric models;
- A "user friendly" interface possibly making use of a graphic user interface;
- More efficient computational algorithms;
- Graphical output representation.

References:

Krotiuk, W.J., "Thermal Hydraulics for Space Power, Propulsion, and Thermal Management System Design," Vol. 122, Progress in Astronautics and Aeronautics, AIAA. ISSN 0079-6050

Chi, S. W. "Heat Pipe Theory and Practice," McGraw-Hill, Series in Thermal and Fluids Engineering. A77-14825

09.09 Manned Spacecraft Internal Thermal Systems

Thermal systems for manned spacecraft require advanced thermodynamic, thermal, and fluid systems and associated computer software. This subtopic is concerned with thermal systems that are located within the pressure vessel interface for the manned module. Innovations are desired in the following areas:

- Advanced heat transport systems and concepts (including refrigeration systems with temperatures ranging from approximately -70°C to 0°C with zero-G operation) with acceptable safety characteristics for use in manned systems.

- Lightweight, high-capacity heat pipes for microgravity missions that can be tested on the ground at one-G.

- Two-phase evaporator and condenser components.

- Advanced interactive user-friendly graphical and computational techniques utilizing state-of-the-art, low-cost workstations for analysis of thermal and fluid 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, data acquisition and transmitting devices and components.

- Thermal control techniques in the field of material processing including high temperature sensing and insulation materials.

- Long-term thermal control and storage of cryogenic or low-temperature fluids, including vapor-cooled shields, leak detection, and dewar systems for frozen sample storage and freeze drying.

References:

Phyllis Hurst. "Proceedings of Annual Compressor Conference at Purdue University," Purdue University, Lafayette, IN, 317-494-0117. A86-21973

"American Society of Heating, Refrigerating, and Air-Conditioning Engineers Transactions," Atlanta, GA, (404)636-8400. A87-45460

M. E. Schlapbach, J. B. Scharp, and M. D. Szeto. "A Preliminary Analysis of the Passive Thermal Control System for Space Station Freedom," SAE 901403, July 1990. AVAIL:ESL

09.10 Manned Spacecraft External Thermal Control Systems

Future manned spacecraft and planetary surface habitats will operate at higher power levels and in more adverse environments than previous systems. Lightweight, high efficiency, thermal control technology is needed to meet these challenges. This subtopic is concerned with thermal control functions that are performed external to the pressure vessel interface. Innovative solutions are needed in the following areas:

- Lightweight, high efficiency, heat pump systems to aid in room temperature waste heat rejection to high temperature environments.

- Unique heat rejection devices which take advantage of heat transfer environments other than Low Earth Orbit.

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

- High-heat-flux two-phase evaporators and condensors.

- Unique monitoring and control methods for large two-phase fluid heat transport systems, including pressure drop and flow distribution control techniques.

- Innovative, two-phase measurement devices.

- Automation software system to locate component failures and perform isolation and system recovery operations.

References:

NASA/Lyndon B. Johnson Space Center, "Human Exploration Program Requirements," Houston, Texas, August 25, 1989. AVAIL:AIAA

Robert E. Smith, George S. West, "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development," 1982 Revision (Vol. 1) NASA TM-82478, 1983. N83-18816

NASA/Lyndon B. Johnson Space Center, "Report of the 90-day Study on Human Exploration of the Moon and Mars," Houston, Texas, 1989. AVAIL:CASI

09.11 Crew Workstation Displays and Controls

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

- Small-volume, low-power, high-resolution, full-color, wide-viewing-angle, and full-motion, video-compatible flat-panel displays.

- Input devices and mechanizations that are simple to use and result in high user efficiency. These devices such as a track ball, "zero-G" mouse, programmable switches, voice actuation and touch screens must be compact, low-power, reliable, and easy to maintain.

- Hand controller devices that could be used to support up to six degree-of-freedom, master-slave-type telerobotic and free-flyer space operations. For telerobotic operations, force feedback shall also be considered.

- High-density, local workstation data storage aids such as optical disks, disk RAM's, and floppy disks.

References:

Monthly Publication of the Society for Information Displays (SID). N90-25582

Proceedings of the Society for Information Displays. ISSN-0734-1768

Proceedings of the American Institute of Aeronautics and Astronautics (AIAA). A90-10476

Proceedings of the Institute of Electrical and Electronic Engineers (IEEE). AVAIL:CASI

09.12 Artificial Intelligence for Manned Space Exploration

Artificial intelligence techniques will play a significant role in the development of intelligent systems for space operations in the Space Exploration Initiative era. Innovative approaches to the development of intelligent systems, both robotic and other knowledge-based, intelligent systems, are desired. Of particular interest are approaches based on intelligent systems that attempt to achieve goals through the interaction between modifiable subgoals, dynamic descriptions of the environment, and dynamic descriptions of the intelligent system itself. Demonstration of systems that use simple, minimally specified descriptions or models interacting with updating information, e.g., sensor information, to perform functions in the following or other space exploration areas are desirable:

- Intelligent control of robots for autonomous navigation and for carrying out assembly, maintenance, servicing, retrieval, and other tasks.

- Intelligent systems for process control functions, for automated diagnosis and repair functions, for data monitoring, and for status reporting.

- System architectures for the integration of potentially complex interactions between and within intelligent system components and interactions between systems and the environments in which they function.

Also of interest are approaches to engineering design and design knowledge-capture for intelligent systems, tools to aid crew and ground support in updating intelligent system software, and innovative approaches to lower level controlling software and hardware in support of intelligent systems. Other interests are increasing the reliability of the space exploration systems through the application of intelligent systems principles.

References:

"Exploring Artificial Intelligence: Survey Talks From The National Conferences On Artificial Intelligence," Morgan Kaufmann Publishers Inc., San Mateo, CA, 1988. ISBN 0934613699

09.13 Tracking Systems for Space Exploration Initiative and Manned Spacecraft

Innovations are sought in microwave, photonic, and image-based tracking systems to support autonomous rendezvous and docking, proximity operations, landing, and hazard avoidance for manned and unmanned terrestrial, lunar, and planetary operations of the Space Exploration Initiative and manned spacecraft including the Shuttle and Space Station.

- Innovations to reduce weight, power, and cost of high-performance tracking systems needed to determine rendezvous target position attitude or altitude and rates or ground-relative altitude/range and velocity for landing, while maintaining high performance and reliability.

- Optical sensor systems for pattern recognition, ranging, and image-based tracking for lunar/planetary landing.

- Digital, photonic, hybrid-image processing system for landing navigation using possibly unknown surface features.

- High-performance, passive, infrared imagers and tracking systems for rendezvous and proximity operations in darkness, unconstrained by ambient lighting and not requiring target illumination.

- Small, light-weight, hand-held, portable, skin-tracking sensor capable of directly measuring range and range-rate with accuracies of 1 percent of range and 3 mm/s at distances from near-zero to 1 km at a 1 Hz output rate for proximity operations of manned spacecraft or manned maneuvering units.

- Innovative light-weight, low-power on-orbit sensor and processor systems and components for detection, tracking, and orbit determination of meteoroids and orbital debris in the 1 to 10 cm diameter range.

- Innovative light-weight, low-power space-qualifiable devices and techniques to point and scan a laser beam over a large field of view rapidly, accurately, and reliably.

References:

Stanley E. Monroe, Jr. and Richard D. Juday, "Multidimensional Synthetic Estimation Filter," Proc. SPIE 1347 179-185 (1990).

B. V. K. Vijaya Kumar, Richard D. Juday, and P. Karivaratha Rajan, "Saturated Filters", JOSA A. (to appear March, 1992)

Richard D. Juday and Tien-Hsin Chao, "Hybrid Vision for Automated Spacecraft Landing", Proc. SPIE 1053, 131-139 (1989).

09.14 Cryogenic Fluid System Components and Instrumentation

Cryogenic liquids such as hydrogen, oxygen, nitrogen and helium are required for many current and future space missions. Operating efficiency and reliability of these cryogenic systems must be improved considering the launch environment, operations in a space environment, system life, cost, and safety. Innovative concepts are requested for cryogenic fluid system components and instrumentation. Hydrogen (both liquid and cold gas) is of the most interest; however, concepts for other cryogenic fluids are also solicited. Although this subtopic solicits unique and innovative concepts in the cryogenic components and instrumentation areas, there is an emphasis at this time for:

- Small solenoid latching valves, 0.25 to 0.5 inch tube size, 50 to 500 lbm/hr flow, 5 to 50 psia operating pressure.

- High efficiency, small compressors to compress the boil-off gas from cryogenic tanks from 5 to 10 psia to greater than 1000 psia. Gas flow rates could vary from 0.1 lbm/hr to 20 lbm/hr. Designs should minimize weight and power usage.

- Cryogenic temperature sensors for both gas and liquid. Sensor should be small, highly accurate and have a large range.

- Small electrical feed throughs with low resistivity, thermal conductivity, and leakage.

- Fiber optics to enable one to look into a cryogenic tank with low heat input and a large viewing angle.

- Unique concepts for ground handling of cryogenic liquids (i.e., lightweight vacuum jackets, etc.)

- Flow control valves for use with high pressure fluids such as LOX or LH_2 that allows change of the valve trim without disassembly or removal of the valve from the system and without disturbing the level of cleanliness.

- High-response measurement and control of the flow of gasses such as H_2, CH_4, CO and O_2 at pressures as high as 6000 psi with flows on the order of 1500 scfm.

References:

S. C. Rybak, et al. "Feasibility Study for a Cryogenic On-Orbit Liquid Depot - Storage, Acquisition and Transfer (COLD-SAT) Satellite," NASA CR 185248, Ball Aerospace Systems Group, August 1990. X90-10475

John R. Schuster, et al. "Cryogenic On-Orbit Liquid Depot Storage, Acquisition and Transfer (COLD-SAT) Satellite, "NASA CR 185249, General Dynamics Space Systems Division, July 1990. X90-10408

William J. Bailey, et al. "Cryogenic On-Orbit Liquid Depot Storage, Acquisition and Transfer (COLD-SAT) Satellite Feasibility Studies," NASA CR 185247, Martin Marietta Astronautics Group, June 1990. X90-10470

09.15 Reusable Interface Seals for Cyrogenic Quick-Disconnects

Innovative concepts are sought for the development of seals that can withstand repeated usage on the ground or in a space environment and still remain leak tight to liquid hydrogen. Many cryogenic quick-disconnects have been developed over the past thirty years, but none have remained leak tight after repeated usage due to seal failure from cryogenic conditions. New seal concepts are needed support the development of advanced concepts as the space replaceable engine, the modular engine, and satellite and spacecraft refueling, all of which will require highly reliable, leak tight quick-disconnects that will hold up to repeated use.

The effort should accommodate the following requirements:

- Remain leak tight ($1x10^{-6}$ secs) to gaseous helium at ambient and LH_2 temperatures.

- Operate for 50 cycles over 5 years.

- Withstand the environment at the Kennedy Space Center and in space.

- Handle internal flow diameters of 4 to 6 inches.

- Handle 50 psia.

- Handle shuttle launch and landing vibration loads.

References:

Russell, J. M., 'On the Selection of Materials for Cryogenic Seals and the Testing of Their Performance,' University of Central Florida, NASA/ASEE Summer Faculty Fellowship Program, October,1989, p. 226-269. N90-16696

Daniels, C. M., 'Aerospace Cryogenic Static Seals,' Lubrication Engineering, vol. 29, April 1973, p.157-167. A73-28800

09.16 Cryogenic Refrigeration for Sensor Cooling

Innovative approaches are sought for the development of long-life, low-power, vibration-free refrigerators and refrigerator components to meet the demands for cooling science sensors. Focal plane arrays on earth observing instruments require motional stabilities on the order of 1 micron to prevent image blur. This places a demand for long-life, vibration-free refrigeration such as can be obtained with sorption coolers or with mechanical coolers using active or passive vibration control. The refrigera'or for interplanetary missions takes advantage of the interplanetary environment to radiatively dissipate small amounts of heat (<1 watt) at the low temperature of 90 to 120 K to reduce the input power requirements.

Innovations are solicited for:

- Hybrid coolers using a sorption refrigeration lower stage integrated with a radiative upper stage to provide 50 mW of refrigeration at 20 to 40 K.

- Single stage Stirling cryocooler technology to enhance cold-end performance in the 45 to 55 K range. Example technologies of interest include improved expander design concepts and Stirling cycle modeling software directed at understanding low temperature operation.

- Active and passive vibration control of mechanical coolers to eliminate generated vibration. Example technologies of interest include, but are not limited to, vibration damping concepts at cryogenic temperatures.

- Cooler lifetime enhancement technologies such as gas contamination control technology for gathering and removal of generated contamination within mechanical coolers.

References:

R.G. Ross, Jr., 'Requirements for Long-Life Mechanical Cryocoolers for Space Application,' Cryogenics 30, 233 (1990). A90-35614, ISSN 0011-2275

J.A. Jones, S. Bard, H. Schember and J. Rodriguez, 'Sorption Cooler Technology at JPL,'' Space Cryogenics Workshop, Pasadena, California, August, 1989. A90-35615

S. Bard, J.A. Jones, and H.R. Schember, 'A Two-stage 80 K/ 140 K Sorption Cryocooler,' Pro. Twelfth Intl. Cryo. Eng. Conf., Butterworth, Guilford, UK, 626, 1988. INSPEC A89052696

09.17 Long-Life Cryogenic Coolers for Unmanned Space Applications

NASA scientific goals require instruments with increased sensitivity. To obtain the required sensitivity, payloads will use sensors, instruments, and in some cases, entire facilities that operate at cryogenic temperatures ranging from 120 K 10.06to 0.1 K or less. Cryogenic coolers will be required to provide these operating temperatures and in conjunction with the new high temperature superconductor applications.

Future unmanned facilities will have operational lifetimes of 10 to 15 years, requiring similar total lifetimes for cryogenic coolers. This requirement can be eased if the cryogenic cooler can be easily serviced. However, on-orbit servicing is extremely expensive so both the lifetime and the reliability of the cryogenic cooler are critical performance parameters. For closed-cycle mechanical coolers, long life and reliable performance favor technologies such as non-contacting bearings and seals. For open-cycle, stored cryogen coolers, approaches are needed to greatly extend the cryogen hold time.

Mechanical cooler technology:

- Flexure bearing technology;
- Magnetic bearing technology;
- Gas bearing technology;
- Regenerator technology, including magnetically enhanced regenerators;
- Low vibration cooler systems;
- Vibration compensation systems;
- Vibration isolation systems;
- High reliability thermal switches;
- Magnetic cooler technology;
- Interfacing mechanical coolers with sensors.

Stored cryogen coolers:

- Low thermal conductance structural support systems;
- Support systems with on-orbit release;
- Concepts to enhance safety;
- Concepts for stored cryogen and mechanical cooler combinations.

References:

C. Keung ET. Al. "Design and Fabrication of A Long-Life Stirling Cycle Cooler for Space Applications," Philips Laboratories, November 1990. N86-21714

Russell B. Scott. "Cryogenic Engineering. MET-CHEM Research Inc., Boulder, CO 80307. AVAIL:ESL

R. W. Fast. "Advances in Cryogenic Engineering," Plenum Press, Important Papers. A87-50751, A8343220, A85-26501, A88-53176

09.18 Contamination Monitoring and Analysis Systems

The needs addressed by this subtopic are contamination monitoring and analytical techniques which will advance the understanding of future spacecraft contamination engineering. Innovative approaches are sought for measurement, prediction and verification of spacecraft molecular and particulate contaminations. New concepts and approaches are required in the following areas:

Molecular monitoring systems to reliably measure the concentration of contaminant species, the velocity distribution, and the resulting effects such as column density, surface deposition, and spectral background.

Particulate monitoring techniques to determine the particle size, density, velocity, trajectory and the resulting effects in space environment.

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

Flight experiments concepts with model validation.

Expert systems to train contamination engineers, to improve project management, and to perform contamination analyses.

References:

Triolo, J., Magg, C., and Kruger, R. "Results from A Small Box Real-Time Molecular Contamination Monitor on STS-3," Journal of Spacecraft and Rockets, Volume 21, Number 4, July-August 1984, pp. 400-404. A83-36050

Green, B., Yates, G., Ahmadjian, M., and Miranda, H., "The Particle Environment Around the Shuttle as Determined By the PACS Experiment," SPIE paper 777-01, 1987. A88-41327

Bird, G. A., "Breakdown of Continuum Flow in Free Jets and Rocket Plumes," Rarefield Gas Dynamics, Progress in Astronautics and Aeronautics, Vol. 74, Part II, AIAA, New York, 1981, pp. 681-694.

09.19 Spacecraft Application of Bionics and Biomimetics

Bionics seeks to derive basic engineering principles and ideas from nature, while biomimetics seeks orders of magnitude improvements in design and performance by mimicking naturally occurring processes. The development of spacecraft subsystems needs advancements in structures, materials, sensory and actuator systems, information processing, data utilization, massively distributed controls, and associated analysis capabilities. Proposed innovations must be inspired by bionics and biomimetics in areas such as:

Actuator Systems - Musculoskeletal systems use redundant linear actuators on light-weight, semi-rigid kinematically redundant frames to provide superior dexterity and lift capability.

Vision Systems - Far-field, near-field, and peripheral vision data are fused within an image processing system that responds quickly to need-based requirements.

Proximity Detection and Control - Proximity sensing of the local environment by a massively distributed somatic sensory system can provide feedback control information for docking, berthing, grasping, and seating.

Data Processing - Data from many sensory systems are fused within a data processing system that produces neuromuscular control commands "any-time". The system limits data processing to needs, it transitions between sensory systems and data fidelity needs, and it saves lessons-learned while making "any-time" decisions from incomplete knowledge.

Adaptive Robust Control - Complex behavior patterns are generated by cerebral and reflex control mechanisms connected by a heterogeneous neural network. The network provides robust autonomous control that quickly adapts to a dynamic environment.

Biostructures - Superior dexterity is achieved by an overdefined system of semi-rigid links and specialized joints. Lubrication reduces friction and wear. Joint surfaces are cushioned and designed to reduce stress induced fracturing. Fluid carrying and containment systems, valves, and pumping systems are long lasting and deformable. Bone is light, strong and tough.

References:

Shepherd, G.M. "Neurobiology," Oxford University Press, 1988.

Seireg, A. and Arvikar, R. "Biomechanical Analysis of the Musculoskeletal Structure for Medicine and Sports," Hemisphere Publishing Corp., 1989.

Kesner R.P., and Olton, D.S. "Neurobiology of Comparative Cognition," Lawrence Erlbaum Associates, Publishers, 1990. ISSN 0805801332

09.20 Spacecraft Subsystem Plume Interaction Effect

Innovative experimental and analytical approaches are sought to improve current on-orbit plume definition techniques. Plume impingement effects from control system microthrusters and vents on spacecraft in orbit can affect thruster performance, aerodynamic stability, and result in excessive localized heating. A better understanding of on-orbit plume-vehicle interaction effects is required for analysis and design of future vehicles such as the Space Station and Cargo Transfer Vehicle. Improvements are needed in the following areas:

- Fully viscous, nozzle-plume flowfield prediction methods including nonequilibrium processes in the transitional regime of the vacuum plume.
- Direct-simulation Monte Carlo method for defining vacuum-plume-induced environments and transport of plume constituents to typical spacecraft surfaces.
- Experimental approaches to quantify gas-surface interaction effects of plume constituents with various spacecraft surfaces.
- Innovative vacuum chamber experiments are sought to investigate on-orbit venting of liquids and gasses.

All Phase I proposals must identify valid Phase II analytical or experimental continuation objectives, and must lead toward ultimate commercial applications.

References:

Bird, G.A., "Simulation of Multi-Dimensional and Chemically Reacting Flows--Past Space Shuttle Orbiter," Rarefied Gas Dynamics, 11th International Symposium, Cannes, France, July 3-8, 1978, Vol. 1, Commissariat a l'Energie Atomique, Paris, p.365-388. A80-34903

Hurlbut, F.C., "Particle Surface Interaction in the Orbital Context: A Survey," Rarefied Gas Dynamics: Space-Related Studies, International Symposium, Pasadena, CA, July 10-16, 1988, p.419-450. A90-37129

09.21 Lifting-Gas Temperature Control System for Scientific Balloons

Scientific balloons made of thin, polyethylene material normally experience lifting-gas (helium) temperature changes as a consequence of varying radiative or solar loads. These temperature changes result in a reduction in gas volume at night and altitude loss. The desire to maintain nighttime altitude with the minimum amount of ballasting suggests the use of a device to control lifting-gas temperatures. The candidate system should consider:

- Balloon systems ranging from 2 million cubic feet (mcf) to 40 mcf in volume;
- Flight durations from 1 to 24 days;
- Compatibility with normal balloon environments, e.g. low temperatures, pressures, and densities;
- Stored-energy requirements for the system;
- System weight;
- Compatibility with existing, scientific balloon hardware and systems;
- Impact on standard procedures for launch and flight;
- Preventing possible damage to the balloon shell.

Phase I should, at a minimum, specifically address projected system reliability, weight, performance, power requirements, integration with current balloon systems and procedures, and costs.

References:

Horn, W. J. and Carlson, L. A., "A Unified Thermal and Vertical Trajectory Model for the Prediction of High Altitude Balloon Performance," Texas A&M University Report No. 4217-81-01, June 1981. NASA-CR-156884, N82-16048

Horn, W. J. and Carlson, L. A., "Thermtraj: A Fortran Program to Compute the Trajectory, Gas, and Film Temperature of Zero Pressure Balloons," NASA Contractor Report No. 168342, February 1983. NASA-CR-168342, M83-22543

Conrad, G. R., "Recent Refinements and Increased Capabilities in Balloon Vertical Performance Analysis," 28th Plenary Meetings of COSPAR, July 1990, Paper S.14.1.10.

10.00 Space Power

10.01 Dynamic Energy Conversion

Innovative concepts are solicited in the areas of dynamic energy conversion for use in manned and unmanned earth orbital and planetary missions, including planetary surface operations. Goals for dynamic Brayton, Rankine, and Stirling heat engine systems include low cost, increased efficiency, decreased weight, and extended operational lifetime (7 to 10 years). Innovations are sought in:

- Single and multiphase alternators, including linear devices.
- Advanced solar concentrators, heat receivers, and thermal energy storage including thermal energy storage systems that utilize materials available on the lunar surface.
- Thermal management techniques including advanced lightweight radiators.
- Bearings and methods for dealing with rotor dynamics and non-contacting reciprocating elements.
- Power systems design and performance analyses methodologies.

References:

R. J. Sovie. "SP-100 Advanced Technology Program," NASA Tech. Memo. 89888. N87-23027

R. J. Sovie and J. M. Bozek. "Nuclear Power Systems for Lunar and Mars Exploration," NASA Tech. Memo. 103168. N90-26873

10.02 Photovoltaic Solar Energy Conversion

Advances in photovoltaics are required in space solar cells and concentrators. Emphasis should be placed on innovative concepts that increase end-of-life efficiency, decrease size, weight, and cost. Considerations should also include concepts which enhance manufacturability. Areas of interest are:

- InP and GaAs on low cost substrates, including monolithically integrated tandem structures.
- Concentrator cells and optics
- Surface passivation of III-V solar cells
- Amorphous silicon and II-VI solar cells
- Multi-bandgap cells
- Improved contacts for III-V cells

References:

Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 12, 1990.

Wanlass, M.W., Gessert, T.A., Emery, K.A., and Coutts, T.J., "Proc. 20th IEEE Photovoltaic Specialists Conf., Las Vegas (NV)," p. 41, (1988).

10.03 Static Thermal-to-Electric Energy Conversion

Future space exploration missions require reliable long-life, high-density power systems. Radioisotope systems need improved efficiency, static thermal-to-electric conversion technology. These improvements will result in reduced mass and cost. Required improvements in thermal-to-electric conversion dictate system efficiency increases of 3-to-5 over state-of-the-art. Candidate improved technologies include:

- Improved, high-temperature, thermoelectric materials with increased figure of merit.
- Zero-G AMTEC (alkali-metal thermal-to-electric conversion) cell designs.
- Improved components and fabrication techniques for static conversion devices.
- Alternative high-efficiency, long-life, direct energy conversion technologies.

References:

C. B. Vining. "High Figure of Merit Thermoelectrics: Theoretical Considerations," Proc. 25th Intersociety Energy Conversion Engineering Conference, Am. Inst. Chem. Engineers, Vol. 2 (1990), 387-391. X89-10321

Underwood, M. L., O'Connor, D., Williams, R. M., et al. "Thermal Characterization of an AMTEC Recirculating Test Cell," Proc. 25th Intersociety Energy Conversion Engineering Conference, Am. Inst. Chem. Engineers, Vol. 2 (1990), 407-412. ISBN 0816094091

10.04 High-Performance Photovoltaic Solar Arrays

Lightweight, high-efficiency photovoltaic arrays are necessary for future Earth orbiting science and inner planet space exploration missions. Present flight technology can provide an array specific performance of 30 W/kg at 1 AU; advanced technology has demonstrated a laboratory capability of 130 W/kg. Further improvements will require the use of advanced thin-film and thin, crystalline materials. Developing the supporting array technology to protect and support these materials is of interest. Specific topics include:

- Transparent, environmentally stable, and rugged low mass protective cell covers or superstrates.
- Thin-film, radiation-resistant solar cells formed on large-area, flexible and/or rugged substrates.
- Efficient array blanket stowage and deployment systems for low (0.2-2 kW) and high (10-100 kW) power arrays, including planar or concentrator configurations.
- Atomic oxygen resistant array blankets.
- Mass-efficient, deployable array concepts for use in high acceleration (0.5 g) environments.

References:

Stella, P. M. and Kurland, R. M. "Development Testing of the Advanced Photovoltaic Solar Array", Proc. 26th Intersociety Energy Conversion Engineering Conference, Vol. 2 (1991), Am. Nuclear Society, La Grange Park, IL, pp. 269-274. ISBN 0-89-44816-3

Stella, P. M. and Flood, D. "Photovoltaic Options for Solar Electric Propulsion," Proc. 21st International Electric Propulsion Conference, Am. Inst. Aeronautics and Astronautics, paper #90-2529, Washington D.C., July 1990. A90-52563

10.05 Electrochemical Storage Systems

This subtopic concerns fuel-cell-electrolyzer systems, rechargeable batteries, and other electrochemical storage systems. Component technologies for electrodes and catalysts are of interest. Proposed innovations should emphasize systems and components with increased efficiency, lifetimes, and cycling capability while reducing cost and weight and simplifying manufacture and checkout operations prior to use in space. Specific areas are:

- Advanced nickel-hydrogen systems
- High-energy-density batteries
- New concepts for lightweight, advanced, primary and secondary fuel cell systems
- Improved rechargeable (but not lithium) batteries
- Advanced energy storage systems
- High-specific-energy or high-specific-power electrochemical systems
- New materials for advanced rechargeable cells

References:

Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 1990.

Ibid. Boston, MA, August 1991.

M. Warshay and P. R. Prokopius. "The Fuel Cell in Space: Yesterday, Today, and Tomorrow," J. Power Sources, Vol. 29 (1990), 193-200.

10.06 High-Specific-Energy Batteries for Unmanned Applications

High-specific-energy rechargeable batteries are needed to provide lightweight, compact, long-cycle-life energy storage devices for future space science and planetary exploration programs. Innovations in rechargeable lithium and sodium cells are of interest in the following specific areas:

- Alternate, lithium-anode materials (lithium alloys and lithium-intercalation and lithium-ion compounds).
- Organic electrolytes with wide operating window and stable towards lithium and lithium-ion electrodes.
- Lithium-polymer electrolyte systems with improved conductivity and lithium transport number.
- Overcharge and overdischarge protection methods to improve the safety of secondary lithium cells.
- High-specific-energy cathode materials with good reversibility for rechargeable lithium and sodium cells.
- Improved, solid ionic conductors for lithium or sodium ions.
- Novel design concepts for lithium or sodium cells.

References:

Subbarao, S., Shen, D., Deligiannis, F., et al. "Advances in Ambient Temperature Secondary Lithium Cells," J. Power Sources, Vol. 29 (1990), 579. A90-33958

DiStefano, S., Ratnakumar B. V. and Bankston, C. P. "Advanced Rechargeable Sodium Batteries with Novel Cathodes," J. Power Sources, Vol. 29 (1990), 301. N90-20459

G. Nagasubramanian and S. DiStefano, "12-Crown-4 Ether-Assisted Enhancement of Ionic Conductivity and Interfacial Kinetics in Polyethylene Oxide Electrolytes," J. Electrochem. Soc., Vol. 137, 3830 (1990). AVAIL:ESL

10.07 Aerospace Nickel-Metal Hydride Battery Cells

The NASA standard rechargeable nickel-cadmium battery, when operated under stringent charge control requirements, has demonstrated a charge/discharge cycle life exceeding 3 years aboard geosynchronous and low-earth-orbit satellites. Aerospace nickel-cadmium battery cells utilize cadmium negative plates. When implemented by OSHA, the lower cadmium exposure requirement may curtail production of nickel-cadmium cells in the USA. Alternative negative plate materials are required. Some progress has been made on the development of metal hydride plate materials to replace cadmium plates. Consequently, innovations to advance the development of nickel-metal hydride battery cells for space applications are sought.

References:

Tummillo A. F. et al. "Evaluation of Nickel/Metal Hydride Batteries for Electric Vehicle Applications," Electrochem. SOC. Meeting, Seattle, Washington, October 1990.

Fetcenko M. A. et al. "Advances in the Development of Ovonic Nickel/Metal Hydride Batteries," Third International Rechargeable Battery Seminar, Deerfield Beach, Florida, March 1990.

Brill et al. "Sealed Nickel/Metal Hydride Batteries for Small Satellite Applications," 4th AIAA Conference on Small Satellites, Logan, Utah, August 1990.

Puglisi V. J. et al. "Nickel/Metal Hydride Product Development Status," NASA Battery Workshop, Huntsville, Alabama, October 1991.

10.08 Portable Rechargeable Energy Storage for Manned Applications

Innovations in portable, rechargeable energy storage concepts yielding significant increases in the energy density over Ni-Cd and Ni-Hydrogen batteries are needed to provide secondary power to such applications for Space Station Freedom as cameras, tools, scientific instrumentation, life support backpacks, robotic devices, and mobile transporters. Much of this equipment is used on EVA's; consequently, it must be low in volume and weight, and rechargeable. Long replacement intervals are needed to minimize the overall weight-to-orbit requirements. Safety is also of prime consideration since many of these systems are handled directly by the Space Station crew and used either inside or outside habitable modules. Of particular interest are rechargeable systems with high energy density (weight and volume) which present the least inherent hazard potential during use. The proposed concepts should provide an energy-storage building block in modular form to meet as many listed applications as possible, and be capable of hundreds of cycles as opposed to the thousands or tens of thousands required by orbiting satellite systems. Finally, the proposed concepts should present minimal constraints to Space Station personnel in their operation, both during energy utilization and energy resupply as a rechargeable energy source.

References:

Viswanathan, S. and Charkey, A. "Bi-Functional Oxygen Electrodes for Rechargeable Metal-Air Cells", Proceedings of 20th IECEC, August, 1985. ISBN 80898837286

Gourdine, M. C., Final Report, DARPA Contract No. DAAHO1-86-C-0975, "Thin Film Solid-State Cells with Three Inorganic Components", March, 1987. N87-25853

Venkatesan, S., Fetcenko, M., Reichman, B., and Hong, K. C., "Development of OVONIC Rechargeable Metal Hydride Batteries," Proceedings of 24th IECEC, August, 1989. A90-38236

Venkatesetty, H. V. "Electrolytes for Rechargeable Lithium Batteries," Proceedings of 24th IECEC, August, 1989. A90-38238

10.09 Power Management and Distribution for Space and Aeronautical Application

Creative concepts are desired in power management and distribution (PMAD) technologies for the control of high-power, high-temperature and/or high-frequency space power systems with increased autonomous operations. PMAD includes hardware (components), software (control applications), and state-of-the-art overall electrical systems concepts that are fault and radiation tolerant. New concepts are sought in the following:

- Advanced materials for power electronics, devices, thermal management, and EMI shielding
- Electronic devices, transformer, transistors, etc., for high-temperature, high-power and/or high-frequency PMAD systems, motor drives, electrical actuation, electro-mechanical systems. Electro-optic devices and sensors are also of interest.
- Power system fault detection and isolation and system restoration, including "smart component", built-in-test and vehicle health management concepts.
- Management control and autonomous operation of space power systems.
- Space environmental interactions with power systems, including environmental factors such as plasmas, atomic oxygen, particulates, and gases in both Earth-orbital and planetary regimes.

- Thermal control of space power management systems by means of high-emittance radiator surfaces and advanced, lightweight, heat pipes for low and high operating temperatures.

References:

Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 1990.

Bercaw, R. W., 'Toward an Electrical Power Utility for Space Exploration'. N89-27704

Hoffman, A. C. et al, 'Advanced Secondary Power System for Transport Aircraft,' NASA Tech. Paper 2463, May 1985 N85-28944

10.10 High-Performance Power Processing

Creative concepts are desired for high-performance spacecraft power conversion technology. Innovations are required for highly efficient processing of 30 vdc power into low-voltage, isolated, multiple, output-power forms with 10 to 100 watts total output power. Flight instruments and spacecraft engineering subsystems require miniaturized, low noise, high efficiency power processors. Technology must be focussed on concepts that can survive in a radiation environment of 100 kRads. Components, materials, and processes must support reliable performance for 10 to 20 year lifetimes. Innovations are sought in areas such as the following:

Hybrid power converters having improved quality and reliability sufficient for long duration missions.

Isolation techniques for highly accurate output voltage and/or current sensing methods compatible with voltage or current control-loop performance.

Circuit techniques that greatly reduce output common-mode noise for sensor loads and also provide low conducted EMI on the input power bus.

Converter hybridization techniques that provide capability to operate standardized individual single-output converters as assemblies having common interface functions including; synchronization, input filtering, power loss recovery and packaging.

References:

Krauthamer, S., Gangal, M., and Das, R. 'State-of-Art of DC Components for Secondary Power Distribution of Space Station Freedom' IEEE Transactions on Power Electronics, Volume 6, Number 3 (July 1991). A91-49368 ISSN 0885-8993

Krauthamer, S., Gangal, M., and Das, R. 'Space Station Freedom Power Supply Commonality Via Modular Design' 25th Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 1990. & September 1989). A91-37989

10.11 Near-Ambient, Solid-Polymer Fuel Cell with a Conventional Solid Electrolyte

The solid-polymer fuel cell is considered to be the most convenient power source among the various fuel cells, since the principal part of the cell, i.e., the membrane and electrolyte assembly, consists of solid materials. In reality, the potential uses of these fuel cells are limited by their ancillary parts -- a humidification unit and high-temperature and high-pressure devices. These could be eliminated by operation in ambient conditions without humidification. Operation at near-ambient conditions has been demonstrated with a small (5 cm^2) electrode area fuel cell having the commercially available Nafion membrane electrolyte. Innovations are required in producing technology for a larger, 25 cm^2 electrode-area fuel cell in order to take advantage of this demonstration. Performance at near-ambient conditions should then be comparable to what would be obtained from a conventional cell at high temperature and pressure and with humidification. The near-ambient fuel cell is expected to have increased lifetime and higher power density because of the elimination of ancillary parts.

References:

Ticianelli, E.A., Derouin, C.R. and Srinivasan, S., 'Localization of Platinum in Low Catalyst Loading Electrodes to Attain High Power Densities in SPE Fuel Cells.' Journal of Electroanalytical Chemistry 25 (1988) 275-295.

Srinivasan, E., Ticianelli, E.A., Derouin, C.R. and Redondo, A., 'Advances in Solid Polymer Electrolyte Fuel Cell Technology With Low Platinum Loading Electrodes.' Journal of Power Sources 22 (1988) 359-375.

Ticianelli, E.A., Derouin, C.R. and Srinivasan, S., 'Methods to Advance Technology of Proton Exchange Membrane Fuel Cells.' Journal of Electrochemical Society 135 (1988) 2209-2214.

Srinivasan, S., 'Fuel Cells for Extraterrestrial and Terrestrial Applications.' Journal of Electrochemical Society, 136 (1989) 41C-48C.

11.00 Space Propulsion

11.01 Computational Techniques for Rocket Propulsion Systems

Innovative concepts are sought for improving numerical computational capabilities to predict fluid flow phenomena in liquid and solid rocket propulsion and launch systems including multi-phase and multi-species considerations. Emphasis should be placed on methodologies and models that will enhance the efficiency and use of CFD in an applications environment. Proposals should address issues such as:

- Computational efficiency, accuracy, speed, and robustness.
- Geometric modeling, new structured and unstructured grid-generation procedures, and adaptive grid-generation methods.
- Implementation of multiblocking and zonal techniques with Navier-Stokes solvers for complex three-dimensional domain of arbitrary mappings.
- Interfacing CAD/CAM IGES files to surface and grid generators used for structured mesh solvers for complex flow geometries.
- Automatic techniques (e.g., knowledge-based systems) for flowfield discretization, flow-solver operation, and flow visualization.
- Post-processing and interrogation of CFD results, e.g., solution enhancement and special purpose algorithms to delineate unique flow features (such as interface energy exchanges) and for efficient comparison data.
- Flow-process modeling for turbulence, chemistry, radiation transport, multiphase, multispecies, shock waves, and their interactions.
- Interfacial heat and mass transfer between liquid and ullage space of cryogens in zero-G during mixing and quiescent periods.
- Condensation rates as a function of liquid- or vapor-side turbulence during different tank operation modes.
- Zero-G cryogenic interface phenomenon during tank dumping, filling, pressurization, and pressure control.
- Validation of analyses of zero-G flow models with one-G test data to limit the need for zero-G space experimentation.
- The prediction of overpressure suppression effects due to the injection of external mass flow (i.e., water) into the exhaust plume relative to SRM start-up.

References:

Wang, T-S. and Chen, Y-S., "A Unified Navier-Stokes Flowfield and Performance Analysis of Liquid Rocket Engines," 26th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, Orlando, FL, July 16-18, 1990. AIAA Paper 90-2494. A90-40638

Meserole, J.S., Jones, O.S., Brennan, S.M., and Fortini, A., "Mixing-Induced Ullage Condensation and Fluid Destratification," 23rd AIAA/SAE/ASME/ASEE Joint Propulsion Conference, San Diego, CA, June 29-July 2, 1987. AIAA Paper 87-20A87-45357

Woo, Jr., J., Jones, J.H., and Guest, S.H., "A Study of Effects of Water Addition on Supersonic Gas Streams," JANNAF 13th Plume Technology Meeting, Vol. 1, 1982. N82-31429

11.02 Thermal Technology for Chemical Propulsion Systems

Advances in thermal technology for propulsion systems and subsystems are needed to meet the requirements for future programs such as the Heavy Lift Launch Vehicle, the Solid Propulsion Integrity Program, Advanced Solid Rocket Motor Space Shuttle Main Engine Evolution (Assured Shuttle Availability), the Space Transportation Main Engine, and the Space Exploration Initiative. Areas of improvement include analytical techniques, hardware component development, and instrumentation concepts for both solid and liquid propulsion systems. Specific areas requiring the application and development of these improvements include:

- Analytical techniques and advanced concepts related to the thermal design of nozzle and combustion chamber walls in liquid propulsion systems.
- Analytical techniques for thermal design of solid rocket motor nozzles and insulation systems, utilizing advanced composite materials.
- Innovative techniques in the design and installation of thermal instrumentation in rocket nozzle and throat regions.
- Analysis and design of components that generate frictional heat within high speed cryogenic turbomachinery.
- Highly reliable (no single-point failure), heat exchanger concepts for advanced vehicle and engine systems.

- Innovative thermal protection system concepts (both ablative and reusable) for launch and reentry vehicles.

- Interactive graphics thermal analysis codes and model generators, utilizing work station graphics environments and computer aided design (CAD) technology.

References:

NASA-CR-120853A, "Graphite Lined Regeneratively Cooled Thrust Chamber." N72-31778

NASA TM-100343 & others, "Research and Technology 1988, Annual Report of the Marshall Space Flight Center." N89-19216

NTIS HC A99/MF E06, "Computer Codes for Thermal Analysis of a Solid Rocket Motor Nozzles." N89-21773

NTIS HC A25/MF A04, "FANTASTIC: A New Code for Thermostructural Analysis of Rocket Nozzles." X8773862

11.03 Propulsion System Combustion Processes

There is need for greater understanding of combustion processes and of heat and mass transfer processes in liquid, solid, and hybrid propellant rocket engines. Requirements include both experimental work for development and validation of improved models for combustion analysis, and enhanced capabilities through improved analytical and computational methods. Innovations are sought in the following areas:

- Spray combustion and combustion stability modeling for liquid rockets including effects of droplet vaporization and/or secondary breakup, droplet combustion, dense spray interactions, and turbulent flow and combustion interactions.

- Application of recent developments in analytical and computational methods to combustion and combustion stability modeling for improvement in modelling fidelity, efficiency, and applicability.

- Experimental studies, diagnostics, and measurement systems for validation of analytical and computational models (for example, performance and combustion stability models) for application to combustion devices.

- Computational methods for the analysis of solid motor ignition transients, including multi-phase flow, grain geometries, and propellant grain ignition thermodynamics and kinetics.

- Models for the ignition, mixing, combustion, flow and burnback processes for liquid and/or solid hybrid propellant engines.

- Adaptations of existing computational models to obtain an advanced and accurate heat transfer model which considers the direct coupling of the heat flow in the hot combustion gas, the solid combustor wall, and the wall cooling fluid for a rocket combustion chamber.

References:

Snyder, T., Jarmowycz, T., Pace, K., et al. ,"Solid Fuel Ignition and Combustion Characteristics Under High Speed Cross Flows," AIAA/SAE/ASME/ASEE 26th Joint Propulsion Conference, Orlando, FL, July 16-18, 1990. A90-42725

Fang, J., Shuman, M., and Dodd, F., "Combustion Characteristics of Rocket Liquid/Gas Coaxial Injectors," AIAA/SAE/ASME/-ASEE 26th Joint Propulsion Conference, Orlando, FL, July 16-18,1990. AVAIL:AIAA

Richmond, R., and Wu, S. T., "Advanced Earth-to-Orbit Propulsion Technology 1988," Vols. 1-2, NASA CP-3012. N90-28611

Richmond, R., and Wu, S. T.,"Advanced Earth-to-Orbit Propulsion Technology 1990," Vols. 1-3, NASA CP-3092. AVAIL:CASI

11.04 Solid Rocket Motor Technology

Innovative concepts and approaches for design, analysis, production, and verification testing of solid rocket motors (SRM's) are solicited. Proposals should aim for improvements in technical knowledge and capabilities, lower cost, and higher reliability.

- High reliability, low-cost cases and/or nozzles.

- Improved constituent materials and/or manufacturing processes.

- Advanced, clean-burning propellants. These will involve a minimum emission of chlorine or other ozone depleting effluents, as well as green-house gases such as carbon dioxide. Offerors need to identify viable fuel-oxidizer alternatives along with estimates of performance and environmental impact.

- Precise, real-time chemical analysis of continuously mixed and cast SRM propellant.

- Experimentally verified failure criteria for carbon-phenolic and/or carbon-carbon materials to be implemented in an algorithm, used to predict failure of specimens at high temperature and with stress to failure, and compared to experimental test data.

- Detection of unbonds, weak bonds, and/or "kissing" unbonds in the propellant-liner-insulation-case interfaces to a level compatible with acceptance inspection of large SRM's.

- Health monitoring sensors and related instrumentation unique to SRM components and interfaces.

- Verification of the surface condition of cases (metal or composite), nozzle parts, liners and/or insulation prior to bonding (cleanliness, tack, etc.). Also desired are techniques and instrumentation for determining the degree of cure in polymer insulation and liner materials.

- Design concepts which provide burn termination and restart capability.

To provide accurate data needed for temperatures up to 2200°C and for strain at temperatures up to 1100°C, advanced instrumentation, both intrusive and non-intrusive, is required to measure the thermostructural behavior of carbon-phenolic and/or carbon-carbon nozzles. New techniques must function accurately and reliably under high heat flux and transient thermal conditions with low strain rates and be useful for validation of analytical models during hot firings.

References:

Solid Propulsion Integrity Program - Nozzle Work-Package 3.0, Annual Report, 1990, Vols. I and II. (NASA CR No. HER8-37801 FR11/0) (NAS8-37801). AVAIL:AIAA

Solid Propulsion Integrity Program - Nozzle Work-Package 3.0, Annual Report, 1991, Vols. I and II. (NASA CR No. HI-010F-1.2.3) (NAS8-37801). AVAIL:AIAA

Solid Propulsion Integrity Program - Bondline Work-Package 4.0, Quarterly Review. (SAIC 4417/0989/02) (NAS8-37802) X90-10405, X90-10818

11.05 Liquid Rocket Propulsion Turbopump Design and Analysis

Concepts, analyses, and design methods are solicited that will eliminate or reduce the hydrodynamic instabilities which occur within high-head turbopumps at severe off-design operating conditions. The concepts are to be verified in an appropriate research test facility.

- Pump rotor and diffusion system design concepts that feature components with low sensitivity to deep off-design operation at near-zero net positive suction head. The goal is to achieve surge-free pump operation at flow coefficients as low as 20 percent of design and cavitation resistant suction performance at high flow coefficients.

- Innovative techniques for delaying pump stall and extending the performance envelope including casing treatment devices that do not penalize the performance near the design condition.

- Turbopump flow modeling codes and correlations to local stall, surge, and cavitation.

- Long-life seal configurations that are effective at controlling the parasytic leakage over a wide range of turbopump operation. (Material compatibility in a H_2 and O_2 environment is desired).

- Advanced materials with improved strength, density, temperature, and life capabilities for turbopump and rocket components that address throttling-related extremes in operating conditions.

References:

Veres, J.P., "A Survey of Instabilities Within Centrifugal Pumps and Concepts for Improving The Flow Range of Pumps in Rocket Engines," JANNAF Propulsion Meeting, 1992.

Sloteman, D.P., Cooper P., Dussourd, J.L., "Control of Backflow at the Inlets of Centrifugal Pumps and Inducers," First Intl. Pump Symposium, Texas A&M, 1984.

Makay, E., "Centrifugal Pump Hydraulic Instability," Energy Research and Consultants Corp., Morrisville, PA., June, 1980. EPRI-CS-1445, N81-15370

11.06 Innovative Technology for Launch Vehicle Rocket Engine Applications

Innovative technologies are required to increase the performance and reliability of rocket engines. Specific innovations are sought within the categories listed below:

Rocket Engine Applications of Fullerene Chemistry: Properties attributed to Fullerene, C-60, molecules may make it useful for turbomachinery lubrication, combustion chamber wall insulation, and advanced propellants.

Metallized Propellants: Methods of demonstrating increased performance with metallized, gelled propellants are sought for hydrogen, RP-1, or monomethyl hydrazine. Innovations can include, improved designs for injectors, combustion chambers, nozzles, cooling methods, and methods of reducing the two-phase combustion losses associated with aluminum particles in the combustion chamber and the exhaust.

Determination of Droplet Asphericity in Dense Sprays: Drop-sizing instruments are based on the requirement of sphericity of the drops. Innovations are sought to determine the asphericity dimensions of droplets in dense sprays in real time so that the data from instruments can be corrected.

Fiber-Optic Components in Rocket Engine Environments : Innovations are sought in (1) fiber-optic databus design architectures which can combine advanced sensing with higher reliability, (2) improvements in the survivability in fiber-optic components, (3) improvements in opto-electrical components. Cables and connectors must survive from -196°F to +500°F temperatures, ambient to vacuum pressure differentials, and vibrations from 20 to 2000 Hz and up to 40 Grms. Sensor requirements can reach temperatures from -423°F to 2200°F, pressures from 0 to 10,000 psia, and vibrations up to 40 Grms.

Hybrid Chemical Rockets: There is need for innovative approaches to improve the understanding and to demonstrate the performance and operating characteristics of hybrid rocket engines (solid fuel and liquid or gaseous oxidizer) in near-flight-scale hardware. Specific topics to be addressed include: oxidizer injector performance, solid propellant burn/recession rate, prediction and verification of solid propellant burnback, effect of nozzle-combustion chamber interface on engine performance, and characterization of combustion products with regard to environmental impact, experimental and theoretical.

References:

Palaszewski, B. and Powell, R., "Launch Vehicle Performance Using Metallized Propellants," 27th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, Sacramento, CA, June 24-27, 1991. AIAA Paper 91-2050. N91-24304

Palaszewski, B. and Rapp, D., "Design Issues with Propulsion Systems Using Metallized Propellants," Conference on Advanced SEI Technologies, Cleveland, OH, Sept. 4-6, 1991. AIAA Paper 91-3484. A91-53709

Altman, David, "Hybrid Rocket Development History," AIAA/SAE ASME/ASEE 27th Joint Propulsion Conference, AIAA 91-2515, June 1991.

Kniffen, R.J., "Hybrid Rocket Development at the American Rocket Company," 26th Joint Propulsion Conference, AIAA 90-2762, July 1990.

11.07 Durability Analysis for Launch Vehicle Engines

Components of the Space Shuttle main engine (SSME) operate in hostile thermomechanical environments. Fracture and fatigue considerations play an important role in the design, analysis, and operation of the SSME and future engines such as Space Transportation main engine (STME). The need for accurate and timely fatigue and fracture analysis of SSME and STME components exceeds the current capabilities of existing analysis tools. This subtopic solicits novel approaches for estimation of SSME and STME component life. Offerors should emphasize concepts and approaches that use existing finite-element models and results from state-of-the-art finite element analysis codes. New and innovative techniques for finite-element grid generation of complex structures are solicited. Of interest are:

- Modeling of damage accumulation, crack nucleation and propagation, and life prediction.
- Methodologies and formulations for the solution of large-scale highly nonlinear problems involving fatigue, fracture mechanics, and viscoplasticity.
- Techniques for efficient generation or enhancement of finite-element grids of complex three-dimensional geometries.

References:

Yerry, M.A. and Shephard, M.S., "Automatic Three-Dimensional Mesh Generation by the Modified-Octree Technique," International Journal for Numerical Methods in Engineering, Vol. 20, pp.1965-1990, 1984.

Liebowitz, H. and Moyer, E. T., Jr. "Finite Element Methods in Fracture Mechanics," Computers and Structures, Vol. 31, No. 1 (1989), 1-9. A89-23017

Saouma, V. E. and Zatz, I. J. "An Automated Finite Element Procedure for Fatigue Crack Propagation Analyses," Paper 83-0841, 24th Structures, Structural Dynamics and Materials Conference, May 2-4,1983. A83-29748

Sun, C. T. and Mao, K. M. "Elastic-Plastic Crack Analysis Using a Global-Local Approach on a Parallel Computer," Computers and Structures, Vol. 30, Nos. 1/2, (1988), 395-401. A87-14586

11.08 Low-Thrust Propulsion for Satellites

Small, power-limited satellites for many civil and defense applications will require, or greatly benefit from, high performance on-board propulsion. Potential uses include orbit adjustments, drag makeup, attitude control, apogee topping, and stationkeeping. Propulsion concepts are solicited that are compatible with small satellites and their mission objectives and that significantly outperform, on a mission-system basis, state-of-art storable chemical propulsion. If power is required, only approaches which use less than 100W are likely of interest. Issues of compatibility include long term in-space operations, EMI, and plumes. Of special interest are concepts with sufficient theoretical and/or experimental bases to provide confidence in projections of the characteristics and interfaces of a flight system. Advanced chemical or electric concepts or those which use beamed energy are candidates for this subtopic.

References:

Byers, D. C., "Advanced Onboard Propulsion Benefits and Status," Symposium on Space Commercialization: Role of Developing Countries", Nashville, TN, Mar 5-10, 1989. NASA-TM-103174. N90-27786

Bennett, Gary L., et. al., "Enhancing Space Transportation: The NASA Program to Develop Electric Propulsion," Oct. 1990. NASA-TM-4244. N91-19181

11.09 Small Chemical Space Propulsion Systems

Innovative techniques are solicited for system and component designs with application to small, chemical, space propulsion systems including auxiliary propulsion for manned space systems and planetary decent and ascent systems. Propellants of interest include: Earth-storables, oxygen-hydrogen, oxygen-hydrocarbon, and gelled-metallized combinations. Proposals should be focused on hardware investigations, not studies. The specific areas of interest are listed below:

- Storage or generation of high-pressure (> 4000 psia) gas for propellant tank pressurization.
- Isolation valves for high-pressure gas and liquid.
- Gaseous pressure regulation, and pressure system relief devices.
- Check valves.
- Seals for fluid containment and leak detection in liquid and gas systems.
- High-response, low-power thruster valves.
- Ground and flight couplings.
- Propellant ignition.
- Long-life, high-cycle capability, injectors and combustion chambers.
- Propellant, mass-gauging in zero- and low-gravity conditions.
- Production of non-contaminating exhaust products for use when docking with space vehicles.
- Liquid-free gas acquisition to allow tank venting in zero-gravity conditions and gas-free liquid acquisition for engine feed systems.
- Transfer and resupply of propellants in orbit.
- Non-intrusive component and systems diagnostics for propulsion system health monitoring.
- Ablative combustion chamber materials.
- Throttling engine concepts.
- Conversion of vented propellant vapor to inert or non-contaminating products.

References:

Huzel, D. K. and Huang, D. H., "Design of Liquid Propellant Rocket Engines", NASA SP-125, 2d ed., 1971. N71-29405

11.10 Electric Propulsion Technology

The high specific impulse of electric propulsion systems for inter-planetary spacecraft enables many significant advantages over chemical propulsion systems for solar system exploration missions. Electric propulsion thrusters of interest include electrothermal arcjets, electrostatic ion engines, stationary plasma thrusters, and magnetoplasmadynamic (MPD) engines. Longer range advanced concepts are also of interest, including beamed energy. Innovative approaches for significant improvements are sought in these areas:

Engine life-testing: Life-testing of high-power electric thrusters is extremely expensive due to the high pumping speeds required. NASA seeks innovative techniques for engine life-testing, erosion modeling, and engine and propulsion system reliability determination that substantially reduce testing costs.

Power processing: Power processing electronics that convert raw input power into the currents and voltages required to operate an electric thruster form a major part of an electric propulsion system. Innovative power processing designs are sought to achieve very high efficiencies. Of particular interest are power processing approaches for ion engines of both conventional and segmented designs.

Performance improvement: Innovative electric thruster concepts or design approaches are sought for engines with improved total impulse capability relative to existing thrusters.

System design: Innovative electric propulsion system designs, particularly for small spacecraft, are sought, as well as innovative packaging designs that minimize the mass and volume of the propulsion system while maximizing the overall propulsion system reliability.

References:

Sauer, C., "Applications of Solar Electric Propulsion to Future Planetary Missions," AIAA-87-1053, May 1987. A87-39633

Patterson, M. J., and Verhey, T. R., "5-kW Xenon Ion Thruster Lifetest," NASA TM 103191, AIAA-90-2543, July 18-20, 1990. A90-52564

Hack, K. J., George, J.A. and Dudzinski, L. A., "Nuclear Electric Propulsion Mission Performance for Fast-Piloted Mars Missions," Conference on Advanced SEI Technologies, Cleveland, OH, September 4-6, 1991. AIAA paper 91-3568. A91-52388

Myers, R., "MPD Thruster Technology," AIAA-91-3568, September 4-6, 1991. A91-52444

11.11 Solid Rocket Plume Control and Neutralization

Innovative concepts to control and neutralize the plumes resulting for the sea-level, static test of very large (greater than 1 million pounds of propellant) solid rocket motors (SRMs) are solicited. Proposals should be directed to improving technical understanding of ways to capture and minimize or neutralize exhaust products. Specific areas of emphasis are:

- Elimination or minimization of hydrogen chloride gas;
- Control of aluminum oxide particulate;
- Control of SRM plumes in excess of 2 minutes with temperatures in excess of 5000 F, traveling at greater than twice the speed of sound, and with pressures in excess of 30 pounds per square inch;
- Dynamics of structures subjected to the SRM plume environment;
- Material technology which can withstand repetitive SRM environments;
- Chemistry associated with use of control or neutralization technology in the SRM plume;
- Scrubbing technology which will use wet and/or dry technology.

References:

Alternate Control Technology Assessment Plan; a plan currently under review by the State of Mississippi as part of the Prevention of Significant Deterioration dated 16 June 1991.

Final Environmental Impact Statement for ASRM Testing at SSC, dated March 1989; Final Supplemental Environmental Impact Statement for ASRM Testing at SSC, dated August 1990.

12.00 Human Habitability and Biology in Space

12.01 Medical Sciences for Manned Space Programs

Permanent manned presence in space demands great understanding of the functioning 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 considerable research has been conducted, it is imperative that proposals emphasize only new and innovative concepts and technologies that could be key to achievement of any of these objectives. Areas of interest are:

- 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.
- Noninvasive medical monitoring.
- Psychological assessment and treatment.
- Human performance modeling and assessment.
- Microgravity countermeasures.
- Dental care and surgery.
- Prevention and treatment of decompression sickness.
- Measurement of changes in bone mineral and muscle status and development of countermeasures.
- Prediction and prevention of space motion sickness and sensory motor disturbances.
- Innovative cell and tissue analysis systems.

References:

Nicogossian, C. L. Huntoon, S. L. Pool, et al. "Space Physiology and Medicine, 2nd ed.," Philadelphia, PA 1989. A90-16625

NASA-CP-10048, Workshop Report: Parmacokinetics and Pharmacodynamics in Space, August, 1988.

12.02 Biomedical and Environmental Health Sciences for Manned Space Programs

Manned space missions require a wide range of environmental and biomedical activities to protect crew health and to counter the effects of space on human physiology. The environmental disciplines are water quality, microbiology, radiation, toxicology, and barothermal physiology. The biomedical disciplines are cell biology, clinical chemistry, nutrition, muscle physiology, endocrinology, radiation biology, immunology, hematology, and pharmacology. The activities require innovative, space flight compatible approaches in clinical laboratory operations and environmental health monitoring and maintenance in these areas:

- In-flight monitoring techniques for chemical, microbial, and physical quality of the spacecraft environment including recycled water and atmosphere, in-flight generated food, and surfaces. Of particular interest is the detection, quantification, removal, and health-effects assessment of organic contaminants in all elements of the spacecraft environment.

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

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

- Techniques for monitoring nonionizing and ionizing radiation and for determining organ doses, and quantitative measurement of the carcinogenic effect of heavy ions.

- The use of fiber optics (IR, UV, or Vis sensors) and biosensors for chemical contaminants in the atmosphere or water.

- Procedures and techniques for assessing the human metabolism of protein, carbohydrate, lipids, vitamins, and minerals during flight.

- Ground-based and in-flight specimen collection and analysis for evaluation of the physiological, metabolic, and pharmacological responses of astronauts in space. Noninvasive methods to measure factors influencing crew performance, as well as methods to assess crew performance itself.

- Documentation, storage, retrieval, and analysis procedures for health-related diagnostic and environmental quality information.

- Approaches for setting and assessing requirements for gas composition and pressure of habitat and pressure suit atmospheres.

References:

NASA JSC 24439, SSF Toxicology and Environmental Monitoring, Nov 1989. AVAIL:SSC

NASA JSC 32024, Conference Report: Space Station Water Quality, March 1987. AVAIL:JSC

NASA JSC 32104, Conference Report: Space Station Infectious Disease Risks, October 1986. AVAIL:JSC

NASA CP10048, Workshop Report: Pharmacokinetics and Pharmacodynamics in Space, Aug 1988.

12.03 Microgravity Effects on Human Physiology

Long-term exposure to microgravity requires new technology and instrumentation to monitor health noninvasively and to develop efficacious countermeasures for maintaining performance of crew members. Innovative concepts and instruments are solicited for use in ground-based studies of normal volunteers and for preflight, inflight, and postflight monitoring of crew exposed to microgravity for periods up to three years. Also, innovations are needed to maintain safe and productive human performance during and after exposure to the environment of space. Technologies that minimize crew time, power usage, and hardware mass and volume while maximizing accuracy, reproducibility, simplicity, and automation are encouraged.

- Instrumentation for reliable and accurate noninvasive monitoring of human physiological function such as the cardiovascular, musculoskeletal, neurologic, gastrointestinal, pulmonary, immunohematological, and hematological systems.

- Methods to monitor physical activity and loads placed on different segments of the human body during space flight.

- Exercise equipment to load the musculoskeletal and cardiovascular systems with the capability to monitor, record and provide feedback about crew performance.

- Noninvasive instruments to provide quantitative data to establish the effectiveness of an exercise regimen in ground-based as well as flight experiments.

- Innovative means to apply artificial gravity to crew members during long-duration exposure to microgravity and to reduce deleterious effects associated with short-arm centrifuges.

References:

Hubbard, G.S., Hargens, A.R. "Sustaining Humans in Space," Mechanical Engineering, Vol. 111 (1989), 40-44. A89-54375

Greenleaf, J.E., Bulbulian, R., Bernauer, E.M., et al. "Exercise-Training Protocols for Astronauts in Microgravity," Journal of Applied Physiology, Vol. 67 (1989), 2191-2204. A90-20981

Aratow, A., Hargens, A.R., Meyer, J.U., et al. "Postural Responses of Head and Foot Cutaneous Microvascular Flow and Their Sensitivity to Bed Rest," Aviation Space Environmental Medicine, Vol. 62 (1991), 246-251. N89-26036

Cowings, P.S. "Autogenic-Feedback Training: A Treatment for Motion and Space Sickness," Motion and Space Sickness, CRC Press, (1988), Chapter 71. N89-15517

12.04 Regenerative Life Support: Air, Water, and Waste Management

Closure of regenerative life support systems is essential for the success of future human planetary exploration. The requirements include micro- and partial-gravity operation, high reliability, elimination of expendables, and low system weight. Innovative, practical concepts are desired in all areas of regenerative physical, chemical, and biological processes, associated hardware, sensors, and instrumentation for basic life support system functions including air revitalization, water reclamation, and waste management. All proposals must lead to specific Phase II experimental development projects that could be integrated into practical life support systems.

Air Revitalization:

- O_2, CO_2, and H_2O vapor concentration, separation, and control techniques (e.g., O_2 recovery from Martian atmosphere), including regenerative physical, chemical, and biological approaches;

- Gas-phase separation of CO_2 from a mixture primarily of N_2, O_2, and water vapor to maintain concentrations of CO_2 below 0.4 percent by volume;

- Gas-phase separation of N_2 from CO_2 to reduce concentrations of N_2 to less than 0.2 percent by volume;

- Regenerative sorbent beds for trace contaminant removal;

- Improved catalysts for catalytic oxidation of trace contaminants (organics) as an alternative to expendable adsorption and chemical sorption techniques.

Water Reclamation:

- Efficient, direct treatment of waste water (e.g., urine, wash water, and condensates) by processes that do not require expendables to provide potable and hygiene water;

- Stabilization of waste waters prior to storage and/or processing and of waste purge gases prior to overboard venting without the use of expendables;

- Potability maintenance (processed water handling and treatment) techniques;

- In situ cleaning and sterilization of potable water systems.

Waste Management:

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

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

- Microbial techniques for waste treatment in micro- or partial-gravity.

References:

NASA/Ames Research Center, "Physical/Chemical Closed-Loop Life Support Project Plan," January 1989. N89-11771

Doll, Susan C. and Case, Carl M. "Life Support Function and Technology Analysis for Future Missions," Boeing Aerospace & Electronics, 20th Intersociety Conference, Williamsburg, Virginia, July 1990. A90-49291

Wydeven, T. "A Survey of Some Regenerative Physico-Chemical Life Support Technology," NASA Technical Memorandum 101004, November 1988. N89-12207

McDonnell Douglas Space Systems Company, Space Station ECLSS "Evolution Study," Huntsville, AL, June 1989. AVAIL:CASI

12.05 Regenerative Production of Food

Regeneration of oxygen, food, and water will reduce the need for resupply and will increase the potential duration and extent of planned missions with human beings in orbit and on flights to and on the surfaces of the Moon and Mars. Innovations are needed in subsystems that will function in micro- and variable-gravity for growing crop plants, processing materials into foods, waste processing, and controlling the system. Components must have minimum mass and volume and consume little power. Requirements for human intervention and replacements of parts must be minimal. Among the areas for innovation are the following:

Sensing and monitoring devices for:

- O_2, CO_2, humidity, dissolved and volatile organic matter, microbial populations and compositions, and plant nutrients.

- Volatile and soluble organic substances produced by plants in air, transpired water, and recirculating hydroponic solutions.

- Control of pH, water levels, flow, salinity, turbidity, electrical conductivity, and nutrient composition.
- Plant growth and photosynthetic and respiratory gas exchange.
- Automated biological tissue sampling and preservation.
- Monitoring plants in closed chambers using color, IR, spectrophotometric, and fluorescence camera systems.

Plant Growth and Use:

- Alternate methods to provide light for plants including bright LEDs; solar light collection, transmission, and diffusion; and high efficiency electrical lighting.
- Utilization of waste heat and humidity and transpired water for bioregenerative processes.
- Processing wastes and inedible biomass (cellulose) into foods for human consumption.
- Automated, robotic, and computer-vision systems for crop seeding, cultivation, harvesting, biomass separation, and food processing.
- Techniques for growing plants with special capabilities such as tissue culture and genetically improved plant materials.

References:

MacElroy, R.D., Greenawalt, S. 'Controlled Ecological Life Support Systems,' NASA TM 102277, March 1990. AVAIL:CASI

Wheeler, R. M., C. L. Mackowiak, J. C. Sager, et al. 'Potato Growth and Yield in Nutrient Film Technique,' American Potato Journal, Vol. 67 (1989), 177-187. AVAIL:CASI

Dreschel, T. W. and J. C. Sager. 'Control of Water and Nutrients Using a Porous Tube: A Method for Growing Plants in Space,' HortScience, Vol. 24 (1989), 944-947. A87-16126

Prince, R. P., W. M. Knott, J. C. Sager, et al. 'Design and Performance of the KSC Biomass Production Chamber,' Transactions of the Society of Automotive Engineers, Vol. 96 (1987), 6.472-6.476. A88-21100

12.06 Regenerative Life Support: Sensors and Controls

Closed loop (regenerative) life support systems will be essential for long duration human space missions for planetary operations on the moon and Mars and in transit to Mars. To manage a regenerative life support system properly requires both sensors and controls that are reliable, effective, efficient, and safe. The sensors and controls must be maintainable during a mission, must degrade gracefully, and be self-calibrating.

- Advanced in situ microsensors for the detection of chemical and microbial contaminants in regenerated air and water streams. Such sensors must be tailored to the specific needs of NASA which relate to process-control strategies of integrated regenerative life support systems.
- Process-control strategies applicable to physical-chemical life support systems to ensure safe, reliable, autonomous operation and to facilitate systems integration.

12.07 Human Factors For Space Crews

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

- Means to acquire anthropometric and biomechanical kinematics and dynamic data to optimize human performance in space and to use in applied design models for space flight.
- Techniques for providing data and models of human perceptual and cognitive processes for use in the development of intelligent systems for space applications.
- Enhanced human interfaces with telerobotic and automated devices.
- Efficient lighting sources for general and task illumination that are lightweight, utilize minimum power, provide high lumen out-put per watt, and are safe for in-flight use.
- Methods to define, reduce, modify and/or control the acoustic environment in a spacecraft, particularly in the speech communications frequencies, with consideration given to weight and volume penalties.
- Layout, arrangement, and decor of spacecraft interiors to promote effective use of both the zero-G and partial-G environments in carrying out living and working tasks.

- Modular approaches to the buildup of zero-G and partial-G crew areas, stressing capability for on-board reconfigurations and modifications and associated interfacing, support, and handling equipment.

- Means to temporarily stow items of loose equipment aboard manned spacecraft with some type of micro-G effective retention system that is nonflammable, does not contaminate the atmosphere, is readily reusable, can be easily cleaned, and can be used under a variety of operational conditions.

References:

B. Woolford, A. Pandya, and J. Maida. "Development of Biomechanical Models for Human Factors Evaluations," Proceedings of Space Operations, Applications, and Research (SOAR) Symposium, Albuquerque, N.M, June 1990. N91-20713

G. Chandlee and B. Woolford. "Previous Experience in Manned Space Flight: A Survey of Human Factors Lessons Learned," Proceedings of the Human Factors Society, Human Factors Society Convention 1988. A89-31610

D. Gillan, R. Lewis, and M. Rudisill. "Process and Representation in Graphical Displays," Proceedings of Space Operations, Applications, and Research (SOAR) Symposium 1989. N9025574

B. Goldsberry, B. Lippert, S. McKee, et al. "Using Computer Graphics to Design Space Station Freedom Viewing," Proceedings of the IAF Congress of Malaga, ACTA Astronautica, Vol. 22. A90-13306

12.08 Human Performance in Space

Rapid development in aerospace and computer technology have made it feasible to automate many crew functions. This has had the effect of intensifying the need for careful attention to human performance. An important objective in aerospace human factors research is to address the interaction of humans with engineered systems. Innovative technological devices, techniques, tools, and models are needed in the following categories:

Space crew support technology that enables optimal crew performance and productivity under conditions of long duration spaceflight:

- Displays, controls, information management, and other techniques to facilitate crew management of on-board systems and robots.

- Enhanced human interfaces with telerobotic and automated devices.

- Modular approaches to the buildup of zero-G and partial-G crew areas, stressing capability for on-board reconfigurations.

Virtual environment technology that includes interface hardware, real time computer graphics systems, and application software that together are used for the simulation:

- Systems for six-degree (translation, roll, pitch, and yaw) accurate head and hand position tracking.

- Small head-mountable, light-weight, high-resolution, color displays (flat panel or CRT based).

- Light-weight, wearable, force-reflecting or tactile effectors to enhance the fidelity of the virtual environment.

- Real-time, three-dimensional, sound simulation systems to create virtual auditory environments that appear as real environments to the user.

- Software utilities for constructing, accessing, and managing graphical data bases used in virtual environment applications.

References:

Begault, D.R., & Wenzel, E.M. "Techniques and Applications for Binaural Sound Manipulation in Human-Machine Interfaces," NASA Technical Memorandum 102279, Aug 1990. N90-28996

Brody, A.R., & Ellis, S.R. "Manual Control Aspects of Orbital Flight." NASA Conference Publication 10056, Moffett Field CA, 1990. AVAIL:CASI

NASA STD 3000, Vols. I and II, Man-System Integration Standards, Washington, DC, March, 1987. N90-71357 N90-71356

Sheridan, T.B., & Hennessey, R.T. Human Factors in Automated and Robotic Space Systems. Washington, DC, National Academy Press 1987. ISBN 0815511361

12.09 Man-Systems Integration in Space Systems

Man-systems integration (MSI) employs the systems approach to achieve the integration of human operator(s), either as on-orbit crew or ground-based support, and space systems. The objective is to form an effective, interactive "man-machine system" (MMS), thereby enhancing functional effectiveness while maintaining or enhancing human well-being and system performance. Optimization of the MMS is accomplished by systematic application of MSI principles and practices to the design of equipment, operations, and systems. Particular attention is given to the man-machine interface (MMI), through which the human is able to sense the state of the system and environment and respond accordingly. The MMI includes hardware, its spatial interrelationships, and the display of information (including modality, quantity, quality, and organization). Areas of required innovation include:

- Small, lightweight input and output devices that the user can "wear" (e.g., monitors, keyboards, hand-controllers, joysticks, etc.) and that are easily accessible and easy to use. Anticipated tasks include "point-and-click" operations and limited alphanumeric entry. These devices should not prevent the user from using both hands to accomplish other manual tasks.

- Real-time, three-dimensional audio tracking of moving and stationary targets.

- Techniques to assign, track, and dynamically update object behavior and dynamic attributes and interactions in real-time, fully interactive, immersive virtual reality systems. This includes coordinate system reassignment, kinetic energy transfer, velocity, and acceleration.

- Incorporation of a fully anthropometric computer model that puppets the user's inputs into real-time, fully interactive, immersive virtual reality systems. This includes individually selectable link lengths; selectable statures with proportionate body dimensions; the ability to add body covering and/or specialized suits; and selectable strength capabilities that accurately vary with mechanical advantages and postural changes.

- Techniques to establish habitat dimensions to accommodate human motion in partial-gravity environments.

References:

Handbook of Human Factors. John Wiley & Sons, Inc. (1987). ISBN 0471880159

Bejczy, A. K. and Salisbury, J. K., "Controlling Remote Manipulators Through Kinesthetic Coupling," Computers in Mechanical Engineering, July 1983. AVAIL:AIAA

NASA STD 3000, Man-System Integration Standards. N90-71357

NASA Proceedings, Technology for Space Station Evolution - A Workshop, 1990. AVAIL:CASI

12.10 On-Board Systems and Support for Space Crews

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

Personal hygiene systems and procedures in a zero or partial gravity environment. The objective is to enhance crew living accommodations while minimizing resources required. Examples of interest include:

- Total body cleaning methods and hardware.
- Hair grooming methods and hardware.
- Personal cleansing agents compatible with both open and closed loop life support systems.

Decontamination methods for crew members exposed to hazardous substances.

Housekeeping solutions to problems encountered in both zero and partial gravity environments including:

- Crew habitat cleaning.
- Trash management systems and techniques.
- Apparel cleaning.
- Noise abatement and control.
- Particulate reduction and control.
- Cleansing agents compatible with both open and closed loop life support systems.

Food management systems and procedures in both zero and partial gravity environments, such as:

- Extending shelf life including packaging and preservation technologies.
- Improvements in acceptability and palatability.
- Improvements in food waste management systems.

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

References:

Bourland, C.T., M.F. Fohey, V.L. Kloeris, et al. "Designing a Food System for Space Station Freedom," Food Technology, Vol. 43 (1989), 76-81. AVAIL:ESL

Klicka, M.V. and M.C. Smith. "Food for U.S. Manned Space Flight," Tech Report TR-82/019. U.S. Army Natick R&D Laboratories 01760, Natick, MA 1982. N83-11745

Richard S. Johnston and Lawrence F. Dietlein. "Biomedical Results of Skylab," NASA SP-377, 1977. N77-33780

JSC 26823, Approaches to the Design of a Housekeeping System in Microgravity. AVAIL:JSC

12.11 Extra-Vehicular Activity (EVA)

Extensive new requirements for extra-vehicular activities of complex future manned space missions will require innovative approaches. All Phase I proposals must suggest rational Phase II continuation activities to establish concept feasibility. Areas of interest include:

- Regenerable, low-power, water vapor and/or CO_2 removal from the Extravehicular Mobility Unit ventilation loop.
- Chemical oxygen systems for an emergency oxygen supply for breathing and pressure maintenance in the space suit.
- Portable life support systems thermal control and crewmember cooling concepts for Lunar and Martian environments.
- Lighter weight materials for space suits to withstand abuse in Lunar and Martian gravity environments.
- Support systems water loops that have 15-30 year lifetimes (without leaching unwanted materials into life support fluids).
- Materials with variable insulation and IR emissivity properties for space suit thermal insulation.
- Highly dexterous EVA gloves.
- Dust exclusion and contamination control techniques for planetary surface airlock and habitation systems.
- Dust protection systems for suit bearings, fluid and gas connectors, and helmet visors optical surfaces for Lunar surface and Mars environments.
- EVA work-site aids and assembly techniques for precise alignment, mating, tool positioning and storage, illumination, and tethering. Methods for fastening, joining, cutting and drilling metallic and non-metallic materials with collection of particle debris. Methods for splicing, cutting, joining and forming of electrical cables and fluids plumbing.
- Analysis techniques for fabric pressure structures and structural attachment systems, including laminate and stitched.
- Adhesive system that allows in-space bonding of a handrail to spacecraft structures.
- Astronaut rescue system that is simple, carried by an EVA crew member, and capable of retrieving an adrift object or disabled EVA crew person.
- Low-power water pump for EVA use (100 Kg/hr against 5 psi). Piezoelectric systems are of interest.

References:

J. J. Kosmo, et al. "Development of Higher Operating Pressure Extravehicular Space Suit Glove Assemblies," SAE 881102. A89-27894

J. J. Kosmo "Design Considerations for Future Planetary Space Suits," SAE 901428. A90-49429

J. Wilson and M. Lawson. "Investigation into Venting and Non-venting Technologies for Space Station Freedom Extravehicular Activity Life Support System," SAE 901319. AVAIL:ESL

L. H. Kuznets. "Space Suits and Life Support Systems for the Exploration of Mars," Senior Research Fellow, National Research Council, NASA Ames Research Center, Moffett Field, California. A91-10120

12.12 Optical Systems and High Resolution Electronic Still Photography

Extended-duration manned spaceflight and exploration missions will require innovative techniques to solve unique optical and hand-held photography problems. Immediate key issues are associated with storage and near-real-time, high-resolution image return. Innovations are desired in both optical systems and mega pixel, high-resolution electronic still photography systems and components. Emphasis in the proposal evaluation will focus upon the uniqueness and level of innovation of a concept and its potential to provide greater utility, efficiency, resolution, image compression, and value to the flight crew on long duration missions.

- Electronic, still camera systems with operation and performance similar to a 35mm film camera.
- Devices for small, removable, high-density, digital-image storage media.
- High-resolution, image sensors for electronic photography.
- Handling and processing of mega pixel image data.
- Image data compression that is adaptable to electronic still photography systems.
- Obtaining lower noise and higher efficiency power conversion from batteries.
- Providing uplink, downlink, display, storage, and archiving images and data.
- Error detection and correction, versatile transmission systems, and image-data compression during transmission.

- Color splitting in a small system utilizing a minimum of three sensors.
- Anti-reflective coatings for image sensors and optical components.
- Image depth perspective and dimension measurement.
- Obtaining ultra-thin optical low pass filters for single color sensors.

References:

Proceedings from the SPIE/SPSE Electronic Imaging Science and Technology Conference, February 24-March 1, 1991, San Jose, CA. ISBN 0818620617

Research and Technology Annual Report, NASA Johnson Space Center, 1989, Subtitle: Electronic Still Camera Project. N90-21721

Research and Technology Annual Report, NASA Johnson Space Center, 1990, Subtitle: Electronic Still Camera Project. AVAIL:JSC

12.13 Life Sciences Spaceflight Technology

The NASA Life Science Program seeks basic scientific information on the response of living systems to the space environment as well as possible explanations of human response and adaptation to space. Innovations are required to enhance or enable the full flight experiment potential of unicellular organisms, animals, and plants through improved care, support, observation, and monitoring techniques for use on Space Station Freedom.

- Implant telemetry for direct biosystem monitoring or control.

- General improvement in physiological monitoring of non-human organisms for in-flight and ground studies of cardiovascular, skeletal, vestibular, hematological, reproductive, and other changes occurring during spaceflight.

- 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.

References:

Space Life Sciences Payload Office, Life Sciences Laboratory Equipment Catalog, May 1989. N87-22391

Spacelab Payload Project Office, STS Investigators' Guide, 1989. AVAIL:MSFC

NASA TM 102264, Research and Technology Annual Report, 1989. AVAIL:CASI

NASA TM 101078, Research and Technology Annual Report, 1988. N89-17584

NASA TM 100051, Research and Technology Annual Report, 1987. N89-13393

NASA TM 89411, Research and Technology Annual Report, 1986. N87-24391

13.00 Quality Assurance, Safety, and Check-Out for Ground and Space Operations

13.01 Shuttle Operations Weather Forecasting, Modeling, and Display

Field Verification of Models for Hazardous Materials Transport: Diffusion and transport of toxic fluids and particulates from an inadvertent release during hazardous ground operations is a major concern at Kennedy Space Center (KSC). Regulations governing exposure limits require high-resolution assessments. Improved models and accurate field verification methods are needed to assess the accuracy of the predictions.

Lightning and Electrification Models: Direct and induced effects of lightning to systems are experienced because of the high frequency of lightning at KSC. Triggering of lightning by vehicles during ascent and descent is a hazard. Models are needed in the following areas:

- Vehicle triggering of lightning.
- Cloud electrification processes.
- Lightning effects on systems and structures.
- Thunderstorm forecasting.

Data Product and Graphic Merger for Display: The weather forecaster today is faced with a multitude of data that must be assimilated in the process of analysis, synthesis, and prediction. A system is needed to process and analyze data sets, process data analyses, merge products, and produce real-time displays that permit easy assimilation of the information content by the user. Some sensor systems produce voluminous data at high data rates; in the case of lightning time-of-arrival data, time correlation of waveforms corresponding to multi-station sensing of lightning events needs to be determined, and techniques to isolate and track storm cells are needed.

References:

Turner, R. E. and Hill, C. K., compilers, "Terrestrial Environment (Climatic) Criteria Guidelines for Use In Aerospace Vehicle Development," 1982. NASA-TM-82473. N82-28317

National Fire Protection Association, National Fire Protection Code, NFPA 78, Lightning Protection Code.

"On-Site Meteorological Program Guidance for Regulatory Modeling Applications," EPA-450/4-87-013, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, June 1987. N88-14498 AVAIL:NTIS:PB87-227542/XAB

13.02 Remote and In Situ Sensors of Weather Hazards

Electric charge resident in clouds along or near the path of a space vehicle presents the hazard of triggered lightning. Ground-based electric field mills remotely sense electric charge but alone cannot provide the structure of the electric field aloft. A ground-based sensor that can provide information on the three-dimensional structure of the electric field in clouds not producing lightning is needed.

For better understanding of risk, characterization of upward traveling lightning discharges from the tops of electrified clouds and frequency of occurrence is needed. Sensors that can operate unattended for long intervals are needed to acquire the data required.

Fog and low stratus clouds frequently form in the uninhabited, swampy areas surrounding the Shuttle Landing Facility (SLF) at KSC but are undetected until advected near the SLF. A low-maintenance, self-powered sensor, robust enough for deployment in remote areas and capable of telemetering the appropriate data is needed for detection and estimation of depth of fog and low stratus cloud formation in the suspect areas.

Remote sensors are needed to assist in producing forecasts of severe weather hazards to ground processing and launch operations. For example, waterspouts and coastal funnel clouds occur frequently near the launch pads during the summer. A sensor for detecting small-scale hazardous vortices of this type is needed.

References:

Turner, R. E. and Hill, C. K., compilers, "Terrestrial Environment (Climatic) Criteria Guidelines for Use In Aerospace Vehicle Development," 1982. NASA-TM-82473. N82-28317

"On-Site Meteorological Program Guidance for Regulatory Modeling Applications," EPA-450/4-87-013, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, June 1987. N88-14498 AVAIL:NTIS:PB87-227542/XAB

13.03 Contamination Measurement and Methods

There is a requirement to analyze quickly a large number of small unknown contamination samples from flight vehicle hardware and ground support equipment. The contamination particulates are collected on filters, clothes, Q-tips, sandpaper, razor blades, wooden spatulas, knifes, dishes, and in soluble solutions. The amount of the sample is usually very small. To characterize the particulates, NASA currently uses optical microscopy, x-ray diffraction, scanning electron microscopy with energy dispersive spectrometer, and an image analyzer. Sensitive detection procedures for semi-quantitive analysis of the various particulates are required, with relatively brief turn-around times.

References:

Stevenson, C. G., Katnik, G. N., and Higginbothan, S. A., "Debris/Ice/TPS Assessment and Photographic Analysis for Shuttle Mission STS-44," NASA Technical Memorandum TM 102153, 1989.

13.04 Fluid and Gas Leak Detection Systems

Hydrogen Leak Detection. A small, lightweight sensor is needed to measure hydrogen concentrations in atmospheres of mixtures of oxygen, nitrogen, and/or helium, where oxygen concentration is unknown and may vary uncontrollably from zero to twenty-one percent. The sensor should not cause any type of hazard in combustible atmospheres. It should cover the range from 200 to 40,000 parts per million, and a wider dynamic range is desirable. It should be capable of operating from -50 to +125 degrees F, exhibit fast response time, and have excellent repeatability and stability for at least one month (longer is desirable). The sensor is intended for use during prelaunch hydrogen loading of space vehicles, both on the ground and potentially on board the vehicles for special tests. Power requirements should be minimized. Electrical output should be capable of signal conditioning to 0 - 5 VDC.

Hydrazine Vapor Monitor. Detection system with +10 percent accuracy for continuous measurement of 10 to 1000 parts per billion hydrazine vapor. The system must operate safely in NEC Class 1 Division 1, Group A, B, C and D environment and have a mean-time-between-maintenance of six months. Chemicals such as alcohols, methylethyl ketone, ammonia and freons and humidity must not effect the hydrazine reading.

References:

Threshold Limit Values and Biological Exposure Indices for 1989-1990. American Conference of Governmental Industrial Hygienists (ACGIH). Cincinnati, Ohio.

"Lower Explosion Limits," Condensed Chemical Dictionary, 10th ed., 1981. Van Nostrand & Reinhold Co., New York.
ISBN 0-44-223244-6

OSHA (29CFR part 1910).

KSC-DL-3411," Hydrazine Vapor Detection System for PSTF-R." (Available from Ms. Rebecca Young, Mail Code DL-ESS-24, Kennedy Space Center, FL, 32899. Telephone (407) 867-4438)

13.05 Aqueous Determination of Non-Volatile Residue

There is a need to replace CFC-113 currently used to verify cleanliness of ground and flight hardware following precision cleaning. Water is the preferred substitute, however, non-volatile residue of numerous compounds in water must be detected and quantified.

A technique must be developed to detect and quantify accurately non-volatile residue in an aqueous medium. Materials to be detected include silicone compounds, hydrocarbons, and fluorinated compounds in the 0.02 to 10 ppm range.

References:

"KSC Precision Cleaning Specification (KSC-C-123)," National Aeronautics and Space Administration, John F. Kennedy Space Center.

13.06 Toxic Propellant Detection

Testing of space flight and ground equipment requires state-of-the-art safety devices to support operations. A technique to detect air-borne, parts-per-billion concentrations of hydrazine, monomethyl hydrazine, unsymmetrical dimethyl hydrazine, and nitrogen tetroxide is desired. Significant reductions in the threshold limit value (.01 PPM for the hydrazines and less than 5 PPM for oxidizers) are scheduled to be implemented in 1992 by the American Conference of Governmental and Industrial Hygienists. Current technology provides techniques to measure concentrations in the parts per million range. The new technique should feature a portable device that will provide accurate and rapid measurements to facilitate field operations.

References:

American Conference of Governmental Industrial Hygienists, Documentation of Threshold Limit Values and Biological Exposure Indices, latest edition, Cincinnati, Ohio.

Eiceman, G. A., Young, R. C. Travis, J. C. et al. "Ion Mobility Spectrometry in Monitoring Hydrazines and Hazardous Organic Compounds in Air and Water," 1990 JANNAF Safety & Environmental Protection Subcommittee Meeting, Livermore, CA.
X91-72095

Grate, J. W., Rose-Pehrsson, S. L. and Barger, W. R. "Hydrazine Detection Using Chemiresistors," 1988 JANNAF Safety & Environmental Protection Subcommittee Meeting, CPIA Publication 485, Monterrey, CA. X89-72537

Smith, P. T., Paige, K. M. and Hawkins, C. M. "Hydrazines Detection Using Photoionization," 1987 Jannaf Safety & Environmental Protection Subcommittee Meeting, CPIA Publication 466, Cleveland, OH. X88-71431

13.07 Barrier Coating for Vacuum-Jacketed Piping Systems

Innovative, thin-film material systems that can be coated on the surfaces of vacuum spaces to serve as a barrier coating are solicited. Such a coating would provide long-term vacuum retention (reducing fabrication time for vacuum-jacketed components) and a simple alternative to costly weld repair operations. A coating system for parts connected to the vacuum space (for example, a 1/4 inch threaded fitting) as well as broad area coverage (for example, a 10 inch diameter pipe surface) is required. The coating must not be susceptible to cracking due to ambient cryogenic temperature cycles. Permeability to gases, including hydrogen, must be very low in order to prevent outgassing from the substrate material (typically stainless steel). In addition, all constituents of the coating must be fully oxygen compatible and have essentially zero off-gassing. Ease of applying the barrier coating is essential, and in-the-field application should be possible without excessive equipment or time requirements. Processing temperatures for in-the-field application must be limited to about 400°F.

References:

Reed, R. P. Materials at Low Temperatures, American Society for Metals, Metals Park, OH. 1983. 606p. A83-45098

Timmerhaus, K. D. and Flynn, T. M., Cryogenic Process Engineering, Plenum Press, New York, 1989. ISBN 0-30-643283-8

NHB 8060.1 C, "Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion." Washington DC: NASA QR, 1991.

13.08 Aerogel Thermal Insulation for Cryogenic Systems

A thermally efficient insulation for use as an alternative to vacuum-jacketing (or where vacuum-jacketing is not reasonable) would have extensive applications in ground as well as flight systems. Applications could include payload servicing systems where weight and safety are critical or ground systems where a temporary installation is needed. The insulation materials should be based on a new class of ultra-low density aerogels which are fabricated by sol-gel ceramic processes. Two forms of insulation are of interest: 1) powder forms (for evacuated or non-evacuated storage vessels and piping components, and 2) non-rigid monolithic forms (for external applications). Off-gassing, moisture sensitivity, and environmental degradation must be minimal. In addition, particulate production must be minimal for the monolithic form of material. Proposals should cover the development, physical characterization, and prototype demonstration of the aerogel insulation material.

References:

Reed, R. P. Materials at Low Temperatures. Metals Park, OH: American Society for Metals, 1983. A83-45098

Timmerhaus, K. D. Cryogenic Process Engineering. New York: Plenum Press, 1989. ISBN 0-30-643283-8

NHB 8060.1 C, "Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion." Washington DC: NASA QR, 1991.

13.09 Improved "Hydrogen Getter" for Vacuum-Jacketed Cryogenic Systems

Palladium monoxide has been the most popular "getter" in the United States and has been used by all of the vacuum-insulated transfer line manufacturers. The purpose of palladium monoxide is to convert hydrogen gas due to metal outgassing into water, which is then absorbed by a desiccant such as a molecular sieve. Palladium monoxide is present in all the vacuum spaces of the 6-inch liquid oxygen transfer lines on Launch Complexes 39A and 39B at the Kennedy Space Center.

In 1991, a liquid oxygen, vacuum-jacketed line at a commercial air separation plant in Illinois exploded. The explosion imploded the inner line and threw shrapnel 200 to 500 yards away, knocking concrete blocks out of a building. Palladium monoxide had been installed as a hydrogen getter. Investigation of some of the unexploded line sections revealed palladium monoxide was loose in the vacuum space. A liquid oxygen leak had occurred in a defective pipe weld. The liquid oxygen reacted with the palladium monoxide and caused the explosion.

Innovations are sought that will lead to a replacement material for palladium monoxide. The new material and/or method must result in a safe , cost-effective hydrogen getter material to be used in vacuum-jacketed lines. It must be efficient in hydrogen absorption and compatible with oxygen, hydrogen, helium, nitrogen, and the molecular sieves used to absorb reaction products. The proposed innovation should address the optimum method of installing the replacement "getter" in new and existing vacuum jacketed lines. The following performance and compatibility parameters should be considered in offering proposals for this subtopic:

- Hydrogen getter performance.
- Compatibility
  - with insulation material,
  - molecular sieves,
  - piping materials, and

- cryogen materials.
- Liquid oxygen impact sensitivity

References:

NBS Report 10 705, A Study of LC-39 Cryogenic Systems, Paul R. Ludtke and Roland O. Voth, U.S. Department of Commerce, National Bureau of Standards, Boulder Laboratories, Boulder Colorado,September 22, 1971.

13.10 High-Pressure, Cryogenic, Liquid-Level Measurement Techniques

Innovative approaches are necessary to develop systems of accurately determining liquid level of cryogenic liquids such as hydrogen, oxygen and nitrogen in large, high-pressure vessels (greater than 500 gallons and 8500-6500 psig). Any measurement techniques must consider heat loss and material component compatibility with liquid hydrogen and oxygen. Accuracy of one to two percent of volume is required. The instrumentation should work under static and dynamic conditions and have a response time of less than 50 milliseconds. Areas of interest include intrusive and non-intrusive measurement techniques.

References:

Kato, Kiyonori, 'Liquid Helium Level Meter by Audio-Sound Detection,' Review of Scientific Instrumentation, Vol. 60, No. 7, 1989, 1343-1345.

Liu, F.F., and Chow, S.W.H., 'Differential Dielectric-to-Density Measurement for Cryogenic Fluids,' Review of Scientific Instrumentation, Vol. 58, No. 10, 1987, 1917-1925.

Woodhouse, C. E., Kashani, A. and Lukemire, A. T., 'Superfluid Helium Tanker Instrumentation.' IEEE Transactions on Instrumentation and Measurement, Vol. 39, No. 1, February 1990, p.274-278. ISSN 0018-9456

Zuckerwar, A. J., Mazel, D. S., and Hodges, D. Y., 'Ultrasonic Level Sensors for Liquids under High Pressure,' Review of Scientific Instruments, Vol. 57, No. 9, Sept. 1986, p.2318-2320. A87-11223, ISSN 0034-6748

13.11 Cryogenic System Components Testing

At the present time, piping components (such as valves) in cryogenic service (typically minus 190°C and below) are tested by submerging them in a bath of liquid nitrogen, allowing them to attain temperature equilibrium, and then pressurizing the interior with helium while monitoring for any leakage. This procedure is not representative of actual conditions of use of the components and is believed to be overly severe. A less severe method is sought for testing cryogenic system components that will predict accurately the conditions to be experienced during actual operations. The innovation should provide a meaningful correlation between the test method and the actual service operating conditions.

13.12 Spacecraft Scientific Instrument Test and Evaluation

To achieve the scientific goals of a spaceflight mission, the on-board scientific instruments must perform as designed, and the function and performance of the instruments must be characterized so that the data received from them in orbit can be properly processed and analyzed. The test, evaluation, and characterization of these instruments is done during a sequence of ground tests that are performed before launch. Innovative ideas are sought that will improve the quality and effectiveness of these tests and that will reduce the cost and the time required to perform them. Specific areas of interest are:

- Generic instrument ground support equipment;
- Telemetry processing;
- Real-time data archive, retrieval, and cataloging;
- Database management;
- Real-time signature analysis;
- Expert system techniques for instrument test monitoring;
- Real-time data display and visualization;
- Generic tool for test procedure development;
- Statistical data analysis and display, realtime and non-realtime;
- Standards and procedures for safety and contamination control.

References:

'CCSDS: Advanced Orbiting Systems, Networks and Data Links: Architectual.' CCSDS 701.0-B-1, GSFC.MIL-STD-1553.

Schonf, Louis L., 'Statistical Signal Processing,' Addison-Wesley, New York, 1991.

Jeffrens, Harold, 'Theory of Probability.' Clonendon, New York, 1985.

13.13 Active-Passive Cathodic Protection Systems

NASA employs many metal structures and piping systems which require aggressive corrosion protection in order to extend their useful life. Presently, an impressed current cathodic protection system protects major sitewide underground piping systems, but its effectiveness along with its effects on other nearby systems is uncertain. Because of the uncertainties and problems encountered and the present lack of other practical methods or means for detecting, measuring, and predicting corrosive activity, innovative approaches or technologies are sought that address the following specific areas:

Measurements of potentials that show the effectiveness of an impressed current system in a specific area. This should also include values that would delineate the difference between corrosion-accelerating potentials and normal non-harmful potentials.

Diagnostic capabilities specifying which systems and structures using different (or no) protection schemes that are attached to protected systems must be isolated to prevent accelerated deterioration of either system.

Alternative types of protection systems for specific environmental conditions with predictable corrosion parameters to facilitate alternative cost benefit analyses to be made with regular required maintenance considered. Isolation alternatives must be included.

13.14 Nondestructive Characterization of Thermal Barrier Coatings

Demands for higher performance from jet and rocket engines have resulted in investigations into higher operating temperatures. Limitations are primarily due to the deterioration of material properties at high temperatures. Application of thermal barrier coating improves the ability to withstand oxidation and corrosion. These thin film coatings are being considered for blades and main combustion chambers.

The effectiveness of coatings is dependent on proper thickness, absence of flaws, and good adhesion to the parent material. Nondestructive techniques for rapid inspection of these coatings are to be developed which will determine the thickness and uniformity of thin-film coatings and provide assurance of good bonding.

References:

Laemmermann, H. and Kienel, G., "PVD Coatings for Aircraft Turbine Blades," Advanced Materials and Processes, Vol. 140, No. 6, Dec 1991, p.18-23. A92-17950, ISSN 0882-7958

G. C. Wetsel et al., Nondestructive Characterization of Coatings on Metal Alloys, Review of Progress in Quantitative Nondestructive Evaluation, Vol 6A, Eds. D. O. Thompson, and D. E. Chimenti, Plenum, New York, p.285-291, 1987. ISSN 0743-0760

13.15 Monitoring Systems for Facility Wastewater Management

All NASA facilities and all municipalities must operate wastewater systems for treatment and disinfection of domestic waste. The final phase of this treatment is the disinfection of the water just prior to release back into the environment. The effectiveness of disinfection is determined by drawing off samples from the wastewater effluent stream, growing cultures for 24 hours, and counting fecal coliform colony growth. Excessive fecal coliform levels indicate unsuccessful disinfection. Existing technology requires that samples of the discharge water be taken and biological oxygen demand (BOD) measurements made after a five-day waiting period. Legal restrictions on the discharge water requires that the BOD not exceed permitted limitations. Phase I deliverables will include sufficient information to outline an approach and prove the feasibility of proposed innovative technologies for:

- Instrumentation that could constantly monitor infection levels (or indicators of infection levels) of water
- Instrumentation that could constantly monitor the BOD (or indicators of BOD)
- "Real-time" monitoring capability of wastewater disinfection and monitoring of the BOD
- Supply output signals for control of treatment systems.

References:

Hoke, S. H. and Rivera, V. R., "A Near Real-Time HCl Monitor," 1988 JANNAF Safety and Environmental Protection Subcommittee Meeting, p.431-434. X89-72541 Limited by ITAR

Stanton, A. C. and Silver, J. A., "A Diode Laser Sensor for Measurement of Hydrogen Chloride Gas," Final Technical Report, Aug. 12, 1987 - Jan. 12, 1988. N89-15389 AVAIL:NTIS:AD-A199 518/2/XAB

Ramalho, R.S., "Introduction to Wastewater Treatment Processes." Academic Press, New York. 1977. 417p.

"Disinfection - Water and Wastewater," edited by J. Donald Johnson, Ann Arbor. Scientific and Technology Information Facility.

13.16 Vibro-Acoustic Design Methods for Rocket Launch Facilities and Equipment

The application of vibro-acoustic design methods to rocket launch facilities and equipment can lead to improvements in cost, design, and survivability. Methods which utilize real and predicted launch acoustic data to predict the vibration response of structures and equipment have been developed, but their complexity and cumbersome nature make them impractical for use during design.

NASA needs innovative concepts and techniques for implementing either the currently developed vibro-acoustic methods or some new methods in a practical form to use during design. Areas which need consideration include:

- Nonstationarity and randomness of the transient launch environment.

- The possible implementation of normalized, cross-power spectra for generic acoustic loading characterization and to account for the transient nature of these data.

- Optimum loads placement on structural and equipment models.

- Simplification of methodology to facilitate use and increase its applicability while maintaining acceptable prediction accuracy.

References:

GP-1059, "Environment and Test Specification Levels Ground Support Equipment for Space Shuttle System Launch Complex 39, Acoustics," Vol. III, November 1991.

KSC-DM-3147, "Procedure and Criteria for Conducting a Dynamic Analysis of Orbiter Weather Protection System on LC-39B Fixed Service Structure," Kennedy Space Center, September 1987.

KSC-DM-3256, "Computation of Generalized Modal Loads in an Acoustic Field Defined by a Distribution of Correlated Pressures," Kennedy Space Center, August 1989.

Margasahayam, R., Sepcenko, V., et. al. "Response of Launch Pad Structures to Random Acoustic Excitation," Second International congress on Recent Developments in Air- and Structure-Borne Sound and Vibration. Auburn University, Auburn, AL, March 4-6, 1992.

13.17 Safety, Reliability, and Quality Assurance Portable Data Collection Unit

Data collection has long been the shortfall of computer-aided task status, requirement tracking, and all the associated trending analysis. The use of computer-based spreadsheet accounting analysis of shuttle processing has significantly increased with increased launch rates and decreases in manpower. Proposals are solicited for innovative methods or machines designed to:

- Capture the essence of the quality assurance task being accomplished--barcode, video scan, magnetic tape, keyboard, touch screen.

- Transfer that information to an automated data collection machine for requirement status and quality assurance trend analysis with cross reference coding back to the original work authorizing document.

- Place a mark, label, or secure ID code on or into the record copy of the work authorizing document. The unit design must capture and mark or label without significantly increasing the task time.

References:

Deming, W. E., Out of the Crisis, (book on U.S. service and manufacturing industry management problems), MIT Center of Advanced Engineering Study, Cambridge, MA, 1989. 518p. A90-34955

Juran's Quality Control Handbook, McGraw-Hill, 4th ed., 1988. ISBN 0-07-033176-6

13.18 Probabilistic Analysis of Schedule- and Cost-Risk

Innovative tools are solicited for developing methods for accurately modeling and assessing the schedule- and cost-risk associated with highly complex and multi-variable space shuttle ground processing. The contributors to this risk include resource unavailability, hardware failure during testing, manifest constraints, and mission-specific processing requirements. Most current processing analysis tools are based on deterministic rather than stochastic approaches. For more effective management of shuttle processing resources, new techniques must be developed to quantify and understand ground processing schedule and cost risk.

The modeling methods should include the capability to:

- Evaluate the schedule and cost risk at various levels of complexity within thousands of processing facilities,

- Prioritize the relative contribution of risk factors to the overall schedule and cost risk at each level of analysis,

- Update and refine the original model as additional data is collected to measure the effectiveness of individual processing improvement efforts, and

- Communicate analysis results via electronic media to appropriate managers in a clear, concise, and timely manner.

References:

Bell, Trudy E., "Managing Risk in Large Complex Systems," IEEE Spectrum, June, 1989, pages 22-52.

Garrick, B. J., 'Risk Assessment Practices in the Space Industry - The Move Toward Quantification,' Risk Analysis, November, 1988.

Kaplan, S., and Garrick, B. J., 'On the Quantitative definition of Risk,' Society for Risk Analysis, Vol. I, No. 1, 1981.

Pullen, Richard A., 'Employing PRA Techniques in an Operational Environment,' Nuclear Engineering International, January, 1986, page 50.

14.00 Satellite and Space Systems Communications

14.01 Communications For Manned Space Systems

Multiple, simultaneous, efficient links will be required to communicate among many elements within automated and manned Lunar and Mars systems, Space Station Freedom, Space Transportation System, satellites, and extravehicular astronauts. Areas of significant innovation potential include:

Multiple beam antennas with near-hemispherical coverage at Ku, Ka, W-band, and optical frequencies for supporting simultaneous multi-access users. The use of photonics to distribute phase information across a large antenna for beam steering is needed.

Efficient, high-gain, conformal array antennas with electronically steerable beams to support advanced personnel launch systems.

Ultra-efficient, low-loss, active transmit and/or receive elements using monolithic microwave integrated circuit technology for Ku, Ka, W-band frequencies and to support high-rate, free-space optical communications for near-range and far-range users.

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

Digital, solid-state imaging, display, and processing systems. Small, lightweight systems for high definition of large scenes, employing high grey-scale resolution and higher order data compression with high quality imagery and with emphasis on packetized transmission.

Highly automated communications control and monitoring systems to allow rapid fault detection, isolation, and recovery, and efficient utilization and prioritization of communications systems resources.

Bandwidth efficient communications systems for telerobotic devices allowing simultaneous multiple channels of high-quality video, high-rate data, and command and control with minimum response delay.

References:

IEEE International Communications Conference - ICC '91, Space Station Communications, Denver, Colorado, June 1991.

IEEE Global Telecommunications Conference - GLOBECOM '90, Space Communications Systems. San Diego, California, December 1990. A91-53161

SPIE (International Society for Optical Engineering) Conference, Application of Ka-band MMIC Technology for an Orbiter/ACTS Communications Experiment, Orlando, Florida, April 1990.

14.02 Optical Communications for Data Relay Satellite Systems

NASA's next generation data relay satellites require improved capabilities: laser transmitter, receiver, and pointing technology 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. Small, efficient laser terminals which can support lunar missions for the Space Exploration Initiative are also needed. Innovations are required in several areas:

Diode-pumped Nd:YAG laser transmitters, high average power (typically 1-to-5 Watts) to increase performance while reducing the size and weight of optical communication terminals.

Optical receivers to detect and demodulate the incoming data stream. High-sensitivity wideband detector-preamplifiers are needed for the 950-1047 nm wavelength band. Bandwidths in excess of 900 MHZ are desired, and the emphasis will be on sensitivity in photons per bit at targeted data rates between 600 and 2000 Mbps.

Innovative optoelectronics implementations for integrating key transmitter and receiver electro-optic hardware assemblies for robustness during launch operations, modular replacement, and reduced weight and power. Examples include fiber-optic coupling and monolithic or hybrid implementation.

Small, lightweight modulators which can impress either phase or amplitude modulation on the Nd:YAG 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 optical power handling capability.

Beam alignment implementations for laser beam combiners which can compensate for slow drifts in pointing direction and exhibit minimal size and complexity. Techniques which utilize thermo-optic, electro-mechanical, or electro-optic effects and small, high-precision, two-axis gimbals which can point laser beams to microradian precision are also required.

References:

Fitzmaurice, M. and Bruno, R. "Laser Communication Transceiver for Space Station Freedom," Free-Space Laser Communication Technologies II, SPIE, Vol. 1218 (Jan. 1990), 439-448. A91-22816

Fox, N.D., Chapman, W.W. and Johnson, T.S. "Performance and Modeling of the GSFC Pointing, Acquisition and Tracking System for Laser Communications," Space Sensing Communications and Networking, SPIE, Vol. 1059 (Jan. 1989), 88. A90-31937

Seery, B.D. "The Goddard Optical Communications Program," Free-Space Laser Communication Technologies II, SPIE, Vol. 1218 (Jan. 1990), 13-26. A91-22778

Davidson, F.M., Sun X. and Krainak, M.A. "Bandwidth Requirements for Direct Detection Optical Communication Receivers with PPM Signaling," Free-Space Laser Communication Technologies III, SPIE, Vol. 1417 (Jan. 1991). AVAIL:AIAA

14.03 Optical Communications for Deep Space

Future deep-space-exploration spacecraft will use optical frequencies to communicate back to near-Earth orbit or directly to the ground. Numerous innovations will be required to facilitate these new systems. Innovative concepts are needed for:

- Lasers that have high-power conversion efficiency (approximately 10 percent), produce single and stable far-field beam profiles, and can be modulated easily using a pulse position modulation format with high peak pulse energies (0.1-1.0 mj).
- Laser sources for heterodyne systems that produce very stable output frequencies and design approaches and concept verifications for coherent optical transponder functions.
- High-gain, focal-plane, detector arrays with electronically-controlled cursor readout. A kilohertz readout rate (with single or multiple pixel), a gain of million, and a responsiveness better than an S-20 photocathode are desired.
- Optical reception telescopes with large aperture (greater than 5 meters in diameter), inexpensive, non-diffraction-limited for use on the ground or in space. Reception wavelengths for these "photon buckets" are in the 0.5-to-1.2 micron region. Concepts and design verifications also are sought for using such telescopes at small angles off the solar limb (ie., at small Sun-Earth-spacecraft angles).

References:

Lesh, J.R. "Optical Communications Systems and Technology for Deep-Space Exploration," Proceedings of Optical Space

Communications Conference at the Second International Congress on Optical Systems and Engineering (ECO2), Paris, SPIE, Vol. 1131 (April 1989), 236-239. A90-38025

Lesh, J.R. "Deep Space Optical Communications-A Program Update," SPIE OE Lase 90, L.A., CA, paper 1218-43 (Jan. 1990), 530-540. A91-22820

14.04 Integrated Global-Positioning Satellite and Inertial Navigation Systems for Mapping Applications

Recent technological advances in component miniaturization opens the door for innovative new, integrated, global-positioning satellite and inertial navigation systems. Example innovations could include more direct use of carrier phase and/or differential techniques for improved accuracies. New designs which incorporate relatively low-cost components such as single-board, multichannel GPS receivers and small, state-of-the-art gyroscopes are needed for cost-sensitive vehicle navigation and tracking applications such as:

- Vehicle position tracking for input to on-board moving map displays.
- Tagging of airborne, electronic imagery with accurate position data.
- Real-time digitizing of road centerlines from moving vehicles.
- Real-time digitizing of pipelines and utility transmission lines from helicopters.

References:

Williams, T. "Micro Gyroscopes Bring Motion Sensing To Low-Cost Systems." Computer Design, November 1991.

Bossler, J., et. al. "GPS and GIS Map The Nation's Highways." GEO Info Systems, March, 1991.

Hossfeld, B. "GPS For Vehicle Tracking." GPS World, October, 1991.

14.05 RF Components for Satellite Communications Systems

Innovations are being sought for devices, components, and subsystems that will enable new applications and increased capabilities for a broad spectrum of civil-space communications applications. Specific applications for Government communications satellites include lunar and planetary exploration, Space Station Freedom, and earth-orbiting, data relay satellites. Commercial communications satellite applications include both fixed and mobile services at geostationary and nongeostationary altitudes. Specific requirements exist for:

MMIC, discrete, semiconductor, superconductor, or vacuum electron concepts for components and subsystems that stress higher frequency of operation or improvement in bandwidth, power, efficiency, noise figure, gain, reliability, size, or cost.

Advanced materials, structures, and devices (FET's, TWT's, MODFET's, or HBT's) whose improved noise, power, efficiency, or frequency response will enhance the performance of communications systems components or systems.

Antenna configurations for producing multiple, scanned, transmitting or receiving beams from a single antenna array using MMIC device technology.

Microstrip antennas. Novel design concepts for enhancing gain, bandwidth, or functional capability.

Packaging and integration of MMIC and/or photonic devices. Advanced techniques, components, and designs in phased-array antenna systems. Interests include multichip packaging, optical-fiber hermetic feed-throughs, and device characterization technologies.

System-level circuit development. Methods, processes, and techniques wherein power-processing, interface, support, and control circuitry are co-located with an rf MMIC at the radiating element of a phased-array antenna system.

Multiple-beam, phased-array antenna concepts and configurations for using photonics technology.

References:

Simons, R.N. "Optical Control of Microwave Devices." Artech House, Inc., 1990. A91-17719

Leonard, R.F. and Romanofsky, R.R. "Microwave Integrated Circuits for Space Applications," Presented at the Technology 2000 Conference, Washington, D.C., November 1990. AVAIL:CASI

Wilson, J.D., Limburg, H.C., Davis, J.A., et. al. "A High-Efficiency Ferruleless Coupled-Cavity Traveling-Wave Tube with Phase-Adjusted Taper," IEEE Transactions on Electron Devices, Vol. 37, No. 12 (December 1990), 2638-2643. AVAIL:AIAA

14.06 Digital Systems for Satellite Communications

Innovative digital and optical concepts are invited that support advanced technology demonstrations in on-board information switching and processing, modems, codecs, and ground terminals. Devices, components, and subsystems are required that support fault tolerant information switching and processing, autonomous network control, advanced modulation and coding, and video data compression. Innovations are requested in the following areas.

- Fault-tolerant switching and routing devices and components for an information switching processor (ISP) system level development. The ISP will support circuit and packet switching. Its architecture must be highly fault tolerant, non-blocking, and flexible. Novel expert systems approaches to enhance fault tolerant architectures.

- Artificial-intelligence for resource planning and scheduling paradigms to configure maps for satellite communication network management.

- Digital chip or chip-set of 50 Mbps burst modulators and demodulators.

- Neural network-based solutions to acquisition and demodulation, error correction, and onboard data flow and congestion control.

- Chip-set implementations of ground-based controller for FDMA uplink data and TDMA downlink data, including acquisition, synchronization, timing control, and terrestrial interfaces for cost-efficient ground terminals.

- Video data compression techniques, both lossless and lossy, that achieve significant bit-rate reductions while preserving high image quality (i.e., quality at or near that of the original source). Particular interests lie in bandwidth-efficient transmission of high resolution, full-motion video and high frame rate (e.g. 1000fps) video.

- Image data compression techniques suitable for image data archival, browse or quick-look.

References:

Harrold, J.L., Budinger, J.M. and Stevens, G.H. "On-Board Switching and Processing," IEEE Proceedings on Satellite Communications, Vd 78, No. 7 (July 1990). A90-51168

"Space Communications Technology Conference: Onboard Processing and Switching," NASA, Cleveland, Ohio, Nov. 12-14, 1991. NASA-CP-3132. N92-14202

Hartz, W.G., Alexovich, R.E. and Neustadter, M.S. "Data Compression Techniques Applied to High Resolution High Frame Rate Video Technology," NASA Contractor Report CR 4263, NAS3-24564, Dec. 1989. N90-14452

14.07 Low Cost Ka-Band Ground Terminals

The Advanced Communications Technology Satellite (ACTS) currently under development uses time division multiple accessing (TDMA) together with on-board switching and multiple, narrow, hopping-beam antennas to route communications traffic among a network of small-user Earth stations. Innovations are needed to develop low-cost, low data rate (2.4 to 9.6 kbps), transmit and receive experimenter terminals to function with this satellite during the experiment period of 1993 to 1995. These terminals need not address the TDMA aspects of the ACTS system and need not operate with burst modems and controllers. The terminals will operate when the spacecraft is in the microwave switch matrix (MSM) mode.

Innovative concepts to achieve small (equal to or less than 0.6 m antenna diameter), low-cost terminals are solicited. Proposals may be submitted for an entire terminal or for portions of the terminal defined below. The offeror is encouraged to include an experiment with the ACTS as a validation of the developed product. Offerors are advised not to submit proposals that suggest design or development based on well-known or conventional devices be obtainable through normal specification procurements.

- 30 GHz power amplifiers in the 10W to 20W range and in the 1 to 10W range.
- 15-to-60-centimeter-diameter reflector antennas.
- Flat, passive, planar antenna arrays at 30 GHz and at 20 GHz.
- MMIC upconverters (C-band to 30 GHz) and downconverters (20 GHz to C-band).
- Combined MMIC, low-noise preamplifiers and downconverters for receivers, 20 GHz to C-band.
- Modems, 2.4, 4.8, 9.6 kbps to C-band.
- CODECS
- Vocoders

References:

Experiments Applications Guide, Lewis Research Center, Cleveland, Ohio. January 1990 Advanced Communications Technology Satellite (ACTS), National Aeronautics and Space Administration, NASA TM-100265 (Revised), ACTS Publication 101 (revised).

14.08 Superconducting Microwave and Millimeter Wave Components and Systems

High-temperature superconductivity holds great promise for cost-effective performance improvements in microwave and millimeterwave systems. Significant decreases in circuit losses compared to normal metals have been demonstrated at temperatures near that of liquid nitrogen, with simpler cooling systems than required for low-temperature superconductor devices. Some simple Josephson-junction and three-terminal devices have been made which utilize high-temperature superconductors. Novel approaches are needed to provide performance improvements or unique advantages over existing non-superconducting alternative technologies that would be significant enough to justify refrigeration. Innovations are solicited in microwave and millimeter-wave devices and subsystems capable of demonstrating such advantages in ground and/or space sensors and communications systems. Possible areas of investigation include:

- Tunable or switchable low-loss filters.
- Low-loss phase shifters.
- Practical antenna concepts, including single elements, arrays, matching circuits, and beam-forming networks.
- Low-noise receiver technology.
- Microwave modulators.
- Low-noise oscillators, including ultra-stable references or tunable oscillators.

References:

Papers presented at the 1990 Applied Superconductivity Conference reported in IEEE Trans. Magn., Vol. 27, March 1991.

Papers on applications of superconductivity in Proc. IEEE, Vol. 77, August 1989.

Special issue on microwave applications of superconductivity, IEEE Trans. Microwave Theory Tech., Vol 39, September 1991.

15.00 Materials Processing, Micro-Gravity, and Commercial Applications in Space

15.01 Materials Processing in Space

The field of materials research and development has always been hindered by gravity-induced disturbances and convection currents. The Microgravity Materials Science Laboratory, Computational Materials Laboratory, and the free-fall facilities at the NASA Lewis Research Center provide easy access and assistance to outside investigators for materials studies and applications to exploit the advantages of microgravity (weightlessness) in advance of potential space flight demonstrations. Innovations are sought for the following developmental and commercial processes:

Materials:

- Electronic materials, semiconductors, and solid-state detectors with improved, controlled crystal growth for a variety of scientific and commercial applications.

- Metallic alloys with improved grain structures by directional solidification and processing involving supercooling and undercooling states.

- Glasses, ceramics, and optical fibers made by containerless processing to eliminate impurities, to control nucleation sites, and to process reactive melts.

Equipment, Instrumentation, and Techniques:

- Experimental methods for thermodynamic and transport property measurements in microgravity, including multiphase and complex regimes in crystallization, solute-solvent separation, phase-change and glass-transition separation.

- Processing techniques including acoustic, electromagnetic, and electrostatic levitation, chemical- vapor transport, physical-vapor transport, directional solidification, and float-zone, and edge-defined growth.

- Furnace and combustion processing specifically for materials processing.

- Characterization of materials for these applications.

Computational Techniques:

- Simulation capabilities which will elucidate the interaction of transport phenomena during processing (e.g. fluid, heat, and mass transport) leading to microstructure and materials properties.

- Experimental design methodologies combining advanced process models, optimization techniques, and advanced controls leading to improved total process understanding and control.

- Models which could be incorporated into standard available transport codes are especially encouraged.

References:

Kohl, Fred J.: Microgravity Research at LeRC. NASA TM 102521, June 1990. AVAIL:CASI

Rosenthal, Bruce N., et al.: Research Opportunities in Microgravity Science and Applications During Shuttle Hiatus, NASA TM 88964, April 1987. A88-13164

Wadley, H.N.G., Eckhart, W.E.: Intelligent Processing of Materials, The Minerals, Metals and Materials Society, Warrendale, PA, 1990.

15.02 Microgravity Science, Engineering, and Applications Other Than Materials

The low-gravity (microgravity) environment of orbiting spacecraft eliminates buoyant currents and natural convection, simplifying some studies of heat and mass transfer but complicating many experimental, operational, and protection techniques for human-crew spacecraft.

To accommodate investigations for short-duration low-gravity science and/or definition of space flight experiments, the NASA Lewis Research Center and Marshall Space Flight Center can make their unique Government research facilities available. Up to 5 seconds of low-gravity time can obtained in drop towers; up to 20 seconds in airplane trajectories. Long-duration demonstrations can eventually utilize the shuttle, free-flyer, and the Space Station Freedom accommodations.

Innovations are sought to meet not only the special microgravity requirements but also the potentially wider commercial applications in the following science, engineering, and technology opportunities:

- Experiments and experimental equipment for the technology areas of
  - energy conversion,
  - space power systems,
  - fluid and thermal management systems,
  - spacecraft fire safety, and
  - space environmental effects.

- Advanced instrumentation, sensors, and diagnostic techniques for non-perturbing measurements of fluid, thermal, and flow field parameters.

- Advanced technology in furnace performance (heating and cooling techniques), methods of insulation, and variable control for future microgravity experiments.

- Development of technology for data recording, storage, processing, and transmission of microgravity experiments in fluid physics, combustion science, and basic material science.

- Other innovative areas such as:
  - property measurement techniques,
  - waste product disposal systems,
  - unique mechanical devices,
  - sample preparation techniques,
  - automated experiment and process control, and
  - acceleration and vibration measurement and control.

References:

Law, C.K., "Combustion in Microgravity: Opportunities, Challenges, and Progress," Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. AIAA Paper 90-0120. A90-23703

Ott, R.H. and Sokolowski, R.S., "United States Microgravity Programs," Microgravity Science and Technology, vol. 3, Dec. 1990, p.132-137. A91-18727

Ross, Howard D.; and Greenberg, Paul S.: New Findings and Instrumentation from the NASA Lewis Microgravity Facilities. NASA TM 103189, May 1990. N90-26163

Kohl, F.J.: Microgravity Research at LeRC. NASA TM 102521, June 1990. Jan. 1991. AVAIL:CASI

15.03 Experimental Diagnostic Equipment and Reconfigurable Containment Systems

On previous materials processing in space experiments the payload on-orbit manipulation of the sample materials by the crew has been limited. Many on-orbit sample exchanges and analyses are precluded by safety requirements and relatively short duration of all previous Shuttle-era manned missions. With the advent of extended manned missions, safe crew access to the contained experiment sample materials and equipment will be necessary for such activities as on-orbit maintenance, sample characterization, sample change-out, and experiment reconfiguration. Innovations should be reliable, light-weight, low-power, and capable of operating safely in a manned environment.

An x-ray system is needed to perform the on-orbit evaluation, analyses, and characterization of protein crystals. Timely feedback into the crystal growth process should ensure the highest quality products in subsequent experiment runs and preclude the loss of protein crystals via damage upon re-entry or deterioration over time.

An ampoule-failure detector system is required to provide a positive indication of sample material release into a containment volume to prevent inadvertent crew contact with potentially toxic sample materials such as metal vapors. Sample materials may include the following: CdTe, HgCdTe, GaAs, PbSnTe, HgZnTe, PbBr, and Hgl2.

References:

NASA/MSFC Document JA01-001, "U.S. Users Space Station Freedom Laboratory Support Equipment/General Laboratory Support Facilities Level II Requirements Document," October 11, 1991, pp. 101-104.

Kristan Lattu, Hershall Fitzhugh, Robert H. White, NASA/JPL Report JPL-D-7976, "Guidelines for the Classification of Space Station Freedom Laboratory Support Equipment and General Laboratory Support Facilities," October 1990.

NASA/MSFC Document JA55-032, "Space Station Furnace Facility Capability Requirements Document," latest revision.

Teledyne Brown Engineering Report DR-7, "Function and Performance Specifications for Space Station Furnace Facility," August 1990. Teledyne Brown, Colorado Springs, CO.

15.04 Automated Wafer Manipulation System for Thin-Film Growth

The successful demonstration of material growth experiments utilizing the microgravity and ultra-vacuum characteristics of space depends greatly on the development of appropriate tools and instrumentation to deliver both the starting materials necessary for thin-film growth as well as manipulation of wafers prior, during, and after the deposition process. A wafer storage and manipulation system is needed. It should withstand the vibration and acceleration loads present during lift off, be modular to allow integration in a variety of experiments, and allow the growth of ultra-high-purity materials on the wafers. Innovations should emphasize design, fabrication, and integration schemes, with low-cost being a major evaluation parameter.

References:

Apelian, Diran and Zemel, Jay, MRS Proceedings, Symposium on Materials Future: Strategies and Opportunities, Fall meeting, 1988.

Tanaka, H. and Mushiage, M., J. Crys. Growth, 111. p 1043, 1991.

Shastry, Shamku K., et al, Microelectronics Manufacturing Technology, April 1991, p. 49.

15.05 First- and Zero-Order Kinetic Delivery of Solutes to Water Solutions

Unattended environments require addition of compounds to storage solutions with minimal power consumption; elimination of problems in packaging to avoid breakage; potential for generic application to a variety of problems; compliance with space vehicle safety requirements; and compatibility with numerous life systems (plants, cells and animals). Current methods for first- and second-order kinetic delivery systems emphasize pumps or syringes; osmotic release containers; or mixtures of "timed release" capsules. All lack one or more of the desired features. Examples of potential applications include: controlled release of sterilizing agents into drinking water for animals and man; operator initiation (followed by unattended function) or release of antibiotics to water to be consumed by animals; and release of growth factors that limit the cultivation of cells in single-pass or recycling bioreactors.

This solicitation emphasizes novel solutions to the generic problem, but proposals must include a list of potential NASA applications that can be addressed in the Phase II.

References:

Johnson, C.C., Rasmussen, D., Curran, G., NASA Ames Research Center, Moffett Field, CA, Bionetics Corp., Moffett Field, CA, "Water Management Requirements For Animal And Plans Maintenance On The Space Station." SAE Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987, 9 p. A88-21125

Mitani, K., Ashida, A., Ebara, A., Nitta, K., Hitachi, Lt., Space Systems Div., Tokyo, Japan, Hitachi Ltd., Hitachi Research Laboratory, Japan, National Aerospace Laboratory, Chofu, Japan, "Water Recycling For Space Station." International Symposium On Space Technology And Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 (A87-32276 13-12). Tokyo, Agne Publishing, Inc., 1986, p. 1361-1364. A87-32459

Wright, B.D., "A Hydroponic Method for Plant Growth in Microgravity," International Astronautical Federation, International Astronautical Congress, 35th, Lausanne, Switzerland, October 7-13, 1984, 6 p. A85-13292

Baldeschwieler, J.D.," Development of Microencapsulation Techniques, TLSP," Final Report, 15 May, 1987 - 24 March, 1990. N90-26159

15.06 Biophysics Research

Biophysics research includes experimental and theoretical research in separation techniques and protein crystal growth to better understand basic effects that occur in the unique low-gravity environment of space. Both electrophoresis and phase-partitioning are used to purify biological cells and proteins in aqueous media by processes controlled or driven by thermal convection and sedimentation. Protein crystals are grown in order to analyze the fluid dynamics processes that limit their growth and quality and to obtain the three-dimensional structure of specific proteins.

Protein crystallography is currently the most powerful method for the determination of the three-dimensional structure of proteins and other macromolecules. This method usually requires crystals which are relatively large (0.1 to 1.00 mm) and possess a reasonably high degree of internal order. Consequently, protein crystal growth has become the subject of an increasing number of fundamental studies, including several ongoing microgravity experiments. Innovative ideas are sought in the protein crystal growth arena and in separation techniques.

References:

J.E. Lyne, D.C. Carter, X. He, G. Stubbs and J.H. Hash, "Preliminary Crystallographic Examination of a Novel Fungal Lysozyme From Chalaropsis," J. Biol. Chem. 265 6928-6930 (1989). A90-40377

DeLucas, L. J., Smith, C. D., Carter, D. C., Snyder, R. S., McPherson, A., Koszelak, S. and Bugg, C. E., "Microgravity Protein Crystal Results and Hardware," 8th American Conference on Crystal Growth, Vail, Colorado, Journal of Crystal Growth, 1991. ISSN 0022-0248

Snyder, R.S., Rhodes, P.H., "Electrophoresis Experiments in Space," Frontier in Bioprocessing (S.K. Sikdar, M. Bier, and P. Todd, eds), CRC Press 1990, pp. 245-258. ISBN 0-84-935839-6

Pusey, M.L., "Estimation of Initial Equilibrium Constants in Formation of Tetragonal Lysozyme Nuclei," Journal of Crystal Growth, vol. 109/110, 1991. ISSN 0022-0248

15.07 Autonomous Support of Microorganisms, Plants, and Animals

Satisfying the life sciences technical objectives involving autonomous support of microorganisms, plants, and animals requires the development of a new generation of sensors that are compact, economical, rugged, reliable, and accurate to monitor concentrations and delivery rates of gases such as O_2, CO_2. As a secondary objective, similar sensors that can monitor temperature, humidity, turbidity, ambient light levels, are also desirable. These sensors should readily adapt to autonomous plant and animal payloads destined for use in the COMET (COMmercial Experiment Transporter), and should be able to communicate readily with payload-based data-loggers, downlink devices, and telepresence facilities. The sensors should also be suitable for use in autonomous and man-tended Earth-based, ground control experimental facilities.

References:

MacElroy, E.D., Greenwalt, S. "Controlled Ecological Life Support Systems," NASA TM 102277, March 1990 AVAIL:CASI

Hoehn, A., Simske, S.J., Luttges, M.W. "The P-MASS: A Plant Growth Module For Autonomous Space Support On Board COMET," International Conference on Life Support and Biospherics, University of Alabama-Birmingham, February 18-20, 1992.

Simske, S.J., Luttges, M.W., Hoehn, A. "The A-MASS: The Animal Module for Autonomous Space Support on COMET I," International Conference on Life Support and Biospherics, University of Alabama-Birmingham, February 18-20, 1992.

15.08 Extended-Duration, Small Animal, Life-Support Unit

Self-contained, extended-duration, small-animal life-support units are needed to enable physiological testing to proceed for 30-90 days aboard unmanned free flyers and Space Station. Research conducted by NASA and others has shown that, in microgravity, humans and animals experience diverse biological changes that appear to mimic a wide range of Earth-based medical problems, including anemia, osteopenia, muscle wastage, secretion disorders such as certain forms of diabetes and cystic fibrosis, immune suppression disorders, and possibly, rapid aging. Rodents or other small animals exposed to the microgravity environment can serve as test models for these medical problems in pharmaceutical product development if suitable life-support units can be developed.

This subtopic solicits innovative, lightweight, reusable, small-animal life-support units which can:

- Operate without human tending and with minimal power consumption
- Sustain groups of 8 to 10 rodents or other small animals in accordance with all Federal animal care and use requirements through launch, 30 to 90 days on orbit, reentry, and landing
- Provide sensor and/or video monitoring of animal vital signs plus remote control of the unit's life

support systems (including temperature pressure, light and dark periods, air, food, water, and waste collection)

References:

Bonting, Sjoerd L., Kishiyama, Jenny S., Arno, Roger D.,"Facilities for Animal Research in Space with Special References to Space Station Freedom," Intersociety Conference on Environmental Systems, 20th Williamsburg, VA, July 9-12, 1990, 24p.

Olson, Richard L., Gustan, Edith A., Wiley, Lowell F., "Plant and Animal Accommodation for Space Station Laboratory," Aerospace Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 (A87-38701 16-54), Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 405-426.

Holley, Danial C., Winget, Charles M., Leon, Henry A., "Proceedings of a Workshop on Lighting Requirements in Microgravity; Rodents and Nonhuman Primates." Workshop held in San Jose, CA. 16-17 July, 1987.

15.09 Microgravity Processing of Quantum-Dot Materials

Quantum-dot materials are composite, nonlinear optical materials (bulk solids or thin films) composed of colloidal-sized (20 to 200 angstroms) semiconducting or metallic particles in an insulating, transparent matrix. These nonlinear optical composites can be used in applications such as optical limiters. As the size of the dispersed semiconductor particles is reduced into the colloidal range, the absorption edge of the semiconductor material shifts, and eventually splits into discrete levels as a result of size-quantization of the nanoparticles. Large resonant optical nonlinearities are observed near the band-edge in this particle size region (typically, 50 angstroms or less).

Attainment of maximum nonlinear effects in quantum-dot materials requires preparation of composites containing large, volume-fractions of semiconductor or metallic particles having a narrow size distribution. However, in the case of bulk filter glasses, the concentration of the dispersed chalcogenide particles is limited to about two weight-percent. Colloidal particles of chacogenide semiconductors can be produced by several methods, but increasing the loading of colloidal particles and optimizing the dispersion of these particles in solid matrices remains important technical challenges. Microgravity processing has potential to improve the dispersability and loading of colloidally dispersed semiconductor particles. Innovations are sought that will produce improved quantum-dot materials through microgravity processing.

References:

Hall, D.W., and Borelli, N.F. Journal of the Optical Society of America, B 5, 1650 (1988).

Borelli, N.F., et al., Journal of Applied Physics, 61(12), 5399 (1987).

Yamamoto, T., et al., Inorg. Chim. Acta, 104, L1-L3 (1985).

Wang, Y., et al, Journal of the Optical Society of America, B 6(4), 808(1989).

NASA

SBIR 92-1 SOLICITATION

FORM 9.A - PROPOSAL COVER

		4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER	
PROPOSAL NUMBER	92-1	__ __.__ __	__ __ __ __	__	(Instructions on Reverse Side)

SUBTOPIC TITLE ______________________________

PROJECT TITLE ______________________________

____

FIRM NAME ______________________________

MAIL ADDRESS ______________________________

CITY/STATE/ZIP ______________________________

PHONE ______________________________

PHASE I AMOUNT REQUESTED: $__________ DURATION: ________ MONTHS

OFFEROR CERTIFIES THAT:

	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	☐	☐
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.	☐	☐
5. The firm has (indicate Yes) or has not (indicate No) received Federal funds for substantially similar work.	☐	☐

ENDORSEMENTS:

	Principal Investigator	Corporate/Business Official
Typed Name	______________	______________
Title	______________	______________
Signature	______________	Signature ______________
Date	______________	Date ______________

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

NOTICE: For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use Information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages _________ of this proposal.

INSTRUCTIONS FOR COMPLETING FORM 9.A

General--Complete Form 9.A and sign in ink. Make five photocopies to use as the cover sheet for each copy of your proposal. Submit the original copy separately (See Sections 3.2, 3.3, 3.4 and 6.1 for further instructions). To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed using a mono-spaced typestyle such as Courier, Letter Gothic, Prestige, Pica, or Elite in 10 or 12 characters per inch (pitch) or 12 point.

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

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

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

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

   Enter the proposal number on Forms 9.B and 9.C.

2. Subtopic Title: Enter the title of the subtopic that this proposal will address. Use abbreviations as needed. Do not use this for the proposal title.

3. Project Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). **Do not use the subtopic title.** Avoid words like "development" and "study".

4. Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

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

6. Phase I: Amount Requested: Enter proposal amount from Budget Summary. The amount requested should not exceed $50,000. Round to nearest dollar. **Do not** enter cents.
   Duration: Enter the proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss the reason in the text of the proposal.

7. Certifications: Enter **Y** for yes or **N** for no in the appropriate boxes.

8. Endorsements: The proposal should be signed by the proposed **Principal Investigator and an official of the firm** qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person. The red copy of the cover sheet should have 2original signatures.

NASA

SBIR 92-1 SOLICITATION

FORM 9.A - PROPOSAL COVER

		4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER	
PROPOSAL NUMBER	92-1	_ _ _ _	_ _ _ _	__	(Instructions on Reverse Side)

SUBTOPIC TITLE ______________________

PROJECT TITLE ______________________

____

FIRM NAME ______________________

MAIL ADDRESS ______________________

CITY/STATE/ZIP ______________________

PHONE ______________________

PHASE I AMOUNT REQUESTED: $ ______________ DURATION: ________ MONTHS

OFFEROR CERTIFIES THAT:

	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	☐	☐
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.	☐	☐
5. The firm has (indicate Yes) or has not (indicate No) received Federal funds for substantially similar work.	☐	☐

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

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

NOTICE: For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use Information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages __________ of this proposal.

INSTRUCTIONS FOR COMPLETING FORM 9.A

General--Complete Form 9.A and sign in ink. Make five photocopies to use as the cover sheet for each copy of your proposal. Submit the original copy separately (See Sections 3.2, 3.3, 3.4 and 6.1 for further instructions). To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed using a mono-spaced typestyle such as Courier, Letter Gothic, Prestige, Pica, or Elite in 10 or 12 characters per inch (pitch) or 12 point.

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

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

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

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

   Enter the proposal number on Forms 9.B and 9.C.

2. Subtopic Title: Enter the title of the subtopic that this proposal will address. Use abbreviations as needed. Do not use this for the proposal title.

3. Project Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). **Do not use the subtopic title.** Avoid words like "development" and "study".

4. Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

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

6. Phase I: Amount Requested: Enter proposal amount from Budget Summary. The amount requested should not exceed $50,000. Round to nearest dollar. **Do not** enter cents.
   Duration: Enter the proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss the reason in the text of the proposal.

7. Certifications: Enter **Y** for yes or **N** for no in the appropriate boxes.

8. Endorsements: The proposal should be signed by the proposed **Principal Investigator and an official of the firm** qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person. The red copy of the cover sheet should have 2original signatures.

NASA

SBIR 92-1 SOLICITATION

FORM 9.A - PROPOSAL COVER

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER	
PROPOSAL NUMBER 92-1	_ _ . _ _	_ _ _ _	_	**(Instructions on Reverse Side)**

SUBTOPIC TITLE ____________________

PROJECT TITLE ____________________

____

FIRM NAME ____________________

MAIL ADDRESS ____________________

CITY/STATE/ZIP ____________________

PHONE ____________________

PHASE I AMOUNT REQUESTED: $__________ DURATION: ______ MONTHS

OFFEROR CERTIFIES THAT:

	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	☐	☐
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.	☐	☐
5. The firm has (indicate Yes) or has not (indicate No) received Federal funds for substantially similar work.	☐	☐

ENDORSEMENTS:

	Principal Investigator	Corporate/Business Official
Typed Name	__________	__________
Title	__________	__________
Signature	__________	Signature __________
Date	__________	Date __________

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

NOTICE: For any purpose other than to evaluate the proposal, this data shall not be disclosed outside the government and shall not be duplicated, used, or disclosed in whole or in part, provided that if a funding agreement is awarded to this proposer as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement. This restriction does not limit the Government's right to use Information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained in pages ______ of this proposal.

INSTRUCTIONS FOR COMPLETING FORM 9.A

General--Complete Form 9.A and sign in ink. Make five photocopies to use as the cover sheet for each copy of your proposal. Submit the original copy separately (See Sections 3.2, 3.3, 3.4 and 6.1 for further instructions). To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed using a mono-spaced typestyle such as Courier, Letter Gothic, Prestige, Pica, or Elite in 10 or 12 characters per inch (pitch) or 12 point.

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

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

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

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

   Enter the proposal number on Forms 9.B and 9.C.

2. Subtopic Title: Enter the title of the subtopic that this proposal will address. Use abbreviations as needed. Do not use this for the proposal title.

3. Project Title: Enter a brief, descriptive title using no more than 80 keystrokes (characters and spaces). **Do not use the subtopic title.** Avoid words like "development" and "study".

4. Firm Name: Enter the full name of the company submitting the proposal. If a joint venture, list the company chosen to negotiate and receive contracts. If the name exceeds 40 keystrokes, please abbreviate.

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

6. Phase I: Amount Requested: Enter proposal amount from Budget Summary. The amount requested should not exceed $50,000. Round to nearest dollar. **Do not** enter cents.
   Duration: Enter the proposed duration in months. If the proposed duration is other than 6 months, be sure to discuss the reason in the text of the proposal.

7. Certifications: Enter **Y** for yes or **N** for no in the appropriate boxes.

8. Endorsements: The proposal should be signed by the proposed **Principal Investigator and an official of the firm** qualified to make a contractual commitment on behalf of the firm. The PI and the Corporate Official may be the same person. The red copy of the cover sheet should have 2original signatures.

NASA

SBIR 92-1 SOLICITATION

FORM 9.B - PROJECT SUMMARY

		4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER	(Instructions on Reverse Side)
PROPOSAL NUMBER	92-1	_ _ _ _	_ _ _ _	_	AMOUNT REQUESTED $ ________

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

KEY WORDS
(LIMIT 8)

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

PRINCIPAL INVESTIGATOR

INSTRUCTIONS FOR COMPLETING FORM 9.B

General:

To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed without using a mono-spaced typestyle such as Courier, Letter Gothic, Prestige, Pica, or Elite in 10 or 12 characters per inch (pitch) or 12 point.

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 and must describe the proposed innovation. (See Section 3.4.2.)

4. **Potential Commercial Applications:** Summarize the commercial potential of the project assuming the goals 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 area, or application of the proposed effort.

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

7. **Principal Investigator:** Enter name of Principal Investigator as shown on the Proposal Cover sheet.

NASA

SBIR 92-1 SOLICITATION

FORM 9.B - PROJECT SUMMARY

		4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER	(Instructions on Reverse Side)
PROPOSAL NUMBER	92-1	_ _ _ _	_ _ _ _	_	AMOUNT REQUESTED $ ____________

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

KEY WORDS
(LIMIT 8)

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

PRINCIPAL INVESTIGATOR

INSTRUCTIONS FOR COMPLETING FORM 9.B

General:

To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed without using a mono-spaced typestyle such as Courier, Letter Gothic, Prestige, Pica, or Elite in 10 or 12 characters per inch (pitch) or 12 point.

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 and must describe the proposed innovation. (See Section 3.4.2.)
4. **Potential Commercial Applications:** Summarize the commercial potential of the project assuming the goals 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 area, or application of the proposed effort.
6. **Name and Address of the Firm:** Enter firm name and mailing address as shown on the Proposal Cover sheet.
7. **Principal Investigator:** Enter name of Principal Investigator as shown on the Proposal Cover sheet.

NASA

SBIR 92-1 SOLICITATION

FORM 9.B - PROJECT SUMMARY

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER	(Instructions on Reverse Side)
PROPOSAL NUMBER 92-1	_ _ _ _	_ _ _ _	_	AMOUNT REQUESTED $ ________

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

POTENTIAL COMMERCIAL APPLICATIONS

KEY WORDS
(LIMIT 8)

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

PRINCIPAL INVESTIGATOR

INSTRUCTIONS FOR COMPLETING FORM 9.B

General:

To facilitate proposal processing, NASA may employ automated optical devices to record proposal information. Towards this end, it is required that the Proposal Cover sheet (Form 9.A) and the Project Summary (Form 9.B) be typed without using a mono-spaced typestyle such as Courier, Letter Gothic, Prestige, Pica, or Elite in 10 or 12 characters per inch (pitch) or 12 point.

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 and must describe the proposed innovation. (See Section 3.4.2.)

4. **Potential Commercial Applications:** Summarize the commercial potential of the project assuming the goals 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 area, or application of the proposed effort.

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

7. **Principal Investigator:** Enter name of Principal Investigator as shown on the Proposal Cover sheet.

NASA

SBIR 92-1 SOLICITATION

FORM 9.C - SBIR PROPOSAL SUMMARY BUDGET

(Instructions on Reverse Side)

PRINCIPAL INVESTIGATOR:

PROPOSAL NUMBER:

FIRM:

AMOUNT REQUESTED:

DIRECT LABOR:

Category	Hours	Rate	Cost
			$

TOTAL DIRECT LABOR: $ (1)

OVERHEAD RATE ______% of Total Direct Labor

OVERHEAD COST: $ (2)

OTHER DIRECT COSTS:

Category	Cost
	$

TOTAL OTHER DIRECT COSTS: $ (3)

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

TOTAL DIRECT COSTS: $ (4)

G&A RATE ______% of Total Direct Costs

G&A COSTS: $ (5)

(4)+(5) = (6)

TOTAL COSTS: $ (6)

ADD PROFIT or SUBTRACT COST SHARING

PROFIT/COST SHARING: $ (7)

(6)+(7) = (8)

AMOUNT REQUESTED : $ (8)

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 92-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE:

TYPED NAME AND TITLE:

SIGNATURE:

DATE:

INSTRUCTIONS FOR SBIR PROPOSAL SUMMARY BUDGET

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. (See Section 3.6 for further information)

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, on a budget explanation page immediately following the budget in the proposal. (See below for discussion of various categories.)

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

2. **OVERHEAD**--Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant Federal negotiating agency, if available. If no rate(s) has(have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I 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. Multiply Direct Labor by the Overhead Rate to determine the Overhead Cost.

3. **OTHER DIRECT COSTS**

    a. *Materials and Supplies.* Indicate types required and estimate costs.
    b. *Publication Costs/Page Charges.* Estimate cost of preparing and publishing project results.
    c. *Subcontracts.* Include a completed budget and justify details. (See Sections 3.5, Part 9 and 5.12 for further information)
    d. *Consultant Services.* Indicate name, daily compensation, and estimated days of service. (See Section 3.5, Part 9 for further information)
    e. *Computer Services.* Computer equipment leasing is included here.
    f. *Equipment.* List each item of permanent equipment to be purchased, its price, and explain its relation to the project.

    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.

4. **TOTAL DIRECT COSTS**--Sum of (1) Total Direct Labor, (2) Overhead and (3) Other Direct Costs.

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. Multiply (4) Total Direct Cost by the G&A Rate to determine G&A Cost.

6. **PROFIT OR COST SHARING**--For information about Profit, see Sections 3.6.4 and 5.9. For information about Cost Sharing, see Section 5.8. In completing Form 9.C draw a line through the unneccessary word.

7. **AMOUNT REQUESTED**--This should exclude any cost-sharing and not exceed $50,000.

NASA

SBIR 92-1 SOLICITATION

FORM 9.D - PROPOSAL CHECK LIST

Company Name: ______________________________

Address: ______________________________

____

Proposal Number: ______________________________

Proposal Title: ______________________________

____

CHECK

1. The offeror has read all instructions in this Solicitation and understands that proposals not meeting all requirements may be nonresponsive and may not be evaluated.
2. This proposal and innovation is submitted in only one Subtopic. (See Section 1.6.2)
3. The proposed innovation is described in first paragraph of proposal. (See Section 3.5, Part 1)
4. All information required by Sections 3.4 through 3.7 is included in order.
5. Phase II objectives are discussed.
6. Phase III potential (NASA and Commercial Applications) and possible intentions are discussed.
7. Any pages containing proprietary information are labeled "Confidential Proprietary Material." (See Section 5.4.1)
8. The Certifications in Form 9.A are complete, and Forms 9.A and 9.C are signed.
9. The period of technical performance does not exceed 6 months and the funding request does not exceed $50,000.
10. The proposal (including any supplementary material) contains no more than twenty-five 8½ x 11 inch pages. Check list is not included in page count.
11. The proposal package includes:
    - A. Original Proposal Cover and Project Summary (red forms, Forms 9.A and 9.B) clipped (not stapled) to Check List.
    - B. Five (5) copies of complete Proposal with Proposal Cover and Project Summary.
12. The offeror understands that proposals must be received in NASA Headquarters by 4 p.m. EDT July 21, 1992.

Signature of person completing this Check List: ______________________________