SBIR 88-1

OMB Approval No. 2700-0042

Small Business Innovation Research

Program Solicitation

Closing Date: July 22, 1988

NASA

SBIR PROGRAM
WASHINGTON, D.C.
20546

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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

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

NOTICE

Recipients of the NASA SBIR 88-1 Program Solicitation are advised that several important changes and additions have been incorporated in the general information and proposal instructions and that failure to follow instructions may result in proposal disqualification.

CONTENTS

APPENDICES

PROGRAM SOLICITATION FOR SMALL BUSINESS INNOVATION RESEARCH

1.0 PROGRAM DESCRIPTION

1.1 Introduction and Summary

The National Aeronautics and Space Administration (NASA) invites small business firms to submit Phase I proposals under this Small Business Innovation Research (SBIR) program solicitation. This, the sixth annual SBIR solicitation by NASA, describes the program, identifies eligibility requirements, outlines proposal preparation and submission requirements, describes the proposal evaluation and award selection process, and provides other information to assist those interested in participating in NASA's SBIR program. It also identifies, in Section 8.0 and Appendix D, the specific Technical Topics and Subtopics in which SBIR Phase I proposals are solicited in 1988.

Firms with strong research capabilities in science or engineering in any of the areas listed are encouraged to participate. NASA expects to select approximately 200 high-quality research or research and development (R/R&D) proposals for Phase I contract awards based on this Solicitation. Phase I contracts are for six months duration and may be funded up to $50,000, including profit. Selections will be based on the merit of the offering and on NASA needs and priorities.

For planning purposes only, NASA anticipates that approximately 50 percent of the Phase I projects—those showing greatest promise at the conclusion of Phase I—will be selected competitively for further development in Phase II continuations. The Phase II period of performance and funding will depend on the project scope, but will normally not exceed 24 months and $500,000. Only those Phase I contractors selected from this Solicitation will be eligible to compete for Phase II continuations of their Phase I programs.

1.2 Three-Phase SBIR Program

The "Small Business Innovation Development Act of 1982," 15 U.S.C. 638, P.L. 97-219, was enacted July 22, 1982, and implemented by SBA Policy Directive No. 65 01.2 dated September 1984. NASA is one of the agencies conducting SBIR programs under the legislation. SBIR program objectives include stimulating technological innovation in the private sector, strengthening the role of small business in meeting Federal research and development needs, increasing the commercial application of Federally supported research results, and fostering and encouraging participation by minority and disadvantaged persons in technological innovation.

Participating agencies establish SBIR programs by reserving a statutory percentage of their extramural research and development budgets to be awarded to small business concerns for R/R&D during the first two phases of a uniform, three-phase process identified 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 at all under any subtopic.

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

Phase I. Project objectives are to establish the feasibility and merit of an innovative scientific or technical concept proposed in response to an agency need or opportunity stated in a subtopic of this Solicitation. Projects may be experimental or theoretical in nature.

In order to reduce the investment of time and cost to small firms in preparing a formal proposal under this Solicitation, the *entire Phase I proposal is limited to 25 pages, including all forms and any attachments or enclosures.* The proposal should concentrate on means to demonstrate or otherwise establish the scientific or technical feasibility of the proposed innovation. Such evidence is a prerequisite for further NASA support in Phase II.

Proposals are selected for awards competitively based on the evaluation criteria and selection steps described in Section 4.0.

Phase I funding agreements with NASA are fixed-price contract awards. Simplified contract documentation is employed. Since price competition is not a factor in Phase I, the basis of selection among the best proposals will be those offering the greatest value to the Government in terms of the stated evaluation criteria.

Successful offerors will usually have six months to carry out their proposed Phase I efforts in order to meet the Phase II proposal submission, evaluation and selection schedule. Phase I results must be submitted in a final report which will also support the Phase II proposal if one is submitted.

Phase II. This SBIR phase is the principal research effort. Only the Phase I contractors selected from the offerors responding to this Solicitation will be eligible to compete for and participate in Phase II continuations of their programs. It is anticipated that Phase II continuations of projects resulting from this Solicitation will be selected competitively during 1989 based on the evaluation criteria and selection steps described in Section 4.0. Phase II awards may be for as much as $500,000 and cover a period usually not exceeding 24 months.

Phase II proposals are more comprehensive than those required for Phase I, and they are prepared in accordance with instructions provided to all Phase I contractors by the contracting NASA Field Installations after the Phase I contracts are awarded.

Because encouraging commercial application of Federally-supported research is a SBIR program objective, NASA urges all its SBIR contractors to seek non-Federal Phase III funding commitments for commercial applications of their research, or of some outgrowth of it, and to do so before submitting their Phase II proposals. In the Phase II award selection process, when Phase II proposals are judged to have equal technical and scientific merit, NASA gives special consideration to those for which valid non-Federal funding commitments have been obtained for Phase III activities.

Phase III. This activity, where appropriate, is conducted by a small business using non-Federal funds to pursue commercial applications based on its Government-funded SBIR activities through Phase II. Phase III may also be follow-on R/R&D or production contracts with a Federal agency for potential products or processes intended for use by the Government; however, such Phase III activities *cannot* be funded by the SBIR program.

1.3 Eligibility and Limitations

The primary requirements for eligibility to participate in the SBIR program, and certain limitations on proposal acceptability, include the following:

a. **Small Business:** Each offeror must qualify as a Small Business for R/R&D purposes as stated in Section 2.2. SBIR eligibility does not require that the offeror qualify as a Small Disadvantaged Business (Section 2.3) or as a Women-Owned Small Business (Section 2.6).

b. **Place of Performance:** For both Phase I and Phase II, the R/R&D must be performed in the United States (Section 2.5).

c. **Principal Investigator:** The Principal Investigator must have primary employment with the small business firm at the time of contract award and during the proposed research, and must make a substantial contribution to the project.

d. **Innovation:** Every proposal must be based on an innovation (Section 2.7) clearly and succinctly stated in the Project Summary and in the first paragraph of the Technical Content section (Section 3.3.c–1).

e. **Relevance:** A proposed research innovation must be relevant to NASA program needs or opportunities identified in a subtopic described in Appendix D of this solicitation and may be submitted under only one subtopic (Section 5.14–e).

f. **Format:** Proposals must be prepared within the general format and physical requirements described in Section 3.

1.4 General Information

a. *Proposals that do not meet all of the requirements in this Solicitation and proposals from ineligible offerors will be rejected without consideration.*

b. **Questions about this Solicitation:** Oral communications regarding this Solicitation during the Phase I proposal preparation period are restricted for reasons of competitive fairness, therefore no telephone inquiries will be accepted. Any and all questions pertaining to this Solicitation must be submitted in writing to the address below:

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

c. **Additional copies of this Solicitation** and additional copies of the Proposal Appendices can be ordered by writing the SBIR Program Manager at the address listed above. *No telephone requests will be accepted.*

d. **Questions regarding proposal status:** Evaluation of proposals and selection of proposals for contract award will require approximately four months, and no information on proposal status will be available until the final selection is made (except for confirmation of receipt of proposal as described and limited in Section 6.5).

e. **Questions about the SBIR Program:** General questions about the NASA SBIR Program, but not pertaining to this Solicitation or to requests for copies, may be submitted to either Harry W. Johnson, SBIR Director, or John A. Glaab, SBIR Program Manager, at the above address, telephone 202-453-8702. If telephoning, please do so between 01:00 p.m. and 4:00 p.m., EDT.

f. **Scientific and technical information:** Information sources include NASA Industrial Application Centers and the National Technical Information Service whose addresses are included in Section 7.0. Specific information on NASA R/R&D programs at any NASA Field Installation may be obtained by contacting the SBIR Program Manager at the Installation; however, *inquiries relating to specific subtopics and individual proposal matters cannot be accepted by NASA Field Installations during the Phase I solicitation period.*

2.0 DEFINITIONS

The following definitions apply for purposes of this Solicitation:

2.1 Research or Research and Development (R/R&D)—Any activity that is (1) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied, (2) a systematic study directed specifically toward applying new knowledge to meet a recognized need, or (3) a systematic application of knowledge toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

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

a. 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 in the United States;

b. Is at least 51 percent owned, or, in 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

c. 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, any individual, partnership, corporation, joint venture, association or cooperative.

2.3 Small Disadvantaged 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: Black Americans; Hispanic Americans; Native Americans (American Indians, Eskimos, Aleuts, and native Hawaiians); Asian-Pacific Americans; or Asian-Indian Americans.

2.4 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.

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

2.7 Innovation—Innovation in the context of the NASA SBIR program includes, but is not limited to, invention. It encompasses new, original and imaginative approaches to the solution of new and old problems, evolutionary and revolutionary improvements to existing technology, exploitation of new technological opportunities, and some limited aspects of basic research.

Most proposals for surveys, studies, and applications of conventional and routine engineering design or developments do not meet these innovation criteria and will not be evaluated in the SBIR program.

3.0 PHASE I PROPOSAL PREPARATION INSTRUCTIONS AND REQUIREMENTS

3.1 Proposal Requirements

The purpose of a proposal under the SBIR Program is to provide sufficient information to persuade NASA that the proposed work represents a sound approach to the investigation of an important scientific or engineering innovation of interest to NASA and is worthy of support under the stated criteria.

A proposal should be self-contained and written with the care and thoroughness accorded papers for publication. Each proposal should be reviewed carefully by the offeror to ensure inclusion of data essential for evaluation, using the check list (Appendix E).

The scientific or technical merit of the proposed innovation is the primary concern for all research supported by SBIR. A proposal may respond to any one of the subtopics in Appendix D, but must be limited to only one subtopic (see Section 5.14–e). The proposed R/R&D must be responsive to NASA program objectives, and it can also serve as the basis for technological innovation leading to new commercial products, processes, or services which benefit the public.

Proposals must be confined to research requiring scientific or technical innovation R/R&D, and they may lead to construction and evaluation of a laboratory prototype where appropriate. Proposals concerned principally with market research or the development of new or proven concepts (proprietary or otherwise, including patents) for commercialization should not be submitted. Such activities are considered responsibilities of the private sector, and are included in Phase III objectives. Neither should proposals be submitted for the development of processes or hardware for NASA use that are not based on significant innovation: such proposals may be considered only outside the SBIR program, either as unsolicited proposals or in response to specific solicitations.

3.2 General Content

Those who wish to respond to this Solicitation should submit a research proposal as follows:

a. The proposal must be directed principally at R/R&D on a specific innovation which addresses a NASA need or opportunity chosen from one of the subtopics in Appendix D.
b. Phase I SBIR proposals shall not exceed a total of 25 standard 8½"x11" pages including, cover page, project summary, project elaboration and supporting material, budget, and all enclosures or attachments. Each page shall be numbered consecutively at the center, bottom. *Proposals exceeding the 25 page limitation will be rejected without consideration.* No type size is to be smaller than elite except as legends on reduced drawings, but not tables. Pages are to be printed on one side only, single or double spaced.
c. The proposal should be direct, concise, and informative. Promotional and non-project-related material should not be included. Offerors should use the entire 25 page allowance only if required; appropriate brevity facilitates proposal evaluations.
d. All required items of information are to be covered fully and in the order set forth in Section 3.3, but the space allocated to each will depend on the project chosen and the principal investigator's approach. In the interest of equity to all offerors, all information must be included in the 25 pages; no additional attachments are allowed.
e. To facilitate proposal processing, NASA intends to employ automated optical devices to record proposal cover sheet and project summary information wherever possible. Toward this end, it is desirable, *but not required,* that the proposal cover sheet (Appendix A) and the project summary (Appendix B) be typed very

carefully on the indicated lines, using one of the following type styles:

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

f. To assist both NASA and the offeror, a Checklist is included (Appendix E). *It is to be filled out and attached to the original cover and project summary pages required in Section 6.1.* The Checklist is not counted as a proposal page.

3.3 Phase I Proposal Format

a. **Cover Sheet.** The offeror shall complete Appendix A as page 1 of each copy of each proposal. No other cover is permitted.

b. **Project Summary.** The offeror shall complete Appendix B as page 2 of each proposal. The technical abstract should include a brief description of the problem or opportunity, the innovation, project objectives, and description of the effort. In summarizing anticipated results, the implications of the approach (for both Phases I and II) and the potential commercial applications of the research shall be stated. *The project summary of successful proposals will be published by NASA and, therefore, shall not contain proprietary information.*

c. **Technical Content.** Beginning on page 3 of the proposal, include the following:

1. **Identification and Significance of the Innovation.** *The first paragraph shall consist exclusively of a clear and succinct identification of the specific innovation proposed, why it is an innovation, and how it is relevant and important to meeting the need or opportunity described in the subtopic.* The paragraph should be limited to 150 words or less. *Offerors are hereby notified that NASA reserves the right to reject, without evaluation, proposals which lack this opening paragraph.* Following the initial paragraph, this section of the proposal should include appropriate background and any necessary elaboration of the proposed innovation.

2. **Phase I Technical Objectives.** The offeror shall state the specific objectives of the Phase I R/R&D effort, including the technical questions it will try to answer to determine the feasibility of the proposed approach. The expected relationship between Phase I and a Phase II continuation shall also be explained. *Offerors are hereby notified that the Technical Objectives and Work Plan will become public information when included in contracts let for successful Phase I proposals; therefore, proprietary information shall not be included in these sections.*

3. **Phase I Work Plan.** This section should be approximately one-third of the total proposal. The offeror shall include a detailed description of the Phase I R/R&D plan. The plan shall indicate not only what will be done, but how and where the research or R&D will be carried out. Phase I R/R&D shall address the stated objectives and the questions cited in (2) above. The methods planned to achieve each objective or task should be discussed in detail. Schedules, including Gantt Charts or other suitable scheduled task displays, task assignments, resource allocations and descriptions of how the work is to be done shall be included in this section. In every proposal, the Phase I Work Plan must be a complete, stand-alone document. *Proprietary data shall not be included in this section. If the offeror wishes to include proprietary information in the proposal, it shall be included in a separate section entitled "Proprietary Addendum to Phase I Work Plan," and the requirement of Section 5.4–a, Proprietary Information, must be met to insure protection.*

4. **Related Research or R&D.** The purpose of this section is to persuade reviewers of the offeror's awareness of key recent developments by others in the specific subject area. It should describe any significant R/R&D that is directly related to the proposal (noting any conducted by the principal investigator or by the offeror's firm) including how it relates to the proposed effort, and any planned coordination with outside sources.

5. **Key Personnel and Bibliography of Directly Related Work.** The offeror shall identify key personnel involved in Phase I, including their directly related education, experience, and bibliographic information. Offerors are requested to avoid extensive vitae and publication lists not pertinent to the proposal. Summaries that focus on the most relevant experience or publications are desired, but must be contained within the 25-page limit.

6. **Relationship with Future Research and R&D.** The offeror shall state the anticipated results of the proposed approach if the

project is successful (Phase I and Phase II), and discuss the significance of the Phase I effort in providing a foundation for Phase II. The expected scope of the Phase II activity should be outlined.

7. **Facilities.** The conduct of advanced research may require the use of sophisticated instrumentation or other equipment. Offerors should provide a detailed description, and discuss the availability and location, of instrumentation and physical facilities necessary to carry out Phase I.

8. **Consultants.** Involvement of expert consultants in the planning and research stages of the project is permitted and encouraged if this increases the probability of success of the proposed effort. If such involvement is intended, it should be described in detail.

9. **Potential Applications.** Offerors should describe briefly whether and how the proposed project appears to have either (or both) commercial application potential or use by the Federal Government. They also shall describe how they plan to seek Phase III funding support for either commercial applications or use by the Federal Government, if needed, to achieve those applications or uses.

10. **Related Proposals or Awards.** Whenever the offeror (a) has received Federal Government awards for related work, or (b) has submitted or intends to submit proposals in the near future for essentially equivalent or similar work under other Federal Government program solicitations, those awards, proposals and intentions shall be identified. In these cases, a statement must be included in each proposal indicating—

(1) The name and address of agencies to which proposals were submitted or from which awards were received.
(2) Date of proposal submission or date of award.
(3) Title, number, and date of solicitations under which proposals were submitted or awards received.
(4) The specific research topic for each proposal submitted or awards received.
(5) Titles of research projects.
(6) Name and title of principal investigator for each proposal submitted or award received.

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

d. **Proposed Budget.** Offerors shall complete Appendix C, then include it and any budget explanation sheets as the last page(s) of the proposal. Some items of this form may not apply to the proposed project and need not be filled out. What matters is that enough information be provided to allow NASA to understand how the offeror plans to use the requested funds if the contract is awarded.

- Equipment may be included in SBIR budgets. The inclusion of equipment will be carefully reviewed relative to need and appropriateness for the research proposed. Equipment is defined as an article of non-expendable, tangible, personal property having a useful life of more than one year and an acquisition cost of $1,000 or more per unit. Title to all property (including equipment) acquired under the contract will be vested with NASA unless it is determined that transfer of title to the contractor would be more cost effective than recovery of the property by NASA.
- Budgets for travel funds must be justified and related to the needs of the project.
- A profit or fee may be included in the proposed budget.

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

4.0 PROPOSAL EVALUATION AND SELECTION

4.1 Evaluation, Selection, and Debriefing.

Phase I proposal evaluations involve several steps, the first of which is screening for compliance with administrative requirements of the Solicitation. All those found acceptable are next reviewed to determine whether they respond to the subtopic chosen by the offeror. Those found to be responsive will be evaluated by scientists or engineers in the topic area, using the criteria listed in Section 4.2. Each proposal will be judged on its own merit, then ranked relative to all others evaluated under the same subtopic. Reviewers will base their conclusions only on information contained in the proposal. It cannot be assumed that reviewers are acquainted with the firm or key individuals or any experiments referred to but not described in referenced professional journals. Relevant journal articles should be identified in the proposal.

Proposals may be evaluated at more than one NASA installation. Proposals judged to have the highest merit and value to NASA will be selected for award. Selection considerations will also include program balance and possible relationship to other research. In the evaluation and handling of proposals, NASA will make every effort to protect the confidentiality of the proposals and their evaluations.

Phase II proposals will also undergo a technical review and competitive selection process using specified Phase II criteria, which include the results of the Phase I activities (see Section 4.3).

After the Phase I and Phase II award decisions have been announced and all offerors notified of the results of the competition, debriefings on unsuccessful proposals may be provided—to the offerors only—upon written request. Debriefings will identify strengths and weaknesses of the proposal, but will not disclose the identity of the proposal evaluators, their verbatim comments or the ranking of the proposal within the subtopic, nor will comparisons be made with other proposals with which it was in competition.

It is not always possible to provide debriefings for requests made after the next program cycle is under way. Those wishing debriefings should request them in writing within 45 days after being notified of the decision on their proposal.

4.2 Evaluation Criteria—Phase I

NASA plans to select proposals for award which offer the best value to the Government, giving approximately equal consideration to each of the following four criteria except for the first, which will receive twice the value of any other item:

a. **The scientific/technical merit of:** (1) the proposed innovation and its relevance to the needs stated in the selected subtopic, and (2) the proposal's statement of objectives and approach for addressing questions of feasibility. Special attention is given to innovativeness and originality.
b. **Qualifications** of the principal investigator, other key staff, and consultants, if any, and the adequacy of available or obtainable instrumentation and facilities.
c. **Anticipated benefits**, technical and/or economic, including the potential for commercial applications of the proposed Phase I and Phase II research if successful.
d. **Soundness and technical merit of the proposed work plan** and its incremental progress toward meeting the Phase I objectives.

4.3 Evaluation Criteria—Phase II

The NASA installations awarding the Phase I contracts will provide detailed instructions to all Phase I contractors regarding Phase II proposal submission, the relative importance of the evaluation factors listed below, and the date when Phase II proposals must be submitted (usually one month after the end of the Phase I performance period and coincident with the submission of the Phase I final report). Evaluation of proposals for Phase II will consider the technical and scientific merit and feasibility of the proposed R/R&D (with special emphasis on its innovation and originality); the results of the Phase I work; the eventual value of the product, process, or technology to the mission of NASA; the validity of the project plan for achieving stated goals; the ability of the project team; and the availability of required equipment and facilities.

For proposals of approximately equivalent merit judged according to the criteria listed above, NASA will give special consideration to Phase II proposals which cite valid non-Federal funding commitments for Phase III follow-on activities. Valid funding commitments may be contingent on the outcome of Phase II (and on other stated circumstances), but must provide that a specific substantial amount will be made available to the firm for Phase III and indicate the source and date or conditions under which the funds will be made available.

In addition, the selection of awards for Phase II will consider any special programmatic or schedule needs of NASA and, of course, the availability of funds. NASA has the right to initiate negotiations for a Phase II award at any time after the proposal has been received.

5.0 CONSIDERATIONS

5.1 Awards

During November 1988, NASA expects to announce the selection of approximately 200 proposals for negotiation of profit-bearing, fixed-price Phase I contracts with values ranging up to $50,000. Following contract negotiations and awards, Phase I contractors will usually have six months to carry out their proposed Phase I programs.

For planning purposes only, NASA anticipates that during 1989 approximately 50 percent of the Phase I projects may be selected for Phase II continuations, based on the results of Phase I activities and competitive evaluations of Phase II proposals.

Funding agreements may be either fixed-price or cost-plus-fixed fee contracts. Performance periods normally will not exceed 24 months with funding not exceeding $500,000.

Both Phase I and Phase II awards are subject to availability of funds.

5.2 Reports

Six (original plus five (5)) copies of a final report on the Phase I project must be submitted to NASA within 30 days after completion of the Phase I effort. The final report shall include a single-page project summary as the first page, identifying the purpose of the research, a brief description of the research carried out, the research findings or results, and potential applications of the research in a final paragraph. The project summary is to be submitted without restriction and may be published by NASA. The balance of the report should indicate in detail the project objectives, work carried out, results obtained, and estimates of technical feasibility. Rights to this data shall be in accordance with the policies set forth in Section 5.5.

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

5.3 Payment Schedule

Payments on Phase I contracts may be vouchered as follows: one-third at the time of award, one-third three months after award, and the remainder upon acceptance of the final report by NASA. Payments will be made 30 days after receipt of valid vouchers or invoices.

5.4 Treatment and Protection of Proposal Information

a. **Proprietary Information.** It is NASA policy to use information (data) included in proposals for evaluation purposes only and to protect such information from unauthorized use or disclosure. While this policy does not require that the proposal bear a notice, protection can be assured only to the extent that the appropriate "Notice" set forth in the clause of the NASA FAR Supplement at 18-52.215-72, Restriction on Use and Disclosure of Proposal and Quotation Information (Data) is applied to the data which constitute trade secrets or other information that is commercial or financial and confidential or privileged. Other information may be afforded protection to the extent permitted by law, but NASA assumes no liability for use and disclosure of information to which the "Notice" has not been appropriately applied. To assure such protection, the offeror is advised to complete the proprietary notice at the bottom of the cover page (proposal page 1) of the proposal. *Offerors are cautioned not to label their entire proposals proprietary. Any proprietary information is to be included in a separable addendum at the rear of the proposal.*

b. **Non-NASA Reviewers.** In addition to Government personnel, NASA, at its discretion and in accordance with 18-15.413-2 of the NASA FAR Supplement, may utilize scientists and engineers from outside the Government in the proposal review process. Any decision to obtain outside evaluation shall take into consideration requirements for the avoidance of organizational or personal conflicts of interest and the competitive relationship, if any, between the prospective contractor or subcontractor and the prospective outside evaluator. Any such evaluation will be under agreement with the evaluator that the information (data) contained in the proposal will be used only for evaluation purposes and will not be further disclosed.

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

d. **Nominal Disclosure.** By submission of a proposal, the offeror agrees to permit the Government to disclose only the title of its proposed project and the name, address and telephone number of the designated official of the proposing firm, to firms that may be interested in contacting the offeror for further information or possible investment.

5.5 Rights in Data Developed Under SBIR Contracts

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

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

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

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

5.6 Copyrights

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

5.7 Patents

The contractor will, as provided in the clause at FAR 52.227-11, Patent Rights—Retention by Contractor (Short Form), have first option to retain title to inventions made in the performance of any Phase I or Phase II contract in accordance with P.L. 96-517 (35 U.S.C. 200, et seq.). This option is subject to the reservations and limitations, including a 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.

5.9 Profit or Fee

Both Phase I and Phase II SBIR contracts may include a 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

If an offeror has submitted to another Government agency (or to NASA in a separate submission) a proposal which is substantially the same as, or similar in intent to one being submitted in response to this Solicitation, that fact must be indicated and the information provided as required in Section 3.3.c–10.

If an award is made pursuant to a proposal submitted under this Program Solicitation, the firm will be required to certify that it has not previously been, nor is currently being, paid for essentially equivalent work by any agency of the Government.

5.12 Subcontracting Limitation on Research and Analytical Work

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

For Phase II, a minimum of one-half of the research and/or analytical effort must be performed by the proposing firm.

5.13 Contractor Commitments

Upon award of a contract, the contractor will be required to make certain legal commitments through acceptance of numerous clauses in the Phase I contract. The outline that follows illustrates the types of clauses that will be included in the Phase I contract. This is not a complete list of clauses to be included in Phase I contracts, nor does it contain specific wording of these clauses. Copies of complete general provisions will be made available prior to award:

a. **Standards of Work.** Work performed under the contract must conform to high professional standards. Analyses, equipment, and components for use by NASA will require special consideration to satisfy the stringent safety and reliability requirements imposed in aerospace applications.
b. **Inspection.** Work performed under the contract is subject to government inspection and evaluation at all reasonable times.
c. **Examination of Records.** The Comptroller General (or a duly authorized representative) shall have the right to examine any directly pertinent records of the contractor involving transactions related to the contract.
d. **Default.** The Government may terminate the contract if the contractor fails to perform the contracted work.
e. **Termination for Convenience.** The contract may be terminated at any time by the Government if it deems termination to be in its best interest, in which case the contractor will be compensated for work performed and for reasonable termination costs.
f. **Disputes.** Any dispute concerning the contract that cannot be resolved by mutual agreement shall be decided by the contracting officer with right of appeal.
g. **Contract Work Hours.** The contractor may not require an employee to work more than 40 hours a week unless the employee is compensated accordingly (that is, receives overtime pay).
h. **Equal Opportunity.** The contractor will not discriminate against any employee or applicant for employment because of race, color, religion, sex or national origin.
i. **Affirmative Action for Veterans.** The contractor will not discriminate against any employee or applicant for employment because he or she is a disabled veteran or veteran of the Vietnam era.
j. **Affirmative Action for Handicapped.** The contractor will not discriminate against any employee or applicant for employment because he or she is physically or mentally handicapped.
k. **Officials Not to Benefit.** No member of or delegate to Congress shall benefit from the contract.
l. **Covenant Against Contingent Fees.** No person or agency has been employed to solicit or secure the contract upon an understanding for compensation except bona fide employees or commercial agencies maintained by the contractor for the purpose of securing business.
m. **Gratuities.** The contract may be terminated by the Government if any gratuities have been offered to any representative of the Government to secure the contract.
n. **Patent Infringement.** The contractor shall report to NASA each notice or claim of patent infringement based on the performance of the contract.

5.14 Additional Information

a. **Precedence of Contract over Solicitation.** This Program Solicitation is intended for informational purposes and reflects current planning. If there is any inconsistency between the information contained herein and the terms of any resulting SBIR contract, the terms of the contract are controlling.
b. **Evidence of Contractor Responsibility.** Before award of an SBIR contract, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to assure responsibility of the offeror.
c. **Limitations on Awards.** This Solicitation is not an offer by the Government to make any specific number of awards under either Phase I or Phase II. NASA is not responsible for any monies expended by the offeror before award of any contract resulting from this Solicitation. Also, awards under this Program Solicitation 88-1 are contingent upon the availability of funds.
d. **Consultants.** Consulting or other arrangements between an eligible small business and universities or other nonprofit organizations are permitted with the small business serving as the prime contractor.
e. **Multiple Proposal Submissions.** An offeror may submit any number of different proposals on different subtopics, or different proposals on the same subtopic. However, every proposal must be limited to one subtopic. Should the offeror consider a proposal to have relevance to more than one subtopic, the offeror must choose the one under which to submit the proposal. Within that proposal, the discussion of the innovation may identify other subtopics for which the concept is believed relevant; however, *such identification will not insure that the proposal will be evaluated within any subtopic other than the one to which the proposal is addressed.*

   Offerors should be aware that identical or substantially similar proposals submitted to *two or more subtopics will be rejected without consideration.*

f. **Classified Proposals.** NASA will not accept classified proposals.

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

6.0 SUBMISSION OF PROPOSALS

6.1 What to Send

For each proposal submitted, offerors must submit the following:

a. Five (5) copies of the proposal, complete with cover sheet, project summary and proposed budget.

b. One (1) original (red) cover sheet (Appendix A), bearing the original signatures of the principal investigator and an official empowered to commit the offeror. Copies attached to each of the proposal copies may be suitably reproduced.

c. One (1) original (red) Project Summary (Appendix B). Copies attached to each of the proposal copies may be suitably reproduced.

d. One (1) completed Checklist (Appendix E).

6.2 Physical Packaging Requirements

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

Packaging—All items (6.1 a through d) for each 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.

6.3 Where to Send Proposals

Proposals to be mailed shall be addressed as below:

SBIR Program Manager
Code CR
National Aeronautics and Space Administration
(Note: No street address is required)
Washington, DC 20546

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

6.4 Deadline for Proposal Receipt

Deadline for receipt of proposals at NASA is 4:00 p.m., EDT, July 22, 1988 NASA assumes no responsibility for evaluating proposals received after the stated deadline or that do not adhere to other requirements of this Solicitation. Offerors are cautioned to be careful of unforseen delays that can cause late arrival of proposals at NASA with the result that they may not be included in the evaluation process. Notwithstanding, NASA reserves the right to consider proposals or modifications thereof received after the date indicated for receipt of proposals, and also the right to consider a revision to an otherwise successful proposal received after the date indicated for receipt of proposals should such actions be in the best interests of the Government.

6.5 Acknowledgement of Proposal Receipt

NASA will acknowledge receipt of proposals by a special card mailed to the company official endorsing the proposal cover sheet. If a proposal acknowledgement card is not received from NASA within four weeks following the closing date of this Solicitation, the offeror should telephone 202-453-8702. *NASA will not accept telephone inquiries of acknowledgement of receipt of proposals prior to August 22, 1988.*

6.6 Withdrawal of Proposals

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

7.0 SCIENTIFIC AND TECHNICAL INFORMATION SOURCES

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

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

Central Industrial Applications Center
Southeastern Oklahoma State University
Durant, OK 74701
(405) 924-6822

NASA Industrial Applications Center
823 William Pitt Union
University of Pittsburgh
Pittsburgh, PA 15260
(412) 648-7000

NASA Industrial Application Center
University of Southern California
3716 S. Hope Street—Room 200
Los Angeles, CA 90007
(213) 743-6132
(800) 642-2872 California only
(800) 872-7477 Toll free U.S.

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

NASA/SU Industrial Applications Center
Southern University
P.O. Box 9221
Baton Rouge, LA 70813
(504) 771-2060

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

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

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

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

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

8.0 TECHNICAL TOPICS

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

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

APPENDIX A - PROPOSAL COVER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION PROPOSAL COVER
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
<T> 88-1 <*>	___ . ___	______	____

ENTER PROPOSAL NUMBER ON APPENDICES B & C

PROJECT TITLE <*> ______________________________

____

FIRM NAME <*> ______________________________

MAIL ADDRESS <*> ______________________________

CITY <*> __________ STATE <*> _____ ZIP CODE <*> __________

AMOUNT REQUESTED <*> $ ________ (PHASE I) DURATION <*> _____ MONTHS (PHASE I)

OFFEROR CERTIFIES THAT:	YES	NO
1. As defined in Section 2 of the Solicitation, this firm qualifies as a:		
1.1 Small business	☐	☐
1.2 Minority and disadvantaged small business	☐	☐
1.3 Women-owned small business	☐	☐
NOTE: 1.2 and 1.3 are not eligibility requirements for SBIR and the offeror may decline to indicate status by stating "Decline" across boxes.		
2. A minimum of two-thirds of the research and/or analytical effort for this project will be carried out within the firm if an award is made.	☐	☐
3. The primary employment of the principal investigator will be with this firm at the time of award and during the conduct of the research.	☐	☐
4 Proposals of similar content have (indicate Yes) or have not (indicate No) been submitted to another agency and the details required by Section 5.11 of the Solication are included in the proposal.	☐	☐

ENDORSEMENTS

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

Signature of Principal Investigator ______________ Date ________

Signature of Corporate/Business Official ______________ Date ________

PROPRIETARY NOTICE (IF APPLICABLE, SEE SECTION 3.3.c.3, 5.4a, 5.5)

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

PROPOSAL PAGE 1

ORIGINAL PAGE COLOR PHOTOGRAPH

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

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

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

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

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

Appendix A:

1. ***Proposal Number:*** Complete the proposal number as follows:
   a. Enter 4 digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

Example: 1. Firm, telephone 273-8126, submits one proposal to subtopic 06.03. Proposal number is: ***06.03 8126.***

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

11.03 4826
11.03 4826A
11.03 4826B

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

Appendix B:

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

APPENDIX B - PROJECT SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION
(Instructions on Reverse Side)

PROPOSAL NUMBER
(TO BE COMPLETED BY PROPOSER)

	4 DIGIT SUBTOPIC NUMBER	LAST 4 DIGITS OF FIRM PHONE NO.	CHANGE LETTER
88-1	___ . ___	______	____

AMOUNT REQUESTED: $

TITLE OF PROJECT

TECHNICAL ABSTRACT (LIMIT 200 WORDS)

ORIGINAL PAGE
COLOR PHOTOGRAPH

POTENTIAL COMMERCIAL APPLICATIONS OF THE RESEARCH

KEY WORDS
(LIMIT 8)

NAME AND ADDRESS OF OFFEROR

PRINCIPAL INVESTIGATOR

PROPOSAL
PAGE
2

INSTRUCTIONS FOR COMPLETING APPENDIX A AND APPENDIX B

General:

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

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

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

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

Appendix A:

1. ***Proposal Number:*** Complete the proposal number as follows:
   a. Enter 4 digit subtopic number.
   b. Enter the last four digits of your firm's telephone number.
   c. If you are submitting different proposals under the same subtopic, enter a change letter as appropriate to differentiate proposal numbers.

Example: 1. Firm, telephone 273-8126, submits one proposal to subtopic 06.03. Proposal number is: ***06.03 8126.***

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

11.03 4826
11.03 4826A
11.03 4826B

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

Appendix B:

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

APPENDIX C - SBIR PROPOSAL SUMMARY BUDGET
(INSTRUCTIONS ON REVERSE SIDE)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SBIR 88-1 SOLICITATION

FIRM: PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

(See Instructions on Back of Form)	TOTAL PRICE
MATERIAL:	$
PERSONNEL:	$
OTHER DIRECT COSTS:	$
OVERHEAD:	$
GENERAL AND ADMINISTRATIVE (G&A):	$
PROFIT:	$
TOTAL PRICE PROPOSED	$

TYPED NAME AND TITLE: SIGNATURE:

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 88-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE. DATE SUBMITTED

PROPOSAL PAGE NO.

INSTRUCTIONS

The purpose of this form is to provide a vehicle whereby the offeror submits to the Government a pricing proposal of estimated costs with detailed information for each cost element, consistent with the offeror's cost accounting system.

This summary does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, on a budget explanation page immediately following the budget in the proposal. (See below for discussion on various categories).

1. **MATERIALS —**
   a. *Materials and Supplies.* Indicate types required and estimate costs.
   b. *Publication Costs/Page Charges.* Estimate cost of preparing and publishing project results.
   c. *Consultant Services.* Indicate name, daily compensation, and estimated days of service.
   d. *Computer Services.* Include justification. Computer equipment leasing is included here. Purchase of equipment is included under OTHER DIRECT COSTS.
   e. *Subcontracts.* Include a completed budget and justify details.
   f. *Other.* Itemize and justify.
2. **PERSONNEL** — On the budget explanation page, list individually all personnel included, the requested person-months to be funded, and rates of pay (salary, wages, and fringe benefits).
3. **OTHER DIRECT COSTS** — List all other direct costs which are not otherwise included in the categories described above. For travel, address the type and extent of travel and its relation to the project. List each item of permanent equipment to be purchased, its price, and explain its relation to the project.
4. **OVERHEAD** — Specify current rate(s) and base(s). Use current rate(s) negotiated with the cognizant Federal negotiating agency, if available. If no rate(s) has (have) been negotiated, a reasonable indirect cost (overhead) rate(s) may be requested for Phase I which will be subject to approval by NASA. If a current negotiated rate(s) is (are) not available for Phase II, NASA will negotiate an approved rate(s) with the offeror. The offeror may use whatever number and types of overhead rates that are in accordance with the firm's accounting system and approved by the cognizant Federal negotiating agency, if available.
5. **GENERAL AND ADMINISTRATIVE (G&A)** — Specify current rate and base. Use current rate negotiated with the cognizant Federal negotiating agency, if available. If no rate has been negotiated, a reasonable indirect cost (overhead) rate may be requested for Phase I which will be subject to approval by NASA. If a current negotiated rate is not available for Phase II, NASA will negotiate an approved rate with the offeror.

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

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION

FIRM: PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

(See Instructions on Back of Form) TOTAL PRICE

MATERIAL: $

PERSONNEL: $

OTHER DIRECT COSTS: $

OVERHEAD: $

GENERAL AND ADMINISTRATIVE (G&A): $

PROFIT: $

TOTAL PRICE PROPOSED $

TYPED NAME AND TITLE: SIGNATURE:

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 88-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE. DATE SUBMITTED

PROPOSAL PAGE NO.

INSTRUCTIONS

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   f. *Other*. Itemize and justify.
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APPENDIX C - SBIR PROPOSAL SUMMARY BUDGET
(INSTRUCTIONS ON REVERSE SIDE)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION

FIRM: PROPOSAL NUMBER:

PRINCIPAL INVESTIGATOR:

(See Instructions on Back of Form)

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

TYPED NAME AND TITLE: SIGNATURE:

THIS PROPOSAL IS SUBMITTED IN RESPONSE TO NASA SBIR PROGRAM SOLICITATION 88-1 AND REFLECTS OUR BEST ESTIMATES AS OF THIS DATE. DATE SUBMITTED

PROPOSAL PAGE NO.

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APPENDIX D
SUBTOPICS

FIELD CENTERS

TOPIC 01.00 AERONAUTICAL PROPULSION AND POWER

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
01.01							*			INTERNAL FLUID MECHANICS FOR PROPULSION SYSTEMS
01.02							*			PROPULSION SYSTEM COMPONENTS
01.03							*			PROPULSION SYSTEM INSTRUMENTATION, SENSORS AND CONTROLS
01.04							*			HYPERSONIC PROPULSION TECHNOLOGY
01.05							*			NOVEL PROPULSION CONCEPTS
01.06							*			STRUCTURAL COMPUTATIONAL METHODS FOR PROPULSION SYSTEMS

TOPIC 02.00 AERODYNAMICS AND ACOUSTICS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
02.01	*							*		COMPUTATIONAL FLUID DYNAMICS
02.02						*				EXPERIMENTAL FLUID DYNAMICS
02.03						*				VISCOUS FLOW
02.04						*				THEORETICAL AERODYNAMICS
02.05	*			*		*				HYPERSONIC AEROTHERMODYNAMICS
02.06								*		PLUME EFFECTS
02.07								*		RAREFIED GAS DYNAMICS
02.08	*									CONFIGURATIONAL AERODYNAMICS INCLUDING VORTICES
02.09	*									ROTOR AERODYNAMICS AND DYNAMICS
02.10	*									PREDICTION METHODS AND CONCEPTS FOR POWERED-LIFT VEHICLE AERODYNAMICS
02.11	*					*				WIND TUNNEL INSTRUMENTATION
02.12						*				AIRCRAFT NOISE

TOPIC 03.00 AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
03.01							*			ICING AND ICE PROTECTION SYSTEMS
03.02						*				AIRCRAFT FLIGHT ENVIRONMENT
03.03						*				CONTROL CONCEPTS FOR FIXED WING AIRCRAFT
03.04	*									FULLY AUTOMATIC GUIDANCE FOR ROTORCRAFT
03.05	*									AIRCRAFT FLIGHT TESTING TECHNIQUES
03.06	*									FLIGHT RESEARCH SENSORS AND INSTRUMENTATION
03.07						*				HYPERSONIC FLIGHT SYSTEMS TECHNOLOGY
03.08	*									MULTI-DISCIPLINARY ANALYSIS TOOLS AND TECHNIQUES FOR HYPERSONIC VEHICLES
03.09	*									EXPERT SYSTEMS FOR AEROSPACE APPLICATIONS
03.10	*									COMPUTER-AIDED DEVELOPMENT, TESTING AND VERIFICATION OF FLIGHT CRITICAL SYSTEMS
03.11	*					*				AERONAUTICAL HUMAN FACTORS AND FLIGHT MANAGEMENT SYSTEMS

TOPIC 04.00 MATERIALS AND STRUCTURES

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
04.01							*			STRUCTURAL COMPOSITE MATERIALS FOR PROPULSION SYSTEMS
04.02							*			HIGH TEMPERATURE STRUCTURAL COMPOSITES METHODOLOGY
04.03						*				STRUCTURAL COMPOSITE MATERIALS FOR NON-PROPULSION APPLICATIONS
04.04						*				LIGHT ALLOY METALLICS FOR AIRFRAME STRUCTURES
04.05				*						SPACECRAFT STRUCTURAL CONCEPTS AND FABRICATION TECHNIQUES
04.06		*								SPECIAL-PURPOSE MATERIALS FOR SPACE FLIGHT APPLICATIONS
04.07				*						ENVIRONMENTAL COATINGS, LUBRICANTS AND PROTECTIVE SYSTEMS FOR SPACECRAFT
04.08			*							ORGANIC POLYMERIC MATERIALS FOR LARGE NONLINEAR OPTICAL SUSCEPTIBILITIES
04.09						*				NONDESTRUCTIVE EVALUATION FOR CHARACTERIZING MATERIAL PROPERTIES
04.10			*				*			SUPERCONDUCTING MATERIALS FABRICATION AND CHARACTERIZATION
04.11				*						LUNAR MATERIALS UTILIZATION
04.12							*			ADVANCED MATERIALS AND PROCESSING CONCEPTS

TOPIC 05.00 TELEOPERATORS AND ROBOTICS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
05.01			*			*		*		TELEROBOTIC SYSTEM PLANNING AND DESIGN
05.02			*					*		TELEROBOTIC SYSTEMS SOFTWARE DEVELOPMENT
05.03		*	*			*	*	*		TELEROBOTIC ELECTRO/MECHANICAL SYSTEMS
05.04				*						ROBOTIC ADAPTIVE GRASPING SYSTEMS
05.05				*				*		ARTIFICIAL INTELLIGENCE FOR SPACE STATION APPLICATIONS

TOPIC 06.00 COMPUTER SCIENCES AND APPLICATIONS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
06.01						*				ENGINEERING COMPUTER SCIENCE
06.02		*								AUTOMATED SOFTWARE DEVELOPMENT AND MAINTENANCE
06.03						*				RELIABLE SOFTWARE DEVELOPMENT
06.04	*									KNOWLEDGE BASED SYSTEMS TECHNOLOGIES FOR AEROSPACE APPLICATIONS
06.05								*		DESIGN KNOWLEDGE CAPTURE
06.06				*						SOFTWARE SYSTEMS FOR MISSION PLANNING AND FLIGHT CONTROL
06.07	*									COMPUTER SCIENCE ADVANCES IN SUPPORT OF COMPUTATIONAL PHYSICS
06.08			*							MULTIPROCESSOR SYSTEM TECHNOLOGY

TOPIC 07.00 INFORMATION SYSTEMS AND DATA HANDLING

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
07.01						*				FOCAL-PLANE IMAGE PROCESSING
07.02		*							*	IMAGE ANALYSIS TECHNIQUES
07.03									*	STATISTICS OF SPATIAL PATTERNS AND SPATIAL INTERACTION PROCESSES
07.04									*	SPATIAL DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEMS (GIS) TECHNOLOGY DEVELOPMENT
07.05		*								SIGNAL AND INFORMATION PROCESSING
07.06						*				INFORMATION PROCESSING TECHNOLOGY AND INTEGRATED DATA SYSTEMS
07.07		*								SPACECRAFT OPERATIONS AND DATA MANAGEMENT
07.08		*								GROUND-BASED DATA MANAGEMENT SYSTEMS
07.09			*							SPACECRAFT GROUND SYSTEM DATA DESIGN AND EXTRACTION
07.10		*								HETEROGENEOUS DISTRIBUTED DATABASE MANAGEMENT
07.11		*								MANAGEMENT INFORMATION COMMUNICATIONS
07.12	*									SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI)

TOPIC 08.00 INSTRUMENTATION AND SENSORS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
08.01			*							INSTRUMENTS FOR SENSING ELECTROMAGNETIC RADIATION
08.02		*								EARTH ATMOSPHERE SENSING FROM SPACE
08.03									*	LOW-COST HIGH RESOLUTION REMOTE SENSING INSTRUMENTATION FOR EARTH SCIENCES
08.04						*				SENSORS FOR ATMOSPHERIC SCIENCE
08.05			*							INSTRUMENTS AND SYSTEMS FOR ATMOSPHERIC OBSERVATIONS
08.06		*								ATMOSPHERIC LIDAR REMOTE SENSING
08.07						*				TUNABLE SOLID STATE LASERS, DETECTORS AND LIDAR SUBSYSTEMS
08.08			*							INSTRUMENTATION FOR GEOLOGICAL RESEARCH
08.09			*							OCEANOGRAPHIC INSTRUMENTS AND SOFTWARE
08.10	*									FLIGHT INSTRUMENT TECHNOLOGY FOR EXOBIOLOGY
08.11			*							INSTRUMENTATION FOR THE STUDY OF PLANETARY ATMOSPHERES
08.12	*		*							INFRARED TECHNOLOGY FOR ASTRONOMICAL APPLICATIONS
08.13		*								DETECTORS AND DETECTOR ARRAYS
08.14			*							SENSOR COOLING FOR 65-80 KELVIN
08.15							*			CRYOGENIC FLUID INSTRUMENTATION FOR ORBITING SPACECRAFT
08.16			*							SUBMILLIMETER ANTENNAS, RADIOMETERS AND SPECTROMETERS
08.17		*								OPTICAL COMPONENTS
08.18			*							OPTICAL SYSTEMS
08.19	*									OPTICAL PROPERTIES OF BOUNDARY LAYER FLOW ACROSS A CAVITY
08.20			*							FOCAL PLANE ARRAY PROCESSING FOR POSITION DETERMINATIONS
08.21			*							INSTRUMENTS FOR PARTICLE COLLECTION AND PROCESSING
08.22								*		ENVIRONMENTAL MEASUREMENTS AND ANALYSES IN MANNED SPACE MISSIONS
08.23		*								BEHAVIOR AND EFFECTS OF CONTAMINATION IN SPACE
08.24							*			LEAK DETECTION FOR SPACECRAFT FUNCTIONAL SYSTEMS
08.25								*		NON-INVASIVE MONITORING OF GROWTH PARAMETERS ON A HANGING PROTEIN DROP

TOPIC 09.00 SPACECRAFT SYSTEMS AND SUBSYSTEMS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
09.01						*				CONTROL OF LARGE SPACE STRUCTURES
09.02				*						SPACE CONSTRUCTION AND MAINTENANCE TOOLS AND TECHNIQUES
09.03				*						SPACE STATION CREW WORKSTATION DISPLAYS AND CONTROLS
09.04								*		SPACE STATION SHELL LEAK DETECTION AND ASSESSMENT SYSTEM
09.05				*						MANNED SPACECRAFT AND PLANETARY BASED THERMAL MANAGEMENT SYSTEMS
09.06								*		SPACECRAFT AND PROPULSION SYSTEM THERMAL DESIGN AND ANALYSIS
09.07		*								THERMAL CONTROL FOR UNMANNED SPACE APPLICATIONS
09.08				*						STS POWER CONTROL AND DISTRIBUTION SUBSYSTEMS
09.09				*						SPACE TRANSPORTATION SYSTEM AND SPACE STATION ROBOTIC TRACKING SYSTEMS
09.10						*				GUIDANCE, NAVIGATION AND CONTROL OF ADVANCED SPACE TRANSPORTATION SYSTEMS
09.11								*		TETHER APPLICATIONS IN SPACE
09.12		*								A LOW COST, CCD SOLID STATE STAR TRACKER
09.13		*								TECHNOLOGIES FOR SCIENTIFIC BALLOONS
09.14		*								HIGH TEMPERATURE SUPERCONDUCTOR APPLICATIONS FOR SPACE

TOPIC 10.00 SPACE POWER

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
10.01							*			SPACECRAFT ELECTRICAL POWER AND ENERGY SYSTEMS
10.02			*							HIGH ENERGY DENSITY AND LONG LIFE BATTERIES
10.03		*								CORONA DETECTION AT 20 KHz APPLIED VOLTAGE
10.04						*				PHOTOVOLTAIC LASER ENERGY CONVERTERS
10.05								*		SPACE POWER SYSTEMS AUTOMATION
10.06		*	*				*	*		POWER TRANSMISSION AND PROPULSION APPLICATIONS OF HIGH TEMPERATURE SUPERCONDUCTIVITY

TOPIC 11.00 SPACE PROPULSION

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
11.01								*		SOLID ROCKET MOTOR TECHNOLOGY
11.02								*		SOLID ROCKET PERFORMANCE AND INTERNAL BALLISTICS
11.03								*		LIQUID ROCKET ENGINE COMBUSTION PROCESSES
11.04								*		LIQUID ENGINE INTERNAL FLOW DYNAMICS
11.05							*			LONG-LIFE, HIGH-PERFORMANCE, SMALL CHEMICAL ROCKETS
11.06							*			SPACE BASING OF ROCKET ENGINES

TOPIC 12.00 HUMAN HABITABILITY AND BIOLOGY IN SPACE

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
12.01				*						MEDICAL SCIENCES FOR MANNED SPACE PROGRAMS
12.02								*		WASTE STABILIZATION, RECLAMATION, AND MONITORING FOR SPACE STATION
12.03				*						ADVANCED MISSION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS
12.04	*									BIOREGENERATIVE LIFE SUPPORT SYSTEMS
12.05				*						HUMAN FACTORS FOR SPACE CREWS
12.06				*						INTRAVEHICULAR SYSTEMS FOR SPACE CREWS
12.07				*						EXTRAVEHICULAR ACTIVITY (EVA)
12.08	*									LIFE SCIENCES SPACEFLIGHT HARDWARE DEVELOPMENT
12.09	*									PHYSICO-CHEMICAL LIFE SUPPORT SYSTEMS
12.10					*					BIOLOGICAL SCIENCES OPERATIONS

TOPIC 13.00 QUALITY ASSURANCE, SAFETY AND CHECK-OUT FOR GROUND AND SPACE OPERATIONS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
13.01					*					GROUND OPERATIONS INSTRUMENTATION
13.02					*					PROPELLANT HANDLING
13.03					*					LAUNCH AND GROUND PROCESSING WEATHER
13.04					*					NONDESTRUCTIVE EVALUATION OF THERMAL PROTECTIVE TILE BONDING
13.05					*					THE USE OF HEAT PIPES FOR REHEATING OF CONDITIONED AIR
13.06					*					MULTI-POSITION PORTABLE LIQUID AIR DEWAR
13.07					*					LARGE MAGNITUDE FORCE TORQUE SENSING
13.08				*						SPACE COMPONENT TEST FACILITY DEVICES

TOPIC 14.00 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
14.01				*						COMMUNICATIONS FOR MANNED SPACE SYSTEMS
14.02		*								FREE-SPACE LASER COMMUNICATIONS
14.03			*							MILLIMETER WAVE DEEP SPACE COMMUNICATIONS SYSTEMS
14.04			*							SPACECRAFT TELECOMMUNICATION SUBSYSTEMS
14.05							*			ADVANCED COMMUNICATIONS SATELLITE SYSTEMS
14.06							*			MONOLITHIC DISTRESS BEACON TECHNOLOGY
14.07		*								EMERGENCY LOCATOR TRANSMITTER BATTERIES AND CRASH-SENSORS
14.08							*			LOW COST Ka-BAND GROUND TERMINALS
14.09			*							COMMUNICATIONS APPLICATIONS FOR SUPERCONDUCTING MATERIALS

TOPIC 15.00 MATERIALS PROCESSING, MICRO-GRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE

	ARC	GSFC	JPL	JSC	KSC	LaRC	LeRC	MSFC	NSTL	
15.01							*	*		MATERIALS PROCESSING IN SPACE
15.02							*			MICROGRAVITY SCIENCE, TECHNOLOGY AND ENGINEERING EXPERIMENTS
15.03						*				CHEMICAL VAPOR DEPOSITION ANALYSIS AND MODELING TOOLS
15.04							*			SPACE POWER GENERATION, PROPULSION AMD RELATED TECHNOLOGIES
15.05		*								OPTICAL MATERIALS AND COMPONENTS
15.06	*									LIFE SCIENCES COMMERCIAL RESEARCH AND APPLICATIONS IN SPACE

LEGEND:

ARC - Ames Research Center
Moffett Field, CA

GSFC - Goddard Space Flight Center
Greenbelt, MD

JPL - Jet Propulsion Laboratory
Pasadena, CA

JSC - Johnson Space Center
Houston, TX

KSC - Kennedy Space Center
Kennedy Space Center, FL

LaRC - Langley Research Center
Hampton, VA

LeRC - Lewis Research Center
Cleveland, OH

MSFC - Marshall Space Flight Center
Huntsville, AL

NSTL - National Space Technology Laboratories
NSTL, MS

TOPIC 01.00 AERONAUTICAL PROPULSION AND POWER

01.01 Subtopic: Internal Fluid Mechanics for Propulsion Systems

Center: LeRC

Innovative techniques are sought for analyzing flows in aerospace propulsion systems:

- Internal computational mechanics: Application of parallel processors, expert systems, innovative graphics, and scientific database structures, etc. Accurate numerical methods for fixed grid density and increased convergence rates. Strategies for multi-block grids and zonal approaches combining two or more numerical methods. Geometry (3-D) and mesh generation techniques for complex surface description, grid-lattice construction, and solution adaptive mesh clustering. Turbulent 3-D flow codes with new turbulence models.
- Inlets and nozzles: Advanced steady-state and time-dependent flow analyses and benchmark data for low subsonic through hypersonic speeds, for component and systems performance, boundary layers, bleed flows, diffusion, jet mixing, separated flow, heat transfer, surface cooling, and external spillage.
- Fans and compressors: Advanced numerical flow field codes, physical models, and supporting validation data for unsteady flows, blade-row interactions, rotor shocks, viscous flows on blades and endwalls and secondary flows for advanced compression systems, including single and multistage axial, centrifugal, and mixed flow fans and compressors. Novel concepts for instrumentation and flow visualization.
- Combustors and augmentors: Efficient computer models, and innovative means to supply validation data for the flows, physical processes, and reaction mechanisms in a combustor including fuel injection, spray evaporation and mixing, and basic reaction mechanisms and kinetic rates for hydrocarbon oxidation and soot formation.
- Turbines: Innovations to improve life, performance and reliability of large and small turbines for aircraft and aerospace application. Rigorous three-dimensional viscous flow models and subroutines for full passage codes that include heat transfer, unsteady flow, rotation, accurate treatment of boundary layer phenomena, and rotor blade tip clearance flows.
- Space fluid mechanisms: To make modern internal computational fluid mechanics a working computational tool which can accelerate fundamental understanding of space-based processes, new capability needs to be demonstrated. Opportunities include fluid behavior, thermal and combustion processes in low earth orbit; advanced thermal control and cryogenic fluid management for Space Station; and parallel processing and knowledge based systems technologies applicable to space-based power and propulsion.

01.02 Subtopic: Propulsion System Components

Center: LeRC

Innovations are sought in four areas: turbine engines, rotary combustion engines, drive train technology, and advanced propellers.

- Turbine engines: Innovative design concepts are needed for more efficient fans, compressors, turbines and combustors applicable to "small" sizes including:
  - —Innovative concepts to improve cycle efficiency;
  - —Advanced materials to minimize or eliminate coolant penalties;
  - —Concepts for recuperators/regenerators which minimize weight, volume, and aerodynamic drag through innovative design and/or use of advanced materials.
- Rotary combustion engines: Advanced, innovative components, material and subsystems are sought for rotary combustion engines (RCEs) capable of burning jet fuel with high efficiency and specific power, light weight and low vibration, including:
  - —High-speed, high brake mean effective pressure (BMEP) multi-fuel combustion system elements, including advanced fuel injection/ignition methods;
  - —Advanced seals, bearings and lubricants for high output RCEs;
  - —Advanced materials and fabrication technology for lightweight and/or heat-resistant (insulative) structural components, such as rotors and trochoid and end housings;
  - —Advanced turbocharger/turbocompounding in the 0.5 to 5 lb/sec flow range having single stage pressure ratios of 5 to 8:1.
- Drive train technology: New concepts are needed to decrease drive system weight and noise and to increase reliability and strength such as:
  - —Lubricants to extend operation temperatures of gear boxes to beyond 200C;
  - —Gear and bearing materials to extend operating temperatures beyond 200C;
  - —Transmission health monitoring systems;
  - —New tooth forms for lower noise and better lubricant action;
  - —New transmission concepts for large transmissions;
  - —Transmission noise prediction methods;

—Elastohydrodynamic film thickness predictive methods for bevel gear sets;
—Expert systems and optimization methods for gear and transmission design.

- Advanced propellers: Propellers designed for flight speeds up to Mach 0.8 require innovative design approaches to maintain high efficiency, low noise and structural integrity. New or improved concepts and analytical and experimental verification methods are needed. Specific needs include:
  —Aerodynamic analysis and design methods and diagnostic or flow visualization methods;
  —Methods for calculating and diagnosing mechanisms of noise generation and propagation;
  —Unsteady flow analysis methods to predict aerodynamic forces, fluctuating pressures on installed blades as input to acoustic calculations and the occurrence of flutter;
  —Approaches to achieve goals of increased efficiency, reduced noise, improved flutter margin, and lower weight;
  —Fabrication techniques for improved strength and weight.

01.03 Subtopic: Propulsion System Instrumentation, Sensors and Controls
Center: LeRC

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

- Strain and temperature on both metal and ceramic surfaces (for up to 1900C operation).
- Gas temperatures and pressures, both static and dynamic (for up to 1900C operation).
- High-temperature electronics and integrated sensors.
- Fiber-optic-based sensors and control systems.
- Aerodynamic flow and turbulence measurements.
- Non-intrusive combustion and rocket plume diagnostics.

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

- Real-time identification.
- Nonlinear or adaptive real-time control design for propulsion systems.
- Reliability enhancement through redundancy management or fault detection for propulsion systems.
- Improved component performance via compressor stall alleviation or combustor pattern factor control.
- Integrated system intelligence.
- High speed Artificial Intelligence (AI) computation.

01.04 Subtopic: Hypersonic Propulsion Technology
Center: LeRC

New concepts are needed for advancing the state of the art for hypersonic (Mach 5 and higher) airbreathing propulsion systems. Examples of innovations sought include:

- Advanced materials concepts to provide the low density (below 0.2 lb/cu. in.) with high temperature (above 2200F) retention of properties. The materials should provide high modulus, low thermal expansion, high thermal conductivity, and must be amenable to fabrication into complex structures for hypersonic application.
- Innovative computational methods to improve understanding of flow phenomena associated with hypersonic propulsion devices, including inlets, ejectors, combustors, and nozzles.
- Fundamental analytical studies leading to an understanding of ignition, flame holding, and flame stability for supersonic/hypersonic combustion.
- Advanced high-temperature structural sealing concepts for:
  —Articulating engine panel-sidewall seals (sliding seals between moving and stationary engine panels) and panel-hinge seals (sealing the hinge line between two neighboring engine panels);
  —Computational methods to assess performance (e.g., determine seal temperatures and leakage rates, etc.) and optimize structural seal concepts based on seal geometry and materials, seal operating environment, seal coolant techniques (e.g., regenerative, film, transpiration), coolant fluid and flow rates.

01.05 Subtopic: Novel Propulsion Concepts
Center: LeRC

Major improvements in propulsion system performance weight, bulk, and cost are cornerstones of many important future aeronautical vehicles, especially viable high-speed accelerators for transatmospheric vehicles and efficient cruise powerplants for super/hypersonic airplanes. Identification and analyses of innovative propulsion system concepts are sought that promise revolutionary advances in vehicle capabilities. Examples of existing concepts include: supersonic through-flow fans, supersonic combustion ramjets, and beamed energy. Potential aero applications and benefits of newly discovered high-temperature superconductors are also of interest. The analyses sought include first-order system concept modeling and/or comparative evaluations against conventional powerplant baselines or other advanced alternatives, but not specific detailed component characterizations.

01.06 Subtopic: Structural Computational Methods for Propulsion Systems
Center: LeRC

Advances in computer technology are rapidly allowing the replacement of costly experimental methods with purely computational approaches. Multiple processor computers will enable faster and more rigorous structural analyses. There are many emerging hardware and software methods to exploit for bringing the anticipated benefits of these new technologies to structural analysis. Novel analysis methods are needed to explore emerging computing hardware architectural concepts to adapt or convert existing structural analyses to effectively utilize these new computer systems.

Innovative methods to exploit modern computer science and emerging computer technologies in order to improve the usage of computers for solving aeropropulsion structural problems include:

- Advanced analytical methods utilizing emerging computer hardware and software technology.
- Methods for adapting and converting existing structural analysis methods to take full advantage of emerging computing technologies.
- Evaluations of how applicable and adaptable a particular computer architecture is for solving aeropropulsion structural analysis problems.

TOPIC 02.00 AERODYNAMICS AND ACOUSTICS

02.01 Subtopic: Computational Fluid Dynamics
Center: ARC
MSFC

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

- Numerical method innovations for solving the fluid flow equations which increase computational efficiency, accuracy, speed and utility. These include construction of new algorithms, improved computer languages, improved geometric modeling, advanced component-adaptive grid operation methods and other innovative techniques.
- Correlation of ground facility and flight data for fundamental aerothermodynamic performance characteristics of advanced aerospace vehicles.
- Innovative analytical, numerical, and experimental techniques that enhance the understanding of turbulence and provide improved models for solving the Navier-Stokes equations. These include improved turbulence models, large-eddy simulation for high Reynolds' Number flows, numerical methods for full and large-eddy simulation, improved subgrid-scale models for large-eddy simulations, turbulence models applicable to aerodynamic flows with massive separation and wakes.
- Innovative methods for efficiently interfacing numerical grid generation and Navier-Stokes solutions to mechanical design in an applications-oriented environment.
- Innovative methods for evaluating the "goodness" of a computational mesh before Navier-Stokes or Euler analyses.

- Correlation of ground facility and flight data for fundamental aerothermodynamic performance characteristics of advanced aerospace vehicles.

02.02 Subtopic: Experimental Fluid Dynamics
Center: LaRC

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

- Test section designs for transonic wind tunnels to reduce wall interference, reduce power requirements, and improve flow quality.
- Methods to study ground effect and transition aerodynamics of models of V/STOL aircraft in wind tunnels.
- Methods to extract dynamic-stability data from wind tunnel models suspended magnetically.
- Methods to simulate propulsion effects for wind tunnel models suspended magnetically.
- Cost-effective ways to recover liquid nitrogen from the exhaust of cryogenic wind tunnels. (Exhaust gas is nitrogen at temperatures from 80K to 300K and pressures from 1.2 to 9 atmospheres).
- Methods to suppress noise and turbulence caused by flow disturbances in wind tunnels.
- Statistical methods to detect anomalies in wind tunnel data either during or after the test. The method should allow user definition of the list of anomalies.
- Automated on-line analyses of unsteady pressure data to provide boundary layer transition location.

02.03 Subtopic: Viscous Flow
Center: LaRC

Innovative methods for predicting and controlling laminar and turbulent viscous flows are desired. Primary emphasis for turbulent flow is on controlling the behavior of turbulent shear flows including boundary layers, free-shear layers, and recirculating vortex flows. The specific needs are:

- Innovative methods and devices for control of turbulence.
- Techniques for turbulent skin-friction reduction.
- Improved understanding through theory and/or new measurement techniques of the physics and structure of turbulent shear flows.

02.04 Subtopic: Theoretical Aerodynamics
Center: LaRC

Innovative theoretical approaches are required to gain an understanding of a broad spectrum of problems associated with the design and analysis of advanced aircraft configurations. New or improved analysis techniques, theoretical studies, and conceptual models are sought to increase our knowledge of underlying physics. Specific needs include, but are not limited to, the following:

- Accurate prediction of compressible 3-D boundary layer stability.
- Numerical and analytical studies of laminar to turbulence transition.
- Theoretical studies of chaos leading to a better understanding of its relation to fluid dynamic turbulence.
- Conceptual and numerical studies of turbulence management and control.
- Analytical studies leading to a better understanding of the physics of high-speed shear layers.

02.05 Subtopic: Hypersonic Aerothermodynamics
Center: ARC
JSC
LaRC

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

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

02.06 Subtopic: Plume Effects
Center: MSFC

In order to analyze, design and optimize the structure and thermal protection system of launch and orbital vehicles, accurate prediction techniques and measurement methods for base heating, plume impingement heating and plume induced aerodynamic effects are required. The objective is to improve the piecemeal solution techniques currently used in generating induced environments and plume definitions for advanced launch vehicles. These improved models must represent subsonic through supersonic flow regimes, turbulence, finite-rate chemistry, and all aspects of plume flowfield modeling. Three-dimensional plume interactions with other plumes, with the freestream and with structures must also be treated. Current state-of-the-art prediction and measurement techniques are deficient because they are hardware and vehicle specific. Areas of interest for analytical and experimental innovation include, but are not limited to, the following:

- Infrared radiation code for solid rocket motor plumes.
- Recirculation plume gas modeling for defining the base gas temperature, surface pressures, and heating rates.
- Vent area/nozzle spacing mass balance analysis.
- Multi-engine prediction methodology for plume induced environments.
- Plume impingement during launch and staging.
- Improved short-duration hot-flow testing techniques for aerodynamics and heat transfer.
- Fully viscous nozzle/plume flow characteristics prediction methods including nonequilibrium processes in the transitional regime of the vacuum plume.
- Accurate and computationally efficient procedures to predict the transport of vacuum plume contamination to spacecraft surfaces.
- Improved short-duration hot-flow testing techniques for aerodynamics and heat transfers.

Large Government test facilities (and computational capabilities) can be made available, if appropriate, for experimental measurements for validating analytical models.

02.07 Subtopic: Rarefied Gas Dynamics
Center: MSFC

Innovative improvements are sought in methods for predicting rarefied gas dynamic phenomena. Of particular importance are aerodynamic and aerothermal load prediction techniques for aeromaneuvering and aerobraking vehicles during high altitude (rarefied) operations including:

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

02.08 Subtopic: Configurational Aerodynamics Including Vortices
Center: ARC

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

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

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

02.09 Subtopic: Rotor Aerodynamics and Dynamics
Center: ARC

Many aspects of rotorcraft aerodynamics and dynamics are not thoroughly understood or adequately modeled, and much remains to be done. Required are innovative methods which describe the basic phenomena involved in rotorcraft aerodynamics and dynamics, provide greater knowledge of the detailed characteristics of these phenomena, and permit well-verified accurate predictions to be made. Innovative developments with application to tilt rotors, single main rotor and tandem helicopters, co-axial helicopters, and rotors with circulation control (i.e., X-Wing type aircraft) are needed to define the next-generation rotorcraft. Examples of problems currently of importance include: aerodynamics of rotor-airframe-tail interactions; rotor blade air flow loading analyses; improved rotor system performance;

analysis of advanced hub designs and their influence on rotor dynamics; rotorcraft vibration and vibration alleviation; aeroelastic stability; and rotor noise. Innovations in new rotor concepts would also be appropriate.

02.10 Subtopic: Prediction Methods and Concepts for Powered-Lift Vehicle Aerodynamics

Center: ARC

Innovative methods for accurate prediction of the flow about powered-lift vehicles are desired. Problems to be addressed include:

- Flow separation effects due both to high angle-of-attack flight and lifting jets.
- Modeling of propulsion-airframe interaction concepts producing either direct or indirect thrust; i.e., thrust deflectors and ejectors.

Considerable ingenuity will be required to include viscous jets in the models and to define and conduct verification experiments.

Innovative concepts for powered-lift configurations and components are desired. Special interest is in concepts that utilize ejectors and provide favorable interactions with the lifting surfaces.

Research may be either theoretical, computational, experimental or a combination.

02.11 Subtopic: Wind Tunnel Instrumentation

Center: ARC
LaRC

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

- Advanced sensor concepts for the nonintrusive detection of boundary layer transition on models tested in cryogenic and other tunnels.
- Advanced smart sensors and miniaturized sensors for pressure measurements in the range 0.0001–50.000 psi in the thermal environments from 100–600K.
- Smart sensors for temperature and heat flux measurements in the range 1800C to 3000C.
- Miniature sensor concepts including pressure, temperature, flow, and shear measurements for both flight and ground test applications.
- Nonintrusive measurement of model angle of attack and deformations.
- Miniature, temperature-insensitive null position sensor.
- Measurement of high level strains at temperatures above 1100C.
- Computer-controlled traveling and survey probes.
- Nonintrusive measurement of mean and turbulent flow properties and gas composition in the test sections of wind tunnels over a wide range of flow conditions.
- Remote measurement of flow properties in the vicinity of models, including innovative holographic techniques.
- Multiprobe concepts for pattern recognition and image enhancement.
- Spectroscopic flow-field visualization schemes.
- Nonintrusive global techniques for measuring fundamental flow field parameters.
- Direct measurement of skin friction in high temperature environment.
- Advanced specific chemical sensors for measuring gaseous constituents in high velocity, high temperature flows.

02.12 Subtopic: Aircraft Noise

Center: LaRC

The control of aircraft and helicopter noise involves sources such as jet exhausts, propellers, and rotors. For each significant noise source on a particular vehicle class, the noise generation mechanism must be understood, prediction methods must be available, and concepts for noise control must be in hand. Innovations are needed to:

- Establish fundamental and applied CFD techniques for aeroacoustic analysis.
- Develop prediction and reduction methods for the noise, acoustic loads, and radiation characteristics of supersonic jets.
- Define the high-frequency fluctuating pressure loads on airframes and engine structures of high speed aircraft.
- Determine the high frequency dynamic response and sonic fatigue characteristics of advanced structures and materials at elevated temperatures.
- Develop active interior noise control technology for aerospace vehicles.
- Develop helicopter noise reduction capability.
- Develop prediction and reduction of near- and far-field noise of aeropulsion systems.
- Develop methods for predicting and assessing the noise and sonic boom impact of supersonic transports.

TOPIC 03.00 AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS

03.01 Subtopic: Icing and Ice Protection Systems
Center: LeRC

Helicopters and general aviation aircraft need an all-weather capability. Advanced commercial transports need ice protection systems compatible with high-bypass and turboprop engines (limited supplies of hot bleed air), modern airfoils, and composite materials. Innovative solutions for aircraft icing problems are needed in the following areas:

- Ice protection systems that minimize weight and power consumption, and design databases for these systems.
- Methods for predicting ice accretion on unprotected surfaces and the resultant aerodynamic penalties.
- Experimental and analytical methods and icing scaling laws to authenticate sub-scale model testing in icing wind tunnels.
- Instrumentation for the detection and measurement of ice accretion and icing cloud properties.
- Methods for predicting how a complete aircraft performs and handles in an icing encounter.

03.02 Subtopic: Aircraft Flight Environment
Center: LaRC

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

Innovations are needed for assessing the effects of lightning on future advanced composite aircraft employing flight critical digital systems. Refined lightning characterization requires: lightning/aircraft interaction models; techniques and methodology for interpretation and generalization of data for prediction of lightning/aircraft interpretation methodology and direct strike data; and, techniques for predicting lightning-induced effects on systems in advanced composite aircraft.

Development of an airborne sensor for the premonitory detection of low-altitude wind shear is of interest. Many microbursts are known to contain water droplets; therefore, conventional radar techniques may be useful for handling this problem. Radar designs must cope with the following factors:

- The suppression of ground clutter effects.
- The achievement of adequate spatial resolution.
- The recognition of an unambiguous, quantitative "signature" associated with the shear phenomenon.

There is interest in development of an airborne weather monitoring and processing system that will accept data from various sensor units (airborne and groundbased) to provide hazardous weather information to the pilot.

03.03 Subtopic: Control Concepts for Fixed Wing Aircraft
Center: LaRC

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

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

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

03.04 Subtopic: Fully Automatic Guidance For Rotorcraft
Center: ARC

Nap-of-the-Earth (NOE) flight in a conventional helicopter is currently extremely taxing for two pilots under visual flight rule (VFR) conditions. Developing a single-pilot all-weather NOE capability will require significant automation. A major goal would be the development of a fully automatic NOE flight-control capability. The NOE flight regime requires the helicopter to fly below tree tops whenever possible, following a preplanned nominal trajectory. The automated flight-control systems may use a combination of advanced sensors for mapping out the vehicle's surrounding for obstacle detection. Innovative concepts are desired with the potential of providing an obstacle-avoidance guidance system that accepts the real-time obstacle information and issues maneuver commands to the autopilot. Potential technologies applicable to the development of such flight-control systems include state-of-the-art techniques in computer vision, sensor fusion/processing, advanced control concepts, various expert-system disciplines and three dimensional computer graphics techniques for presentation of terrain information.

03.05 Subtopic: Aircraft Flight Testing Techniques
Center: ARC

Innovative real-time measurement and analysis methods using both onboard and ground-based processing are sought which would:

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

03.06 Subtopic: Flight Research Sensors and Instrumentation
Center: ARC

Real-time measurement techniques are needed to acquire aerodynamic, structural, and propulsion system performance characteristics in flight and to safely expand the flight envelope of aeronautical and aerospace vehicles in subsonic, supersonic, and hypersonic flight regimes. Accurate measurement of pressure, temperature, strain, flow, and other parameters are important to the design of advanced aeronautical and aerospace vehicles. Innovative concepts in advanced, minimally intrusive, fast response, low power, and low volume sensors and instrument systems are needed for aircraft and small rocket launched flight research payloads. Sensor systems considered for aerospace vehicle application should be highly durable, low out-gassing, and such that the boundary layer is not disturbed. Some specific needs are:

- Static and dynamic pressure sensor for external adaptation over fuel tanks without disturbing air flow in thin boundary layers.
- Transition/boundary layer sensor systems for defining frequency components up to 0.5 MHz at temperatures up to 3200F.
- Sensor system to accurately determine angle-of-attack to within 0.1 degrees at velocities from Mach 4 to Mach 15.
- Non-intrusive sensor system to determine total temperature from Mach 4 to Mach 15.
- Surface acoustical measurements employing optical technology.
- Strain on advanced structures at temperatures of 1700C and above.
- Wide ranges of pressure at high temperatures in jet engines.
- Fuel flow to determine 1–2% differences in thrust.
- Strain on rotating propulsion system components.
- Structural deflections and shape dynamically in flight.

03.07 Subtopic: Hypersonic Flight Systems Technology
Center: LaRC

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

Proposals for innovative concepts in the supporting technical disciplines are invited in other places in this solicitation, e.g., Topics 1, 2, and 4, and will not be considered in this subtopic. The purpose of this subtopic is to identify opportunities for systems-oriented innovations, including, but not limited to, the following:

- Optimization strategies applicable to component and vehicle geometry.

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

03.08 Subtopic: Multi-disciplinary Analysis Tools and Techniques for Hypersonic Vehicles
Center: ARC

Many modern high-performance aircraft exhibit strong interactions between structures, propulsion system, and aerodynamics. These interactions will become more pronounced in hypersonic vehicles. Innovative analysis techniques and applications of those techniques in computer-aided analysis tools are sought to provide methods of the understanding, flight qualification, and flight test of such vehicles. Of particular interest are innovative techniques for combining methods for the analysis of:

- Aerodynamic controls.
- Unsteady aerodynamics.
- Structural dynamics.
- Aero-thermal heating.
- Propulsion/airframe interaction.

03.09 Subtopic: Expert Systems For Aerospace Applications
Center: ARC

Concurrent advances in computer design and computer science have established the knowledge-based expert system as a realistic alternative in computer-aided decision tools. Current activities in expert systems involve the development of application systems, the development of flexible expert system "shells," and artificial intelligence research that increases expert system performance (knowledge representation, learning, etc.). Efforts to date have addressed a diverse but restricted set of subject domains in order to demonstrate capabilities. Future expert systems must be flexible, reliable, and capable of being used for domains that have the complexity of typical real-world problems.

The purpose of this subtopic is to solicit novel, innovative, and relevant applications of knowledge-based systems, or the development of expert system building tools applicable to aerospace vehicles. All research that would apply within the broad scope of aerospace technology is eligible for support, though Space Shuttle and Space Station applications are excluded. Areas of interest involve systems (whole or in part) that address the design, operation, survivability, maintainability, or other aspect of aerospace vehicles.

The proposer should be aware of any on-going research in areas releated to this topic to avoid duplication and to enable statement of the relative advantages of funding such work. Proposals funded in previous years have addressed accident investigation, aircraft design and automatic fault diagnosis. Further proposals in these areas are not encouraged. Research that provides results that can subsequently be used in aerospace applications (i.e., tools tailored for requirements unique to the aerospace domain) are also of interest.

03.10 Subtopic: Computer-Aided Development, Testing and Verification of Flight Critical Systems
Center: ARC

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

Innovative proposals are sought for computer-aided systems that:

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

03.11 Subtopic: Aeronautical Human Factors and Flight Management Systems
Center: ARC
LaRC

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

Innovative approaches to improved flight management techniques may include:

- Exploration and development of control/display operational concepts and crew/system interfaces involving cockpit displays of flight management information that will insure the efficient and safe use of ATC system technology.
- Development and validation of electronic control/display technology for consolidating and integrating the man/machine interface, including electronic display media, pictorial multimode display generation, and multifunction controls.
- Establishment of a qualitative and quantitative database for display format/arrangement factors.
- Expert or intelligent systems that monitor status and inform, advise or aid the flight crew, and other advanced input and output devices and methods such as voice synthesis and recognition, pointing, and touch devices which could increase the effectiveness of the flight crew.
- Planning/replanning and communication management to facilitate safe and efficient flight operations.
- Determination of single-pilot cockpit requirements for safer and efficient operation in the ATC environment.
- Development and validation of human response measurement technologies for a broad range of human functions including assessment of aerospace crew mental states.
- Development of the basis for reliable substitution of simulators for research applications involving atmospheric environment factors.

Considerations in each area should include the automation environment, crew information processing and decision making, and the associated cognitive workload.

TOPIC 04.00 MATERIALS AND STRUCTURES

04.01 Subtopic: Structural Composite Materials for Propulsion Systems

Center: LeRC

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

- Monolithic ceramic SiC and Si_3N_4 materials with higher reliability and reproducibility goals:
  - —Techniques for providing understanding of the relations among starting materials, processing parameters, microstructure, and properties including additions of toughening phases;
  - —Powders and sintering aids which will provide more homogeneous microstructure with minimum flaws in both size and number;
  - —Processing, e.g., modeling, sintering and hot isostatic pressing, to minimize flaws, improve temperature capability and enhance fracture toughness.
- Ceramic matrix composite materials:
  - —Ceramic-matrix composites of improved toughness and reliability;
  - —Ceramic fibers of improved, high-temperature strength, purity and handle-ability;
  - —Material models to predict and optimize ceramic performance based on matrix and fiber properties.
- Polymeric materials:
  - —Polymer matrix composites and adhesives suitable for use at temperatures above 650K and amenable to design and fabrication using extensions of conventional technology including lower cure temperatures;
  - —Optimization of process monitoring to allow adequate control and verification of chemistry changes during the fabrication of composite structures;
  - —Computational methods for matrix resin molecular design and synthesis;
  - —Materials models to predict matrix properties and also to predict composite properties based on matrix and fiber design.
- Nondestructive evaluation (NDE) methods:
  - —Novel NDE techniques to inspect and predict ceramic and composite strength and life.
- Laminated composite structures tailored to specific types of loads, temperatures, and reducing or oxidizing environments are also needed, and unique processes are sought such as hot pressing, explosive bonding, HIP diffusion bonding, vapor or fluid infiltration, or a combination of several methods to core and layer these structures.

04.02 Subtopic: High Temperature Structural Composites Methodology

Center: LeRC

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

- Test methods for fiber properties: Test procedures to determine fiber properties at room, cryogenic and high temperature, including time and nonlinear stress effects. These properties are: physical, thermal, mechanical, electrical, magnetic, etc. in both the longitudinal and transverse directions. The procedures/equipment to be developed shall have sufficient flexibility to be used to measure all the fiber properties and configured for bench-top type testing.

- In-service life monitoring of fiber composites: Dedicated systems to monitor in-service life/durability. These monitoring systems must be configured to be located on board strategic locations so that the critical structural areas can be continuously monitored. The systems must be sufficiently sensitive to nondestructively pick up degradation in both stiffness and strength. The monitoring system must have provisions to accommodate deviations by real time probabilistic analysis and statistical inference.
- Composite mechanics for parallel processing computers: Adaptation of composite mechanics (micro, macro, fatigue, life) to multiparallel processing computers. Composite mechanics consists of numerous, complex equations which describe multilevel composite behavior from constituents to structural response/life/performance. The computations with these equations are presently made using sequential computers. These sets can be performed simultaneously, thus making it possible to design composite structures in one pass through the multiparallel processor.
- Computational simulation of structural fracture toughness: Dedicate computational methods to predict fracture toughness in composite structures. Fracture toughness is traditionally considered as a material property. There are strong indications, however, that this is a structural property where the material, the geometry, the supports, and the loading conditions contribute to it. With the success of computational simulation, it appears quite possible to computationally simulate the structure fracture toughness in terms of parameters such as critical crack length and strain energy release rate.
- Probabilistic structural mechanics for parallel processing computers: Adaptation of probabilistic structural mechanics to multiparallel processing computers. In probabilistic structural mechanics, the governing deterministic equations, which simulate the structural behavior, are solved thousands of times. Probabilistic structural mechanics is presently performed sequentially in mainframes. This is too time consuming and costly for even simple structures of practical interest. However, these calculations can be performed in parallel, which makes it ideal for parallel processing computers.

04.03 Subtopic: Structural Composite Materials for Non-Propulsion Applications
Center: LaRC

Resin matrix composite materials offer potential for significant structural weight savings in the next generation airframe vehicles. Innovations are needed to improve composite structural efficiency and to reduce the cost of fabricated structures:

- Damage tolerant fiber architectures using textile processes.
- Failure mechanics analyses to predict mechanical behavior and residual strength.
- Cost-effective processing and automated fabrication concepts.
- New material forms such as thermoplastic, powder-coated graphite tows.
- Science-based models and sensors for in situ cure monitoring. Innovations are needed in the area of high-temperature refractory composites and coatings (such as coated carbon-carbon) for hypersonic airplanes, improved mechanical properties, lifetime, and fabrication.

Improved graphite reinforced polymer- and metal-matrix composite materials for precision space structures are need. Areas of innovation include, among others:

- High quality thin-gage composite tubes for space structures.
- Composite materials and cure cycles which will minimize residual stresses and distortions at sub-zero temperatures.
- Microcrack-resistant composites for high-precision reflector panels for deflection-limited telescopes.
- Stable, long-life thermal control coatings which minimize the effect of thermal cycling in space.
- Concepts for on-orbit repair and refurbishment of coatings.

04.04 Subtopic: Light Alloy Metallics for Airframe Structures
Center: LaRC

Future aerospace vehicles will require higher structural efficiencies than currently possible with available metallics over the entire range of aerospace applications, from light alloy systems to low density refractories. Improvements in structural efficiencies may be attainable through innovative structural concepts, processing methods and new alloy products with significantly improved properties. Areas of interest include, but are not limited to, the following examples:

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

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

04.05 Subtopic: Spacecraft Structural Concepts and Fabrication Techniques

Center: JSC

Advanced materials such as graphite/epoxy, metal matrix composites, and improved basic aluminum and titanium are being used in many commercial and military aircraft and have significant benefits in weight and cost savings for spacecraft applications. New concepts for applying these and other materials to a spacecraft such as the Space Station are desired, together with structural design criteria for new materials applications. Suggested areas of innovation would include, among others:

- Tubes and open sections fabricated from thermally stable composite materials connected with joints to form the basic structure.
- Joints and couplings with low or zero coefficient of thermal expansion for use on large space structures to achieve improvements in thermal stability.
- Module-to-module couplings to form large space systems.
- Innovative space-deployable and space erectable structures for pressurized or unpressurized applications.
- Innovative methods for fabricating continuous fiber preforms including inserts for casting metal matrix composite structural parts.
- Development of design techniques to cool and/or protect structure in a thermally hostile environment. Concepts for design verification are required for the above.

04.06 Subtopic: Special-Purpose Materials for Space Flight Applications

Center: GSFC

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

- Development of improved paints (black and white) for spaceflight applications.
- Development of a light-weight metal hydride collector that readily and safely binds hydrogen is required to allow hydrogen coolers to be used for Shuttle launched instruments without the expensive vehicle modifications that would be required for overboard venting.
- Transparent photo-elastic thin film materials that can be used for measuring and monitoring stress on structural member surfaces.
- An anaerobic compound that can be used for thread-locking applications and also meets spacecraft outgassing requirements.
- Inert films exhibiting low friction and long life at cryogenic temperatures.

04.07 Subtopic: Environmental Coatings, Lubricants and Protective Systems for Spacecraft

Center: JSC

The Space Transportation System enhancement and Space Station programs will need innovative new materials and improvement of current material systems. Identification of specific research areas include:

- Lubrication concepts possessing long life in the space environment, including atomic oxygen.
- Concepts and detection techniques to quantify material degradation in space.
- Protective coatings and methodology for improved life of structures subjected to the space environment, including ways to reduce residual and induced stresses.
- Testing and/or analytical approaches to long life certification.
- Advanced composite material systems that possess low CTE, low density, and low cost; e.g., MMC and liquid crystal polymers.
- Material systems that operate at elevated temperatures or serve as protection for conventional structural materials.

04.08 Subtopic: Organic Polymeric Materials for Large Nonlinear Optical Susceptibilities
Center: JPL

Future NASA missions will require smart, autonomous instruments or vehicles which are capable of executing a variety of tasks that require acquisition and processing of visual or optical information. Optical information or image processing devices are currently greatly limited by material performance. Materials with enhanced nonlinear optical properties, χ^2 and χ^3, are of great interest in this context and if developed, will provide an enabling material technology for optical processing devices. Materials are being sought for evaluation of nonlinear optical susceptibilities. Specific materials of interest are processable organic materials which include but are not limited to:

- Polymeric materials with rigid rod backbone structures comprised of aromatic and/or conjugated units.
- Polymeric materials with liquid crystalline properties resulting from main chain or pendant group moieties.

Features of the molecular structures should be identified to illustrate:

- Molecular design strategies for large optical nonlinearities χ^2 and/or χ^3.

Material properties should include:

- Good optical transparency in the visible and/or near infrared (IR) spectral region.
- High thermal stability.
- Processability into thin film forms.

04.09 Subtopic: Nondestructive Evaluation for Characterizing Material Properties
Center: LaRC

Innovations are desired in Nondestructive Evaluation (NDE) and measurement science for the characterization of material properties. Traditionally, NDE has been thought of as a final checkout procedure for quality assurance. Today, the needs for NDE go far beyond flaw detection to fundamental quantitative measurements of material and microstructural properties. The results of such measurements need to provide real physical properties that can be evaluated to determine their effect on performance of the material or structure. Quantitative NDE should be applied at developmental phases of new materials as well as process phases of engineering materials.

This subtopic focuses on development of probing energies that can be used in a nondestructive fashion to determine aerospace material properties related to their performance requirements. NDE opportunities include the development of measurement science instrumentation for: characterization of new high temperature materials, effects of atmospheric and space environment on materials, effects of stress and fatigue, microstructural imaging/characterization, in situ lifetime monitoring of materials/structures, and electronic materials NDE. Measurements under normal as well as harsh environments are needed.

The desired benefits of this program are improved reliability of aerospace systems, reduced development time for introducing new materials/structures, reduced costs in developing and operating aerospace systems, and the life extension of existing systems. The desired benefits should be applicable to NASA and the commercial sector.

04.10 Subtopic: Superconducting Materials Fabrication and Characterization
Center: JPL
LeRC

The new high temperature superconductivity materials promise significant benefits in weight and power savings for spacecraft applications. New concepts for applying these materials to spacecraft are desired, together with the development of fabrication methods and techniques for characterization of the superconductivity properties. Suggested areas of innovations would include, among other:

- Fabrication methods to produce bulk and thin film materials having high current carrying ability at 77K. Characterization techniques for the critical current density.
- Fabrication methods to produce bulk and thin film material displaying near 100% Meissner effect. Methods to characterize this expulsion of magnetic field.
- Fabrication methods for producing large samples (>100 cm^3) of superconductor with good superconducting properties (Tc + 90K, high current density, near 100% Meissner effect).
- Techniques to protect the materials against degradation by ambient atmosphere or vacuum.
- Fabrication methods for thin or thick film microwave transmission line circuit elements, e.g., cavities, filters, couplers, dividers, delay lines.

04.11 Subtopic: Lunar Materials Utilization
Center: JSC

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

- Novel, efficient methods of extracting a range of useful gases, metals, and non-metals from lunar materials.
- Highly automated mechanical equipment, sized for the lunar or earth-orbital environments to extract and move lunar materials from their source to processing facilities.
- Simplified, self-contained systems that can process metallic elements into useful shapes, including bars, rods, wires, bricks and can be utilized either in the space environment or on the lunar surface.
- Numerical modeling systems for evaluating the interrelationship between various aspects of the lunar materials mining, extracting and processing subsystems to select best technical approaches or systems.
- Novel transportation systems for lunar materials.

04.12 Subtopic: Advanced Materials and Processing Concepts
Center: LeRC

Innovations are sought in the following areas:

- Develop processing and alloying concepts for intermetallic compounds of near equiatomic iron, nickel, and niobium aluminides having high temperature strength and room temperature ductility:
  —Melting, powder metallurgy, and rapid solidification processing techniques to produce high purity materials;
  —Alloying concepts to improve ductility, strength and oxidation resistance.
- Developing fibers and matrices for metal matrix and intermetallic matrix composite materials:
  —Fibers having low density, high elevated temperature strength, high elastic modulus with thermal coefficients matching those of metallic and intermetallic matrices and that are a chemically compatible with metallic and intermetallic matrices;
  —Matrices which are light weight and capable of high temperature (1500–3000F) applications in aerospace structures.
- Rapid solidification via chill block melt spinning:
  —Rapid solidification via chill block melt spinning offers the potential for developing new strengthening concepts in metals, alloys, and intermetallics by quenching at 1,000,000 degrees per second to produce structures with ultra-fine grains and precipitates.

TOPIC 05.00 TELEOPERATORS AND ROBOTICS

05.01 Subtopic: Telerobotic System Planning and Design
Center: JPL
LaRC
MSFC

Advances in teleoperation and automation modes for task sequencing hold the potential for substantially increasing the overall level of capability for Space Operations. Planned space applications include the Polar Platform, the Space Station, the Smart-Front-End Orbital Maneuvering Vehicle, the Space Servicer, and the Mars Lander. Innovations in all areas of teleoperation and robotic/autonomous technology, basic system design and implementation concepts are sought, including:

- Telerobot/autonomous system integration: System level architecture for variably structured space servicing, assembly and replacement operations; end-to-end hierarchically integrated run-time control, run-time exchange of automation/teleoperations; knowledge base generation and automated activity planning for unstructured workspace, teleoperation to autonomous system hierarchical hand off; man-in-the-loop structured sequences and operator-aided recovery from random errors.
- Spatial planning and control: Path look-up using off-line representation and spatial and environmental constraints; fast collision detection (spatial occupancy); robust grasp planner; compliant motion/path/frame strategies.
- Operator-machine interface: Breadboard operator control/information interface devices and techniques in stand-alone mode and in integrated control station environment for alternative traded/shared manual and automatic modes of control of dual redundant arm telerobots equipped with smart/dexterous end effectors and operated under varying radio transmitter (R/T) communication time delay conditions.
- Sensing and perception: Acquisition and tracking of moving and stationary objects, recognition and 3-D perception of objects in a cluttered environment.
- Manipulator dynamics and stability: High fidelity modeling and control methods for manipulator flexibility and vehicle dynamics during attachment and stabilization; inverse kinematics and control algorithms for manipulators with redundant degrees of freedom; adaptive/distributive

control methods and architectures for flexible manipulators and flexible/deformable end effectors.

05.02 Subtopic: Telerobotic Systems Software Development
Center: JPL
MSFC

Operation of remote scientific instruments in space will be required as the Space Station becomes an operational entity. This capability, as it evolves, will enable a human operator to be supplied with all sensory cues, control capabilities, communication with/without time delay necessary to simulate operator presence at the remote instrument site; fused displays; automatic instrument command sequence generation; automatic multi-payload operation profile generation; automatic on-line command sequence training; fault diagnostics and recovery; multi-mission co-registration ground support data base management; automatic mission operations; and ground teleoperation interfaces. Innovative advances in the above technology elements are sought in addition to basic system design and implementation concepts, including:

- Appropriate base and remote control software systems that reflects necessity to perform off-line planning at the base and on-line planning/monitoring at the remote site.
- Appropriate heuristics, control, and error recovery management at the remote site that places robot in a safe state with no damage to the task environment.
- Modeling/simulation of the time delay envelope as a function of the base and remote control architectures.
- Use of both local and global computer graphic simulations that allow the operator to control the simulation in the exact manner the remote manipulators are actually controlled; the graphics simulations also give the operator the appropriate relational data not necessarily visible from the video camera feedback due to shadows or limits in field of view.
- Operator error/damage assessment heuristics which provide warnings of impending catastrophic failures as a function of the imposed time delay.
- Development of low volume, high speed, high memory computing capability to accommodate the base and remote architecture for robust error recovery.
- Automatic systems health monitoring, trend analysis, reconfiguration and alarms to alert the operator of the telerobot. Increases in the reliability and efficiency of the telerobotic system that will incorporate real-time access to the system designer's knowledge through expert systems.

05.03 Subject: Telerobotic Electro/ Mechanical Systems
Center: GSFC
JPL
LaRC
LeRC
MSFC

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

- Mechanical manipulators and actuators that can function very smoothly in near-zero gravity environments with relatively high acceleration motion that does not disturb the acceleration level of the surroundings via reaction forces or moments.
- Real-time programmable robot joint stiffness and back driveability with fail safe joint locking.
- Rolling friction rotary to rotary drives with special emphasis on high efficiency, reliability, compactness, strength and no backlash problems.
- Heat-energized payload fasteners and sensors verifying the attachment.
- End effectors and integrated sensor systems.
- Cableless power and signal transfer across robot wrist joint.
- Ultra strong and compact low power fail safe brakes for end effector drives.
- Ultra-reliable strain gauge mounting techniques. Highly accurate strain gauge temperature compensation.
- Alternatives for strain gauge sensors which perform the same functions but which are not vulnerable to separating from the structure they are mounted on. Also these must be capable of being used on end effector fingers, sensitive, wide dynamic range and good immunity to temperature changes.
- Sensors to prevent robots from grasping or colliding with hot objects in space.
- Fiber optic-based end effector micro controllers. Fiber optic-based digital-to-analog (D/A) and analog-to-digital (A/D) converters and multiplexers/demultiplexers.
- Fiber optic-based strain gauges and tactile sensors.
- Tactile, proximity, imaging (range and video), and force and torque.
- Real time control algorithms, dealing with all levels of driving the robot.
- Path planning on the low level.

- Safety is a great concern, i.e., algorithms which vary robot "soft" limits, monitor arm currents and mechanical stress on the arm (torque, load).
- Sensing and Perception systems that permit real-time 3-D visual tracking of moving and stationary objects in a cluttered environment. Representation methods of forces and torques for teleoperation are needed to permit rapid and easy operator perception.
- Training methods to improve operator performance and relieve the operator work load.

05.04 Subtopic: Robotic Adaptive Grasping Systems

Center: JSC

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

- Robotic hand and arm design, especially the integration of a dexterous hand and a multiple degree of freedom arm.
- Sensor systems required to allow object sensing, adaptive grasping, and recognition of stable grasps, as well as integration of sensors with a robotic hand and arm.
- Computer systems for intelligent, autonomous control of robotic hand and arm operation.
- Integrated software systems combining object location and recognition, task planning, sensor fusion, and grasp control.

05.05 Subtopic: Artificial Intelligence for Space Station Applications

Center: JSC
MSFC

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

- Intelligent control of robotics for autonomous navigation and for carrying out assembly, maintenance, servicing, retrieval and other tasks. Demonstrations of intelligent robotic control software integrated with robotic hardware performing such tasks is highly desirable.
- Intelligent systems for process control functions, for automated fault diagnosis and repair functions, for data monitoring and reporting to the ground, and for planning crew schedules and activities.
- Hierarchial and distributed self-updating systems for Space Station Module subsystem management functions, and hierarchical control mechanisms for distributed networks.
- Approaches to knowledge-based systems for engineering design and knowledge capture, tools to aid spacecraft crew and ground support personnel in updating intelligent systems software, innovative approaches to lower-level controlling software and hardware in support of intelligent systems, and approaches toward increasing the reliability of the Space Station through application of intelligent systems.
- Tools to aid crew and ground in updating expert system software for Space Station Module management functions.
- Also of interest are innovative approaches to the automation of Space Station computer code generation, e.g., ADA code, from system specifications developed in AI development environments such as Knowledge Engineering Environment (KEE) or Automated Reasoning Tools (ART).

TOPIC 06.00 COMPUTER SCIENCES AND APPLICATIONS

06.01 Subtopic: Engineering Computer Science

Center: LaRC

Aerospace productivity promises to make significant gains through improved management of engineering data, advances in low-cost microprocessor hardware, and the use of artificial intelligence concepts. Needed innovations include:

- Procedures to interface engineering data management software to disciplinary and multidisciplinary engineering analysis methods and based on

AI, couple logic systems to engineering data systems.

- Relational and other data structure approaches for engineering applications, data management applications concepts for managing geometric and non-geometric data to integrate computer-aided design/computer-aided manufacturing (CAD/CAM) tasks and distribution of data management over networks of heterogeneous computers.
- "User-friendly" subsets of database management systems that address scientific and engineering data and are sufficiently modular to be usable across different computer and operating systems.
- High-level engineering software tools such as algorithms for modeling three-dimensional objects realistically, and display techniques for visualizing functions of three variables. Improved interface systems for communicating information between humans and computers.
- Direct, iterative, or partitioning algorithms and methodologies in hardware and software applied to distributed engineering analysis, optimization and design computations over a large number of parallel processors operating asynchronously.
- New computing architectures using networks of processors offering the promise of order-of-magnitude improvement in computations in terms of increased speed and problem size.

06.02 Subtopic: Automated Software Development and Maintenance
Center: GSFC

Innovative approaches, including expert system concepts, are sought for the development, verification and maintenance of efficient and cost-effective automated software development and support systems. Automated support systems of particular interest to NASA include management control and tracking, requirements analyses and design specification, analysis and verification methods, development languages and support libraries, reusable software base development and systems integration techniques, code verification and testing techniques, and adapting and maintaining software for long-term missions and projects (10 to 20 years). Special support systems are needed for developing and testing time-critical applications, distributed system software, and fault-tolerant software. All such support systems must provide good documentation and visibility for the users. Potential applications extend across all NASA activities.

06.03 Subtopic: Reliable Software Development
Center: LaRC

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

06.04 Subtopic: Knowledge Based Systems Technologies for Aerospace Applications
Center: ARC

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

- Information extraction and understanding from multiple sensors with capability for automated interpretation of complex objects and data.
- Global knowledge understanding, representation, and control of multiple, domain-independent knowledge bases.
- Integrated data bases for distributed knowledge-based systems.
- Machine learning with automated capability for the generation of new heuristics.
- Automated programming development, data base management, verification, and validation.
- Hierarchical control architectures for distributed knowledge-based systems.
- Task planning and reasoning knowledge-based systems capable of operating in dynamic domains with rich representation capabilities to enable reasoning about concurrency and subsystem interaction.
- Man-machine interfaces capable of displaying integrated dynamic system relationships that are understandable and accessible to the human at a higher level of communication, i.e., allows the operator to input into the computer in a flexible and natural manner what is desired and the reason for the request.

06.05 Subtopic: Design Knowledge Capture
Center: MSFC

The capture of design data and, to a lesser extent, design knowledge, is already an integral part of large-scale development programs within NASA. However, it is primarily a manual and paper-based process. Even where design knowledge is developed or stored in an electronic medium, there is no common framework or representation which permits the results of the traditional engineering activities comprising the development effort to support an integrated application.

At present, design data is shared through the development of an enormous set of paper documents on any major project, and knowledge is shared by means of design reviews based on these documents. These reviews are very costly, involving dozens of experts, and typically identify hundreds of discrepancies which must then be corrected in the design. Most of these discrepancies could be avoided if each expert had the benefit of the other experts' related expertise throughout their design instead of only at checkpoints such as Preliminary and Critical Design Reviews. If that expertise exists only in the heads of our engineers, we will not be able to effectively share it even within a project, much less between projects. But it is now possible to capture that design knowledge in a form which will make much of it constantly available. The capture of such knowledge and the design data to which it refers in a particular domain, however, will result in a knowledge base whose scale greatly exceeds that of current knowledge engineering efforts. It also implies an ability, not currently available, to utilize knowledge about the design of a system to support multiple engineering activities such as evolutionary design, fault diagnosis, planning for operations and maintenance, training, etc.

In order to provide a required capability to support Design Knowledge Capture (DKC) efforts in NASA projects, several tasks must thus be accomplished:

- A theoretical framework for DKC (and, therefore, design) utilizing the technology of knowledge based systems.
- Methods for constructing, verifying, maintaining, and using large-scale knowledge bases.
- Knowledge representations and knowledge based system architectures which support reuse of knowledge in multiple applications.
- Approaches for integrating DKC into NASA's traditional engineering activities.

Innovative approaches to each of these tasks are needed in the near-term to support DKC efforts on major NASA programs such as the Hubble Space Telescope, the Space Station, Shuttle-C, and Advanced X-ray Astronomy Facility (AXAF).

06.06 Subtopic: Software Systems for Mission Planning and Flight Control
Center: JSC

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

- Automated knowledge acquisition expert systems.
- Intelligent computer aided training systems.
- Artificial neural systems.
- Intelligent computer-aided engineering (CAE) systems.
- Concurrent AI on parallel processors.
- Real-time distributed database systems for parallel processors.
- Auto decomposition of programs on parallel processors.
- Establishment of benchmarks for parallel processors.
- Robotics software development.
- Machine vision software development.
- Integration of different AI systems (vision, speech, expert systems, etc.).
- Fuzzy logic.
- Porting AI software to ADA.
- Phoneme based speech recognition systems.
- Speech recognition system based on audio cortex windowing mechanisms.
- Massive parallel processing speech recognition systems.
- Semantic knowledge-based voice recognition systems.
- Low bit rate speech output systems.
- High fidelity single frame graphics systems.
- 3–D graphics object generation systems.

06.07 Subtopic: Computer Science Advances in Support of Computational Physics
Center: ARC

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

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

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

06.08 Subtopic: Multiprocessor System Technology
Center: JPL

Advances in multiprocessor technology promise significant gains through the improved management of data. Innovations are sought in the following areas of interest:

- Hardware support for virtual-time-based multiprocessor systems: While multiprocessors have great theoretical promise, a straightforward conversion of existing simulation code is not possible, and new techniques are required to enable multiprocessors to support large simulations. Several mechanisms have been proposed for this purpose of which the time warp paradigm based on the idea of virtual time is most promising. Systems based on virtual time have a number of recurring requirements for queue management and precision timekeeping, which can best be met by specialized hardware. Some specific functions suitable for hardware implementation have been identified, but there is a need for innovative products to actually implement these functions in real systems.
- Test equipment for large-grain tightly-coupled multiprocessors: Several manufacturers are using large numbers of processors in various innovative architectures to create machines with supercomputer capabilities at relatively low cost. This class of machine is characterized by thousands of tightly-coupled high-performance processors, each with significant local memory. There is a need for general-purpose test equipment for test and analysis of such machines.
- Fault-tolerant multiprocessor system software technology: Multiprocessor architectures provide hardware capabilities for system fault tolerance through creative use of their inherent redundancy. There is a need for development of general software techniques which can be integrated into operating systems, database primitives, and other system software for such machines. The goal is an extremely reliable virtual machine to support general applications, consisting of a large scale multiprocessor and an operating system which incorporates fault tolerance technology.
- Design environment for multiprocessor system software: The value of Computer-Aided Software Engineering (CASE) tools is becoming appreciated throughout the software development community. However, existing tools are aimed primarily at conventional data processing applications, with some interest in realtime systems. Existing tools are particularly inadequate for coping with system software for multiprocessors. A design environment for this purpose should have a graphical user interface, operate interactively on an industry-standard workstation, include an interactive debugger, and be optimized for development of system software for large scale large-grain, tightly-coupled multiprocessors such as hypercubes.

TOPIC 07.00 INFORMATION SYSTEMS AND DATA HANDLING

07.01 Subtopics: Focal-Plane Image Processing
Center: LaRC

The end-to-end performance of image gathering and processing for (near) real-time teleoperations and robotics is severely constrained by the requirement for a serial stream of image data from the (2-D or 3-D) image-gathering system to the image-processing computer. Innovations in focal-plane image-processing techniques are required to overcome this constraint. These innovations may typically be concerned with coding for image compression, detecting edges and segmenting images, analyzing features in the image for patterns of interest, detecting and tracking moving objects, and restoring or enhancing images. The techniques may typically include integrated sensor-array sensing and processing, multi-resolution parallel processing, Gabor elementary signal coding, correlation and feature extraction, shift- and distortion-invariant recognition, and optical and acousto-optic processing.

07.02 Subtopic: Image Analysis Techniques
Center: GSFC
NSTL

As the spectral and spatial resolution of spacecraft sensors increases, so does the volume of data available for analysis. There is increasing emphasis on enhancing scientists' productivity by presenting the data in image form to facilitate the quick detection of patterns in the information (something the human eye and mind can do better than any current machine). Advances in image processing and display hardware and parallel computing architecture (such as GSFC's Massively Parallel Processor (MPP)) have led to a point where there is a substantial potential for significant breakthroughs in techniques for analyzing image data. Improvements in image analysis technology will result in greater automation and convenience in the analysis of the massive volumes of data that are to come and will significantly increase the productivity of the scientists using the data. Suggested areas of innovation are:

- Development of low-cost, remote, image display techniques including microcomputer display devices and image coding techniques to support the rapid transmission of image data to remote locations.
- Integration of image and graphic data structures to provide rapid identification and access to images with particular features in a multi-image database and to permit the selection of subsets of images selected on the basis of information content.
- Development of pattern recognition and image analysis techniques for use with multispectral data which emphasize the use of both the spatial and spectral characteristics of the data.
- Development of techniques for effectively assessing and analyzing data sets derived from sensors with non-congruent resolution and/or varying time observation.
- Development of new techniques for generic data representation through computer graphics to study such data streams.
- Development of expert systems to perform image analysis and information extraction.
- Development of graphics-oriented applications executive for current and future NASA data and information systems.
- Development of data compaction techniques which will efficiently store large volumes of data.

07.03 Subtopic: Statistics of Spatial Patterns and Spatial Interaction Processes
Center: NSTL

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

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

07.04 Subtopic: Spatial Data Management and Geographic Information Systems (GIS) Technology Development
Center: NSTL

Classified remote sensing data have been used in conjunction with ancillary data for analysis of environmental problems. Most of this analysis has taken place within a geographic information system (GIS) using the techniques of spatial data management. The level of analytical sophistication is increasing within public and private GIS software. However, user interaction with GIS software required to accomplish complex modeling of multivariate data is becoming more difficult. Recent advances in the development of natural language processing (NLP) offer the researcher the capability to focus on the solution of problems rather than specific command language needed to process data. NLP would serve as a preprocessing step in the execution of multiple spatial data management functions within the GIS software environment. Innovative solutions are sought which integrate NLP and GIS technology.

07.05 Subtopic: Signal And Information Processing
Center: GSFC

The recent development of heterodyne arrays require the need to process the radio frequency (RF) spectral information from the array elements. A multichannel acousto-optic spectrometer in which a layered Bragg crystal with independent RF input processes the IF signal of different array elements is now needed in order to obtain the high spectral resolution of the new class of heterodyne instruments.

As future spacecrafts and platforms become more complex and sophisticated, complicated connections among various components of the spacecraft systems will be needed to distribute electric signals. Thus a significant portion of the spacecraft weight will be due to the electrical harnessing wires. Innovation is required to minimize the weight due to the harnessing. Innovative ideas leading to the reduction of the spacecraft harnessing weight by using fiber optics technology are sought in the areas of:

- Multiplexing of signal processing.
- Distribution network.
- Application of fiber optics sensors.

Optical data storage devices promise to replace the traditional magnetic tape recorders as the principal on-board spacecraft data storage system. There is a need for innovative approaches to optical head assemblies whose scope should encompass the following:

- Reduction in size and mass, e.g., 20 grams.
- A new methodology for the redirection of the optical paths internal to the optical head in order to recover more optical signal energy.
- Lower cost via less optical elements and a reduction in complexity of the manufacturing process.
- More resistance to shock and vibration and possible misalignment.
- Design flexibility for both WORM and M–O erasable applications.
- Resistance to temperature variations via hybrid packaging of the laser diode and quadrant detectors.
- Increased data reliability by utilizing separate detectors for focus, tracking, and data collection.

07.06 Subtopic: Information Processing Technology and Integrated Data Systems
Center: LaRC

High performance, fault tolerant information data systems are needed for advanced aerospace missions. These data systems must be capable of providing data communication bandwidths and 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. Futhermore, these data systems may carry real-time data; therefore, both delays and variability of delay must be kept to a minimum for correct operation. For the higher level communications and processing functions, the delays and variability are dominated by the distributed operating system. For the lower level communications and processing, the delay and variability are dominated by the physical properties of the hardware implementation. Innovations are sought in distributed operating systems and hardware implementation for meeting future data system needs. Suggested areas for innovation are:

- Distributed operating system concepts.
- Network topology forms.
- Hybrid electro-optical and optical network nodes.
- Optical and electro-optical components/devices.

Innovative techniques are also needed to provide interactive development of application algorithms for embedded multiprocessor execution. The application algorithms are functionally represented by a directed graph, which embodies the data and control flow for the algorithm. Automated optimization features are needed to assist the user in tailoring the graph interconnect and node granularity for maximum system throughput. Innovative automatic or semi-automatic approaches are also needed to integrate the optimum graph attributes into ADA-coded graph nodes suitable for compilation and execution on a specific multiprocessor system.

07.07 Subtopic: Spacecraft Operations And Data Management
Center: GSFC

Spacecraft operations, control and scheduling are conducted through a complex interaction of project scientists, network support managers, and network control managers, using mission planning terminals, payload operation control centers, network operation control centers and other facilities. This requires the assimilation and processing of massive amounts of data. The end result is the generation and transmission of suitable commands from the control center to the spacecraft and reception and processing of the telemetry and scientific data sent by the spacecraft. New and innovative concepts are needed to improve and upgrade systems and procedures so that they are fully able to meet the demands of the coming decade. The future environment will include the independent control and operation of some experimental payloads by experimenters from their home institutions; the use of expert systems to automate monitoring, control, scheduling, and fault isolation functions; and distributed scheduling of communication links and processing systems. This will require innovations in the following areas:

- Scheduling algorithms that are efficient for distributed, individually controlled resources.
- Development tools to aid in the implementation of expert system knowledge bases for control centers.
- Design of distributed expert systems for performing control, monitoring, and fault isolation for spacecraft and payload components, and supervi-

sory expert systems for monitoring and advising operators based on these subsystem expert system inputs.

- Control center designs with optimal allocation of planning, scheduling, and monitoring functions between operator and machine.
- Data system designs that allow selective processing and display of limited payload data subsets in near real time for control purposes by sampling network communications.

07.08 Subtopic: Ground-Based Data Management Systems

Center: GSFC

Current users of data management and analysis systems require the in-depth knowledge of a host of operating systems, applications programs, networking protocols, and storage devices. This plethora of diverse computer interfaces and operating requirements greatly hinders the effectiveness and efficiency of a given user's objectives. For example, a scientist may need relational data for the creation of 3-D graphics to be superimposed on a remotely sensed image that is correlated to topological surface data from several data sources. This implies the use of database management, 3-D graphics display and manipulation, image analysis, data reformatting techniques and image generation. Unfortunately, these technologies usually reside on separate computers (optimized to the relevant technologies) and in separate software packages developed by different vendors with different operating systems and interfaces.

Innovative techniques are needed which can dynamically allocate the appropriate resource according to the user's application requirements. AI techniques hold a promising solution for addressing and coordinating multiple software packages and operating systems across multiple processors remotely located. A possible approach would be the development of an intelligent planner/controller that would be aware of the current state of existing computer resources that are most appropriate for a given application task. Such a capability would optimize available resources based on a user's application needs and not on computer efficiency requirements.

07.09 Subtopic: Spacecraft Ground System Data Design and Extraction

Center: JPL

Testing, operating and controlling spacecraft requires extensive interactions between personnel with disparate interests and backgrounds and massive amounts of data. This data is located on assorted types of computers ranging from small desktop workstations to large mainframes, all of which may operate in either stand alone mode or networked together. Data may consist of pure text material, pure graphical material, or a combination of the two. Improving the productivity associated with testing, operating and controlling spacecraft, as well as managing these activities requires timely access to the data and the ability to assemble data elements into various configurations to provide specific types of information.

Advanced data system technology must be developed that uses new and emerging technologies relating to data structures and graphical database designs to allow for rapid location, extraction and assembly of data into meaningful information units. Information once generated, must be assembled in a form that allows for perusal by personnel via concepts or keywords that have been imbedded within the data without being constrained to a fixed, linear access mode. This will require innovative development in the following areas:

- Logical data structures for both textual and graphical materials that maintain data context within interconnected systems.
- Intelligent methods for determining data context within the total data domain.
- Advanced processes that can condense, categorize, and summarize the contents of textual and graphical data.
- Processes that can trace test results back to functional requirements through documents contained in a variety of electronic forms and formats within a networked system.

07.10 Subtopic: Heterogeneous Distributed Database Management

Center: GSFC

One of the most serious problems affecting NASA, both in the scientific and administrative realm, is the tremendous diversity of databases and database management systems. In order to access data from sources other than their own, users are forced to learn a plethora of different languages and access methods. Consequently, an "its too much trouble to do attitude" has resulted in a further increase in this proliferation.

Research is needed for developing tools for uniformly accessing heterogeneous distributed databases. Suggested areas for innovation are:

- A "library-like" interface that will enable users to locate data in a manner similar to the way in which patrons locate books in a library.
- Automated retrieval aides that will interact with a user, help the user locate specific problem-solving software and assist the user in using the software.

- Generalized report generation capabilities that will provide a large set of report formats and allow user-generated report formats.
- Host programming language-based database access that will enable users to access heterogeneous distributed databases via programming languages such as C, FORTRAN, LISP, ADA, etc.
- View update capabilities that will enable users to update virtual databases that are made up of actual databases that may be of diverse structure (i.e., relational, hierarchical, network, etc.) from different database management systems (DBMS's) (i.e., INGRES, ORACLE, IMS, FITS, etc.) and over different locations (i.e., distributed).

07.11 Subtopic: Management Information Communications
Center: GSFC

Innovations are sought using advanced communications and data management technologies to provide vastly more effective means than now available to enhance productivity in program and project management. Improving productivity in management of technical projects and programs is possible through the use of timely, readily accessible, and efficient means for communicating and controlling status, requirements for action, and changes. An immediate, accurate flow of information among all concerned with management is essential for making major enhancements in decision-making, project and program control, and intra-agency communications. One example of this would be innovative techniques in the development of an effective measure of procurement productivity in an R&D environment.

A variety of computer connections and local area networks are being formed with an increasing need for resource connectivity. Furthermore, fiber optic technology will be used to help satisfy the demand for higher data transfer rates. Accordingly, new interface, software and hardware technology needs to be developed to allow common use of fiber local area networks (LANs) by hosts with different protocols. In addition, the proliferation of new host interfaces requires careful monitoring and adjustments since the technology is changing rapidly. Innovative uses of microcomputer technology are sought to develop routers and gateways to provide connectivity, addressing, protocol conversion and network management functions.

New and imaginative management approaches must be adopted that when applied across multi-discipline matrix organizations enhance the in-house team approach in a manner that preserves the management structure but more effectively responds to the technically and programmatically complex program needs. One example of this would be an in-house programs office that could use new and emerging computer technologies to intelligently perform task management functions in accordance with prior negotiated task implementation plans and that could be linked to each of the task team members via desk computer terminals.

07.12 Subtopic: Search for Extraterrestrial Intelligence (SETI)
Center: ARC

The search for Extraterrestrial Intelligence Program is developing equipment to conduct a high resolution microwave search of the sky with very high resolution of solar type stars for evidence of signals of extraterrestrial intelligent origin. The project will use the existing radio antennas with unique radio frequency spectrometer (wide bandwidth, high resolution) and signal analysis equipment (optimization in low signal to noise environment). Expert systems for autonomous archiving, signal test and verification, and telescope scheduling and control will be used. Proposals should demonstrate knowledge of technical requirements for SETI, and present innovative ideas to meet/exceed technical requirements, which have potential for commercial application.

Areas needing innovation beyond the state-of-the-art include:

- Wideband, high resolution radio frequency spectrometer with 100+ million channels.
- Real time scheduler for antenna control that would be interactive with a changing data base.
- High speed custom chips (efficient signal analysis algorithms realized in hardware) hardware systems for use in constant/drifting continuous wave and low duty cycle pulsed signal detection in low signal to noise environment.
- Hardware and software system to identify both radio frequency interference (RFI) of terrestrial origin and known radio astronomy sources and to allow for their rejection.
- High speed/high density data storage media.

08.01 Subtopic: Instruments for Sensing Electromagnetic Radiation
Center: JPL

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

- Charge-coupled devices: Improvements or alternatives to traditional overlapping gate structures utilizing state-of-the-art submicron fabrication techniques; reduced readout noise through the development of lower noise on-chip amplifiers; fabrications on monolithic non-silicon materials; dark current reduction techniques or structures.
- Infrared detector arrays: Innovative concepts for detector materials with cutoff wavelengths between 2.5 and 300 microns; advancements in multiplexer architecture, interconnect technology, and monolithic structures. Requirements include extremely low noise, high uniformity, very low dark current, and high radiometric fidelity. Of special interest are innovative concepts for area array focal planes operating with cutoff wavelengths longer than 14 microns and operating temperatures between 40 and 80 Kelvin.
- Calibration techniques: Techniques for absolute radiometric characterization of IR detectors to simulate very low backgrounds, such as zodiacal light.
- High-operating-temperature infrared detector arrays: New materials and innovative concepts are required for application of non-cryogenic infrared detector arrays suitable for operation in the 1.0 to 16.0 micron wavelength regions. Mapping spectrometer detector work in the wavelength areas of interest suffers from high noise or the requirement for operation at cryogenic temperatures, necessitating elaborate and massive passive radiative coolers or short-lifetime cryogenic cooling materials. Use of such non-cryogenic detector arrays would require concurrent technology development of appropriate multiplexing and interconnect architecture and materials. Requirements include low noise and dark current values, high uniformity and high quantum efficiency at the wavelengths specified.
- Bolometer detector arrays: The NASA Planetary Science program carries out ground-based observations of solar system objects in the thermal infrared region of the spectrum. A detector array based on silicon bolometers is needed for use in a camera or spectrometer covering the wavelength region from 2.5 to 500 micrometers. The array should be at least 1 x 64 elements, but potentially expandable to larger formats. Each element should achieve a noise-equivalent power not exceeding 10^{-16} watts/$\sqrt{\text{Hz}}$, approximately, when operated at He_3 temperature. Interface features, data acquisition and control, and cryostat performance must be considered in the overall design.

08.02 Subtopic: Earth Atmosphere Sensing from Space
Center: GSFC

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

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

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

- Development of short pulse (approximately 1 nsec) laser transmitters employing diode-pumped solid-state laser technology.
- Integration of detector, preamplifier, pulse discriminator, range-gate, and time-interval electronics into a miniaturized, low-power altimeter processor.
- Implementation of waveform-digitization electronics to analyze pulse-spreading effects caused by interaction of the laser pulse with a rough target surface.

- Noise reduction in silicon avalanche photodiode receivers.
- Development of a compact, low-power laser altimeter instrument-controller computer with on-board buffer memory and serial data interface.

High dynamic range signals from active remote sensors measuring meteorological and global surface parameters require the development of high accuracy and stable transfer function modifying preprocessing electronics. Innovations and developments are necessary to extend analog preprocessor bandwidth, switching transient response, settling time, dynamic range temperature insensitivity and noise figure.

Infrared heterodyne spectrometers have been extensively applied to remote sensing of planets and stars, but none of the instruments existing to date have achieved the small size and power requirements which would qualify them for space flight use. Innovations and developments are required for heterodyne spectrometers aboard spacecraft which will require small, highly efficient RF components which will operate within the constraints of a free-flying spacecraft power budget.

Satellite Data Interpretation: Improved techniques are needed to quantitatively estimate the components of the radiation balance at the surface of the Earth using high spatial resolution (10 kilometers to 1 meter) satellite Earth-observing sensors. Innovative methods are needed to use multi-band Earth-observing sensors with relatively high spatial resolution capabilities to accurately and precisely estimate the components of the radiation balance at the surface of the Earth for application to crop or plant growth and productivity models, models of evaporation and transpiration, etc., from earth surface cover classes in relatively local regions; e.g., a few square kilometers to areas as large as approximately 10 square kilometers are required.

08.03 Subtopic: Low-cost High Resolution Remote Sensing Instrumentation for Earth Sciences
Center: NSTL

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

08.04 Subtopic: Sensors for Atmospheric Science
Center: LaRC

Innovations are desired in sensor techniques, sensors and sensor systems to permit ground-based, airborne and/or spaceborne monitoring of atmospheric aerosols produced naturally or from man's activities, including determination of:

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

08.05 Subtopic: Instruments and Systems for Atmospheric Observations
Center: JPL

A Fourier Transform Ultraviolet Spectrometer (FTUVS) or measurement of the vertical column density of several important atmospheric species. The design and development of a reliable, inexpensive, FTUVS prototype is sought for this application and for possible use, with adaptation, aboard aircraft or balloons.

The FTUVS is to be a Michelson-type interferometer which will operate in the visible and near-UV regions (300–800 nanometers) with an apodized resolution of 0.25 cm^{-1}. The instrument package would consist of the collection optics, mirror drive, internal optics, detectors, drive electronics, and signal processor.

- Wind velocities in the middle atmosphere can be measured by means of the Doppler shift induced in the naturally-occurring atmospheric infrared emission. It is intended to measure this shift remotely from a spaceborne platform by use of electro-optic phase modulation gas correlation spectoradiometry, in which an electro-optic phase modulator (EOPM) is used to bring the shifted emission into correlation with a sample of a reference gas. The application of EOPMs requires modulators with modulation indexes of 1.8 in the 8 to 15 micrometer wavelength range at modulation frequencies between 400 and 700 MHz. Sought are:
  —Materials with improved electro-optical characteristics in the stated wavelength and frequency ranges;

—One dimensional array of EPROM elements with 5 to 10 rectangular elements covering approximately a 2.5 mm square image area.

08.06 Subtopic: Atmospheric LIDAR Remote Sensing
Center: GSFC

High accuracy measurements of the atmospheric temperature and pressure fields from aircraft and spacecraft platforms require the development of various technologies. For operation from spacecraft, considerations of efficiency and lifetime are also of prime concern. Innovations are needed for the following:

- Single longitudinal mode pulsed laser.
- Visible red diode array.
- Frequency stabilized near I-R diode lasers.
- Holographically scanned large aperture telescopes.
- Low-cost LIDAR targets.

08.07 Subtopic: Tunable Solid State Lasers, Detectors and LIDAR Subsystems
Center: LaRC

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

- Tunable laser materials from 0.180 microns to 11.0 microns.
- Diamond films for laser hardening of optical elements and diamond-based devices.
- Semiconductor arrays to optically pump solid state host materials.
- High temperature superconductors for superconducting-insulating-superconducting (SIS) detectors in the 100 micron wavelength region.
- Lightweight mirrors in the 1 meter range.
- Single element detectors and time-delay-and-integration (TDI) detector arrays with increased sensitivity at thermoelectric cooler temperatures.
- Heteroepitaxy devices for low-noise and high-speed applications.
- Hybrid or monolithic detector/preamplifier structures to reduce electronic noise.

08.08 Subtopic: Instrumentation for Geological Research
Center: JPL

The NASA Geology Program carries out multispectral infrared imaging from aircraft and satellites for surface compositional mapping. Field-based measurements are a necessary link between aerial imaging data and detailed laboratory measurements. A field-portable reflectance spectrometer operating in the 2.0–2.45 micrometer range is needed which could:

- Measure the continuous reflectance spectrum over the stated wavelength range with a bandpass of between 5 and 10 nanometers for a 10-degree field-of-view.
- Provide signal-to-noise ratio greater than 100 for over head sun and 30% albedo.
- Be able to acquire and record a spectrum on a suitable medium in under 30 seconds, and provide real-time display of raw data.
- Be rugged, small, and weigh less than 20 pounds.

The Program also carries out research on volcanology, with emphasis upon active lava flows. Currently available aircraft-borne thermal imaging instrumentation is exceedingly accurate for temperatures below 100C, but calibration does not extend to the range of interest here. A broadband thermal IR imaging radiometer for use aboard an aircraft such as the NASA Land Survey C130B is needed which could:

- Provide downlooking image data in digital format for one or more thermal channels.
- Determine actual surface radiation temperatures to within 1 degree at 0C and 10 degrees at 1200C.
- Achieve 1 m per pixel resolution on the ground from operational altitude.

Investigations of radar backscatter from natural land, ocean, and ice surfaces require microtopographic maps of representative areas on these surfaces. Technology is sought which would enable the mapping with cm-scale resolution of target areas for which the albedo is between 5% (lava) and 80% (ice), relief variations encountered are up to 2 m vertical within a 1 m horizontal range, there is little or no vegetation cover, and the site may be inaccessible by road. The requirements are:

- Two-dimensional square grid at least 20 x 20 m.
- Grid spacing of 0.5 cm or less in both lateral dimensions and 0.2 cm vertical resolution and accuracy.
- Datum may be locally defined and need not be horizontal.
- Acquisition time of one hour or less per 20 x 20 m area.
- Digital output on CCT.

08.09 Subtopic: Oceanographic Instruments and Software
Center: JPL

NASA carries out various research programs on physical and biological oceanography. Improvements are sought in the area of sensors and in technology for the transmission of data acquired thereby. Topics of particular interest include:

- Acoustic doppler or other shipboard instrumentation for remotely-sensed measurements of ocean current. The measurement system must be designed for easy, short-term deployment on various type ships of opportunity. The system must be sufficiently automated and user-friendly to reduce the training requirements of shipboard personnel.
- A system to measure chlorophyll, upwelling radiance, and primary production in the ocean. The measurement system must be designed for use on various type ships of opportunity, as well as on drifting or moored buoys which incorporate satellite data transmission. Emphasis should be on low cost, ease of deployment, and minimum manpower requirements.

08.10 Subtopic: Flight Instrument Technology for Exobiology
Center: ARC

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

- Miniaturized gas chromatographs and subsystems including innovative detectors, columns, and sampling devices to rapidly detect the quantitate organic compounds at parts-per-billion levels.
- Ion Mobility Spectrometers to unequivocally identify and quantitate organic effluents from a gas chromatograph at concentrations of 10^{-14} MOLS per sec.
- Components and systems to extend mathematical analytical techniques to the flight environment (e.g., Multiplex Gas Chromatography, Fourier Transform Spectrometry).
- Infrared Diode Laser Spectrometers for high resolution molecular spectrometry of gases in the range of 3–30 micrometers to measure biogenic molecules (e.g., C and N isotopes in CO_2 and NOX) with precision of 0.1% or better.
- Miniaturized elemental analysis techniques (e.g., Gamma-Ray and Alpha backscatter spectrometers) with extended range and greater sensitivity for the biogenic elements (C, H, N, O, P, and S).
- Systems and subsystems for the production, manipulation, collection, levitation, observation and analysis of particles inside a vacuum chamber in a microgravity environment.

08.11 Subtopic: Instrumentation for the Study of Planetary Atmospheres
Center: JPL

Innovations are sought in the development of instrumentation for the study of planetary atmospheres. Areas of interest include:

- NASA and the European Space Agency are planning a Saturn orbiter which would include an instrument for obtaining two-dimensional maps of Saturn and its satellites in the linear-polarization Stokes parameters (I, Q, U). The instrument may utilize acousto-optic tunable filters (AOTFs) optimized to operate in the near-UV (200 nm to 400 nm) and visible to near-IR (400 nm to 5 um) ranges with selectable resolution. With this it should be possible to characterize the properties and distributions of aerosol particles in the atmospheres of Saturn and Titan and to characterize surface properties and mineralogies of the airless satellites. Innovations are sought in:
  —Spacecraft-borne AOTFs and associated electronics capable of tuning over the stated ranges;
  —AOTF materials with superior performance in the near-UV to visible wavelength regime;
  —Techniques for the apodization of passbands through simultaneous excitation of several acoustic frequencies; methods for compensation for various optical distortions induced within AOTFs;
  —Systems for on-board data reduction and compression.
- The NASA Planetary Science Program carries out ground-based observations of planetary and satellite atmospheres and surfaces. New instru-

mental methods, such as AOTFs, and the associated technology are needed for the development of a rapid-scanning imaging spectropolarimeter. The desired instrument would:

—Be capable of imaging planets at wavelengths from 0.3 to 3.0 microns with selectable spectral resolution and with 0.25 arc-sec resolution;

—Accomplish wavelength switching in less than 50 microseconds, approximately;

—Enable simultaneous acquisition of orthogonally-polarized images.

- Studies of planetary atmospheres and interstellar clouds conducted in the millimeter and sub-millimeter wavelength ranges require spectrometers with frequency resolution of 1 part in 10^6. Many spectrometer designs utilize heterodyning to reduce the frequencies to the 1–2 GHz range, with spectral analysis being accomplished by analog, digital, or acousto-optic technology. The latter seems potentially best suited to spacecraft use in terms of bandwidth, number of channels, size, power consumption, etc. Existing acousto-optic designs intended for military applications meet many requirements, but do not possess adequate stability. A prototype submillimeter spectrometer design suitable for use aboard spacecraft in scientific applications is needed. Requirements include:

—Bandwidth of at least 500 MHz, preferably 1–2 GHz; 1000 to 2000 channels (Nyquist-sampled);

—Frequency draft less than 0.2 channel per 5 min.;

—Amplitude drift less than 1 part in 2×10^4 per 5 min.;

—Size less than 1000 cm^3 and weight less than 2 kg.

08.12 Subtopic: Infrared Technology for Astronomical Applications
Center: ARC
JPL

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

- Achieving ultimate performance in low-background instruments, improvements in the sensitivity of discrete IR detectors and integrated IR detector array electronics operating at cryogenic temperatures. Means to extend the spectral coverage beyond 200 micrometers, and means to reduce device dark current and susceptibility to particle radiation are also required.
- Methods to count individual IR photon events, either directly or via upconversion, including bolometer technologies.
- Novel techniques in long-wavelength (>20 micrometer) IR filter design and manufacture.
- Novel coolers and their components. Examples are continuous cooling between 2 and 20K and between 1 and 2K; nonhydrated refrigerants, magnetic shielding, and low-current/quench-protected magnets for 1K magnetic refrigerators; and pulse tube refrigeration techniques.

  —A long life upper cooling stage at 4k would greatly facilitate lower stage cooling for space. Specific areas of improvement over present cryogenic systems are development of an oil free helium compressor for J-T refrigeration; development of a helium sorbent regenerator; or other very high volumetric specific heat regenerator for cooling between 4k and 15k.
- High-quality, low-cost fabrication techniques for optics capable of diffraction-limited performance down to 1 micrometer. Included are both small optics for instrument applications, and large (>1 M) lightweight panels for use in segmented mirrors.
- Novel techniques for in situ evaluation of image quality in cooled IR telescopes. This includes development of sensing instrumentation and algorithms for correction of focus.

08.13 Subtopic: Detectors and Detector Arrays
Center: GSFC

Detectors and detector arrays for space astronomy, astrophysics, geophysics, and atmospheric studies at varying wavelengths require innovations. Among the areas needing innovations beyond the present state of the art are:

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

- Microchannel plate arrays with no ion feedback, high quantum efficiency, high resolution, low radioactivity, controlled conductivity.
- High quantum efficiency near infrared photocathodes.
- Charge-coupled device (CCD) array improvements, including lower noise amplifiers (<5 els rms readout noise), low dark current, UV sensitivity, defect reduction, anti-reflection coatings.
- A spaceborne sensor is required for the direct measurement of magnetospheric currents in space.

08.14 Subtopic: Sensor Cooling for 65-80 Kelvin

Center: JPL

For spacecraft sensor cooling in the 65K–80K temperature range, it is desired to have a refrigerator with extremely long life, and virtually no vibration. One such refrigerator uses a reversible oxygen reaction to generate high pressure gas, which when expanded, produces liquid oxygen. It has been demonstrated that $Pr_{1-n}Ce_nO_x$ (PCO) materials reversibly absorb and desorb oxygen. Oxygen is chemically absorbed at about 0.3 atm when the PCO compound is cooled to 325C, and when heated to 650C the oxygen is liberated, i.e., vented, at about 28 atm. With precooling at 140K, the high pressure oxygen is liquified, and when expanded to 0.3 atm, net cooling is provided at 80K. The entire process has no wear-related moving parts and thus has a very long-life with virtually no vibration. Unfortunately, PCO reversible chemicals absorb only about 1.5% of its weight with oxygen, and the entire refrigeration system is therefore relatively inefficient, i.e., about 200 watts of power are required to provide 1 watt of cooling at 80K. If alternate metal-oxygen reversible solid solutions can be found to improve the oxygen weight loading, or if alternate, long-life vibrationless cooling systems can be developed, then cooling of sensitive imaging system sensors may become practical for long-life spacecraft applications. Specific areas for innovation are:

- Development of other very long-life, metal-oxygen solid solutions with potential high oxygen-loading characteristics for temperatures below 650C.
- Development of other long-life vibrationless active refrigeration systems for 65K–80K cooling.

08.15 Subtopic: Cryogenic Fluid Instrumentation for Orbiting Spacecraft

Center: LeRC

Innovative concepts and techniques are needed in the area of advanced instrumentation for spacecraft utilizing cryogenic fluids. Liquid hydrogen and cold gaseous hydrogen are the principal fluids of interest; however, the concepts proposed should be applicable to other cryogenic fluids such as oxygen, nitrogen and normal liquid helium.

Concepts for advanced instrumentation are needed in the following areas:

- Flowmeters:
  —Cold gaseous hydrogen flowmeters with a full-scale measurement capability from 0.02 to 10 lb/hr.;
  —Liquid hydrogen flowmeters in the range from 0 to 200 lb/hr. These flowmeters should be capable of measuring bi-directional flow and also be capable of measuring two-phase and gaseous hydrogen flow with the same instrument. The flowmeter output should be in terms of mass flow rate with an indication of the fluid phase and a measurement of the fluid quality when two-phase flow is present.
- Liquid mass gauge:
  —Mass gauging is required to determine the quantity of liquid hydrogen in an aluminum tank containing liquid and vapor in a zero-gravity environment. A nonintrusive instrument is required to minimize heat conduction to the fluid. The tank may also contain other components such as screen liquid acquisition devices and thermodynamic vent systems.
- Point source phase detectors:
  —A means of determining whether hydrogen liquid or vapor is present at numerous points within an aluminum tank at any given time while in a zero-gravity environment. Heat conduction to the cryogenic fluid is to be minimized.

08.16 Subtopic: Submillimeter Antennas, Radiometers and Spectrometers

Center: JPL

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

- Antenna systems, with apertures up to 4 meters, with multiple beams.
- Focal plane radiometer arrays.
- Cryogenic low-noise radiometers with operating times of 2 years.
- Solid state phase-locked local oscillators.

Low-power spectrometers to simultaneously analyze signal bandwidths up to 10 GHz with a frequency resolution of 1 MHz are required for future spaceborne sub-mm radiometers. Small size, lightweight and low power (<10 mW per channel) are required, along with high stability and lifetimes >5 years. Acousto-optic or digital technologies may be the best choices.

08.17 Subtopic: Optical Components
Center: GSFC

In the area of optical components and systems for Earth-orbiting spacecraft/platforms, innovations are needed for the following:

- Innovative techniques for the fabrication of low scatter mirrors with sub-arcsecond image quality for applications in the conventional and grazing incidence optical systems used for the spectral region above 5 nanometers.
- Development of testing apparatus and methods to evaluate the effects of spacecraft contamination on critical surfaces such as low scatter mirrors and exposed photocathodes.
- Development of concepts and designs for optical coating in space technology.
- Development of techniques for the deposition of low scatter, high temperature superconducting materials on optical surfaces.
- Optical coatings for use in the extreme ultraviolet to the far IR spectral region that provide wide and narrow band filters, beamsplitters, polarizers and reflectors.
- New technologies for producing diffraction gratings for use in the ultraviolet and soft X-ray spectral region.
- IR filters, beamsplitters and polarizers for use at cryogenic temperatures.
- Apparatus for the measurement of the refractive index of materials as a function of temperature from 4K to 273K. Accuracies of one part in ten thousand are needed.
- Computer algorithms for design, tolerance measurement and/or optical performance evaluation of space flight optics. Reflective imagers and grating based spectroscopic instruments should be emphasized. Novel design approaches or new analysis capabilities are of primary interest. Optical performance measures of primary interest are image quality and polarization dependent radiometric throughput.
- Development of low cost, 3 axis machine which can generate precision high order aspheric surfaces, on glass or glass ceramic substrates, which are free of mid-frequency ripple and tool marks to the extent that the surface can go directly to a final polishing operation. Desired surface sizes which can be handled by such a machine are 12 inches by 12 inches with a surface depth generation capacity from a plane surface on the order of 1 inch.
- Techniques for combining aspheric mirrors with low scatter surfaces and low scatter coatings for the visible and UV.
- Materials with very low coefficient of thermal expansion are required for optical bench structures, which are low weight, non-magnetic, and do not outgas water and hydro-carbons. Methods using graphite combined with non-outgassing or cladded matrix materials are of particular interest, to limit focus changes and contamination.

08.18 Subtopic: Optical Systems
Center: JPL

Optical systems modeling and optical components are needed for a variety of space instruments. Specific areas of interest include:

- Optical Systems Modeling:
  —Modeling of large optical systems. Applications of Fresnel diffraction theory. New approaches to diffraction modeling in far IR/submillimeter.
  —Polarization analysis of optical systems. Enhancements of polarization ray-trace capability including reflection and transmission gratings.
  —Optical interferometry. Techniques for optical image reconstruction from partial u-v plane coverage.
- Optical/photonics devices for space applications:
  —Imaging systems for detection of faint sources in vicinity of bright companion sources. Techniques for fabricating and testing low scattering optics. Modeling of coronagraphic systems.
  —Development of space-based interferometers. Techniques for co-phasing telescopes including high fidelity radiometric wavefront sensors.
  —Optical information processing. Device development including 2-D Spatial Light Modulators and volume holograms. Algorithm development for pattern recognition and feature extraction.
  —Optical materials for space applications including space hardened polarizers and optical thin films for specialized applications.

08.19 Subtopic: Optical Properties of Boundary Layer Flow Across a Cavity
Center: ARC

When the wavefront from a distant astronomical source passes through the Earth's atmosphere it is subject to disruption by atmospheric density fluctuations. The resultant image at the focal plane of a telescope is broadened and scintillates. This effect is known as "seeing." Airborne telescopes (e.g., Learjet Observatory, Kuiper Airborne Observatory (KAO)) also suffer from seeing effects, even though they are carried well above the bulk of the Earth's atmosphere. This is primarily due to the turbulent shear layer that is formed by the airflow over the open cavity in which the telescope resides. The purpose of this research task is to understand and quantify the seeing effects, to study methods of reducing the effects, and to define the limits on the optical environment to be expected in future airborne observatories such as the Stratospheric Observatory for Infrared Astronomy (SOFIA). It is expected that the research program would involve some or all of the following elements:

- Theoretical modeling.
- Wind tunnel testing.
- Tests on a currently operating observatory (i.e., KAO).

08.20 Subtopic: Focal Plane Array Processing for Position Determinations
Center: JPL

The history of the Solar System is influenced by the statistics of encounters with passing stars. The traditional detection of nearby stars by their proper (tangential) motion cannot identify stars having velocity vectors towards or from the solar vicinity. As a consequence, the stellar population in the solar vicinity is only partially known. To identify the missing population it will be necessary to measure all stars to find those with parallaxes >0.05 arcseconds. Observation of millions of stars is now within the advanced stage of the art of CCD arrays and of data processing and storage technology.

Innovative approaches are needed to develop an instrument and associated subsystems to observe a large area of the sky each year. This instrument would be for testing proof-of-concept on the 1.2 meter F/8 telescope at the NASA–JPL Table Mountain Observatory. Observation modes to be considered include (1) a tracking telescope plus framing mode CCD operations, and (2) a fixed telescope and CCD clocking for compensation of sidereal drift rate of the field of view. The concept should also be applicable for a space telescope for a voyage to 1000 AU (TAU). Innovative concepts are desired in the following system and subsystem areas:

- Develop a data collection, management, storage and retrieval concept to handle image coordinates for 105 to 106 starts per night in either the framing or clocking mode. The output display will include stars that show parallax >0.05 arcseconds from position measurements taken approximately 6 months apart, along with position coordinates of the selected objects and the magnitude of parallax and proper motion.
- Develop a CCD camera to maximize sky coverage that is compatible with the concept proposed, assuming that the telescope is used at prime focus and should attain precision measures of stars as faint as magnitude 20. The CCD camera should be optimized for the data collection and management strategy proposed.

08.21 Subtopic: Instruments for Particle Collection and Processing
Center: JPL

Innovations are required to advance the performance of instruments for the collection and processing of particles in space. Areas of interest include:

- Collection techniques for high speed dust particles in space: New concepts and techniques are needed for collection of solid micron and submicron solid particles at velocities up to a few hundred m/s in planetary atmospheres (including the Earth) and the vacuum of space. It is desirable to collect particles in a manner which does not damage them and which permits direct scanning electron microscope imaging, ion probe and X-ray analysis, with little or no handling or preparation. It is desirable that the collection surfaces not introduce interfering X-ray lines from elements heavier than fluorine.
- Sample coating techniques for use on spacecraft: New concepts and techniques are needed for applying thin (about 20 nm) carbonaceous and noble metal conductive coatings to insulating specimens with areas of about 1 mm^2, in preparation for examination by scanning electron microscopes, ion and laser microprobes on unmanned or manned space missions. The techniques should lend themselves to automation and extreme miniaturization while needing only a few watts average power for a few minutes, little expendable resources and little or no instrumentation for insuring reproducibility of the coating thickness. The process should take place in at least partial vacuum and the specimens should not be heated. Techniques might include processes such as evaporation, sputtering or chemical vapor deposition. The coatings should contain only elements lighter than sodium or a single noble metal.

08.22 Subtopic: Environmental Measurements and Analyses in Manned Space Missions
Center: MSFC

Innovative concepts are sought for measuring systems to determine the composition and levels of contaminants in confined environments such as Space Station or long duration manned missions including planetary exploration, and to determine atmospheric composition and possible toxic constituents. Included are sensitive analysis and detection methods and automated systems for integrating the various sensors required for analysis of a complex atmosphere and to compress data and present it in a usable form.

08.23 Subtopic: Behavior and Effects of Contamination in Space
Center: GSFC

With the development of highly sensitive optical instruments for use on spacecraft, it is very important to evaluate the possible mechanisms by which space systems materials can degrade system performance by condensing on functional surfaces and changing critical optical properties. These evaluations can be made by laboratory analyses, analytical modeling, or flight experiments. Innovative methods are needed in the development of scientific instruments to aid in the evaluations, especially instrumentation which can be adapted to flight use. The end results of these evaluations are to be that they supply the following information:

- Quantification of molecular and particulate contamination environment.
- Identification of the sources of contamination, its means and paths of travel, and the surfaces of possible deposition.
- Effects of ultra-violet light source upon contaminants.
- Effects of contaminants upon functional and optical surfaces.

The necessity for repair and refurbishment of spacecraft while in orbit has been demonstrated, but servicing of contamination sensitive instruments/spacecraft require a controlled environment within an enclosed volume. This environment should be similar to the one in which the spacecraft was manufactured and tested. Since clean room technology is not applicable in this case and venting/dumping the contamination generated in an enclosed volume to the external environment is not practical, development of methods and hardware for the collection of molecular and particulate contamination is essential. A further constraint is that the methods and hardware be of low power, weight, and volume. Innovative methods and hardware are needed to provide the proper environment in an enclosed volume for servicing, thus maintaining the integrity of the spacecraft.

08.24 Subtopic: Leak Detection for Spacecraft Functional Systems
Center: LeRC

A critical requirement for the successful, long-term operation of a spacecraft in orbit and the completion of its mission objectives is the integrity of its various working fluid systems. Although the repair of a fluid leak in an orbiting spacecraft, in most cases, is not practical, the timely detection of a leak could allow for the initiation of corrective actions that would minimize the fluid loss and maintain the operational life of the spacecraft.

Innovative concepts and techniques are needed to provide for early detection of a fluid leak (either liquid or gas at cryogenic or ambient temperatures) into the vacuum environment of an orbiting spacecraft. The concept should be developed with the following objectives:

- Ability to determine the magnitude and location of the leak.
- Designed for minimum size, weight and electrical power usage.

08.25 Subtopic: Non-Invasive Monitoring of Growth Parameters on a Hanging Protein Drop
Center: MSFC

Innovations are desired in non-invasive sensor techniques, optical and otherwise, to permit monitoring of growth parameters involved in protein crystal growth. The desired monitoring parameters include:

- Protein concentration.
- Salt concentration.
- pH.
- Onset of crystal nucleation.
- Imaging of crystals.

TOPIC 09.00 SPACECRAFT SYSTEMS AND SUBSYSTEMS

09.01 Subtopic: Control of Large Space Structures
Center: LaRC

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

- Advanced control system analysis and synthesis techniques.
- Fault identification, isolation, and reconfiguration.
- Advanced integrated control systems and associated components.

The focus should be on both control system design and control devices and may involve ground validation of advanced system concepts and attendant breadboard hardware.

09.02 Subtopic: Space Construction and Maintenance Tools and Techniques
Center: JSC

Innovative devices and techniques are needed in all areas of construction, repair and maintenance of structures and mechanisms in space. All tools and techniques must be compatible with the space environment and be operable by an extravehicular crewman.

- Welding and bonding: Fastening and joining of metallic and non-metallic materials.
- Electrical cable, gaseous and fluid plumbing: Splicing, cutting, joining, and forming of electrical cables and fluids plumbing. Requirements include low pressure water up to 250 psi. Gases include oxygen, hydrogen, nitrogen, argon, carbon dioxide, xenon, and helium, and pressures up to 6000 psi (nitrogen).
- Plate and structures modification: Capability for sawing and drilling of metallic and non-metallic materials with collection of particle debris.
- Alignment and measurement: Precise alignment of mating structures and measurement of relative distances upon and between object surfaces.
- Worksite aids for workplace and tool positioning and control, tool storage, illumination, instructional information, crew positioning and control, and tether systems.

09.03 Subtopic: Space Station Crew Workstation Displays and Controls
Center: JSC

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

- Multicolor flat panel electronic displays: Currently available flat panel displays for Space Station applications offer only monochromatic capability. A small volume, low power, multicolor, flat panel display is needed.
- Input devices: Develop input devices and mechanizations that (1) are simple to use; (2) the communication language results in high user efficiency; and (3) are reliable and easy to maintain.
- Data storage: Develop high density local workstation data storage aids such as optical disks, disk RAM's, floppy disks, bubble memory, etc.
- Voice recognition: Develop a voice system for data and command input that is voice independent, can understand word phrases, has a large vocabulary and has a 99% or greater accuracy rate.
- Hand controller: Develop compact hand controller devices with force feedback that could be used to support six degree-of-freedom master/slave type telerobotics space operations.

09.04 Subtopic: Space Station Shell Leak Detection and Assessment System
Center: MSFC

Air leakage from Space Station can result from (1) pressure wall perforations due to collisions with natural meteoroids or man-made orbital debris and (2) seal failures. Timely detection and repair of such leakage can become critical to crew safety and mission success. For example, a leak from a 1 mm diameter hole, or leaks with equivalent total area, can cause the 45-day make-up air supply to be consumed in 8 hours. In addition to the disruption of activity in the affected modules, the cost of a single STS resupply mission establishes the need to effect repairs promptly.

Innovative sensor and expert systems are sought which will (1) detect leakage in excess of operational specifications, (2) rapidly localize significant leaks, and (3) apprise the crew of the criticality of a leak and value of remedial actions in terms of relevant parameters such as leak rate, time to effect repairs, remaining air supply and time until next resupply mission.

09.05 Subtopic: Manned Spacecraft and Planetary Based Thermal Management Systems
Center: JSC

Future large space systems will require efficient and economical thermal management because generation, transfer and usage of electrical energy needed for these systems will result in the dissipation of huge quantities of waste heat. Innovations are needed in the following heat acquisition, transport, and rejection areas:

- Non-toxic thermal fluid: A non-toxic thermal fluid, which has a high heat of vaporization, low freezing point, high vapor pressure, high thermal conductivity and good capillary characteristics, is needed for two-phase thermal bus application internal to manned spacecraft.
- Waste heat utilization: Innovative and efficient approaches are sought to utilize low or medium temperature waste heat generated by spacecraft systems for heating and power generation applications.
- Heat pump systems: High efficiency, low electric power consumption heat pump systems are sought to raise the temperature of spacecraft waste heat at the thermal transporter/radiator interface in order to achieve significant radiator weight and area reductions.

- Advanced space radiator systems: Revolutionary low risk/high payoff approaches compatible with high temperature heat rejection such as moving belt radiators, bubble membrane radiators, and super thermal conductors should be investigated in parallel to the heat pump systems for overall reduction of radiator system weight and size.
- Thermal management in variable-gravity environments: Analysis and conceptual demonstration of thermal management applicable to spacecraft with spin-induced artificial gravity environments are required to develop conceptual designs of thermal management systems for future spacecraft.
- Multi-phase fluid flow computational analysis techniques: Techniques for computational fluid dynamic and heat transfer analysis of multi-dimensional, multi-phase flows in a zero or low gravity environment are essential to provide vital information for development of advanced multiphase thermal management technology.

09.06 Subtopic: Spacecraft and Propulsion System Thermal Design and Analysis
Center: MSFC

Analysis and design of spacecraft systems and advanced propulsion systems require advanced technologies in the area of fluid and thermal systems. This may include innovative component designs or innovative analytical techniques. Applications are related to both manned and unmanned spacecraft, launch vehicles, and upper stages. Specific areas of interest may include the following:

- Advanced heat transport systems and concepts with acceptable safety characteristics (flammability and toxicity) which can be utilized in manned spacecraft systems.
- Advanced refrigeration and heat pump system technologies are sought to meet special thermal requirements on board manned spacecraft, for storage of food and biological samples and for meeting requirements for heated water.
- Advanced techniques for low power thermal control systems in the area of coating and insulation systems and heater control circuitry, for unmanned spacecraft and payloads.
- Innovative concepts relative to high power density thermal management in propulsion system components. This may include combustion devices and turbomachinery.
- Advanced analytical techniques for fluid and thermal modeling of the systems and concepts discussed above. Analytical developments should be compatible with standard higher order languages and mainframe computer systems utilized within NASA.

09.07 Subtopic: Thermal Control for Unmanned Space Applications
Center: GSFC

Future unmanned spacecraft and space facilities will require closer temperature control than current space systems. Many missions will be farther from Earth and of long duration. These conditions will place increased requirements on thermal control systems. Areas of innovation include, but are not limited to:

- Fluid systems technology:
  - —Modeling of multiphase flows, and flow measurement techniques in zero or low gravity;
  - —Detection of very small leaks in single component, multiphase systems;
  - —High temperature (1000K) long-life heat transport devices;
  - —Low temperature (e.g., 100–250K) heat pipes;
  - —Heat pipe evaporator interfaces including contact heat exchangers, integral heat exchangers or heat pipe disconnects;
  - —Space radiator concepts and design innovations, including systems integral with spacecraft exterior structure;
  - —Radiator coatings or concepts to provide self-sealing;
  - —Modular, self-contained heat pump to allow equipment to operate at a temperature close to, but different from, the saturation temperature of a central two-phase thermal bus.
- Special thermal system capabilities:
  - —Waste heat utilization of low or medium temperature waste heat generated by spacecraft systems for heating, cooling, and power generation applications;
  - —Thermal energy storage system which periodically charges and discharges to accommodate intermittent heat loads;
  - —Integration of thermal and power subsystems to minimize total energy requirements.

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

- Mechanical cooler technology:
  - —Flexure bearing technology;
  - —Magnetic bearing technology;
  - —Gas bearing technology;
  - —Regenerator technology, including magnetically enhanced regenerators;
  - —Vibration compensation systems;

—Vibration isolation systems;
—High reliability thermal switches;
—Magnetic cooler technology.

- Stored cryogen coolers:
  —Low thermal conductance structural support systems;
  —Support systems with on-orbit release;
  —Concepts to enhance safety;
  —Innovative concepts for stored cryogen/mechanical cooler combinations.

09.08 Subtopic: STS Power Control and Distribution Subsystems
Center: JSC

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

- Solid state high power switching components: In order to handle large amounts of power on new aerospace vehicles and to provide the necessary instrumentation to support expert systems, "smart," computer-controlled, high-power switching components need to be developed.
- 20 KHz AC signal transducer/conditioners: The use of high frequency electrical power for space applications creates the need for new instrumentation. The instruments should be applicable for voltage, current, frequency, phase, and power factor measurements in AC circuits of up to 600 volts and at frequencies up to 20 KHz.
- High-efficiency 400 Hz converters: New aerospace vehicles require devices that can convert DC or unregulated AC into 400 Hz regulated power and provide maximum efficiency with minimum practical weight. Because of the many unique requirements of various loads, the approach to a modular design is desirable.
- High efficiency DC-to-DC converters: As new switching devices make high voltage DC more desirable for primary power distribution, the need for more efficient DC-to-DC converters becomes apparent. A design study should be conducted to find innovative ways of increasing the efficiency of these converters for relatively high power levels (1 to 5 KW). A second phase of the contract should deal with prototyping any concepts devised during the first phase.
- Remotely actuated (mate/demate) electrical connectors: Payload retrieval and construction in space make it highly desirable to have a series of electrical connectors which can be both mated and demated without assistance by the crew. The system should be reliable, lightweight, simple and might involve the use of robotics.
- High efficiency contactless connectors: AC power is being considered for power transmission in space. It is desirable to have a series of contactless AC connectors to aid in vehicle assembly and extra-vehicular power transmission.
- High frequency transmission line terminations and splices: The use of high frequency (20 KHz and above) will require special conductor configurations and unique termination and splicing techniques.

09.09 Subtopic: Space Transportation System and Space Station Robotic Tracking Systems
Center: JSC

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

- Solid state laser scanning device: The need exists for new and novel ways of scanning a narrow laser beam over a larger field of view. New approaches for doing this with no mechanical parts are sought.
- Hand-held optical radar: Recent studies have indicated that hand-held, in-space skin tracking optical radar can be built using new modulation techniques which enable operation over long distances in full sunlight. Direct measurement of range and range rate (doppler) are required with accuracies of 1 percent range and 0.01 fps.
- Global Positioning System: The need exists for new and novel receiver and software implementation for accurate tracking and navigation for orbital operations.
- High resolution microwave and millimeter-wave radars/radar sub-systems: Lightweight, low power radar systems are needed to solve various short range, rendezvous, station-keeping, and target tracking problems during manned and unmanned space operations. These operations will require higher tracking resolutions than are generally available. Examples include navigation aids for the Manned Maneuvering Unit (MMU), the Orbital Maneuvering Vehicle (OMV), and other proximity operations involving deployed satellites and scientific payloads.
- Laser diode LIDAR systems for ranging and velocity information.
- Optical sensor system for pattern recognition, ranging and vision.
- New signal processing techniques and hardware.
- Improved optical components such as sources, detectors, couplers, switches, modulators, and lenses for imaging systems.

- Laser and video tracking/vision sensors for autonomous and tele-operated (end-effector) automation and robotics applications. These include programmable/adaptive and high resolution 2-D video and 3-D high frame rate range/doppler imaging radars and image processors for target/feature acquisition, identification, and tracking.

09.10 Subtopic: Guidance, Navigation and Control of Advanced Space Transportation Systems
Center: LaRC

Future space transportation systems include heavy lift launch vehicles (HLLVs), AOTVs, Shuttle II, transatmospheric vehicles, and interplanetary spacecraft. To permit the economic viability of such systems, advanced techniques for guidance, navigation and control (GN&C) must be developed. These advances will be needed to improve system reliability, autonomy, and operational capability, and to reduce life-cycle costs. The objectives of these innovations are:

- Autonomous GN&C techniques which can be implemented on a typical flight computer.
- Adaptive GN&C methods which can readily adapt to environment uncertainties encountered by an AOTV or an HLLV during atmospheric maneuvers.
- Fault tolerant systems which will permit system survivability. The focus of these activities should be on derivation of GN&C techniques and algorithms and validation of promising concepts through computer simulations.

09.11 Subtopic: Tether Applications in Space
Center: MSFC

Tethers have potential roles in space in forming constellations of spacecraft and as one-dimensional structures. Applications concern power and force generation through motion through the Earth's magnetic field, spacecraft docking assist, formation flying of and momentum transfer between tethered spacecraft. Innovative uses of tethers in space and engineering approaches to tether deployment and retrieval problems are desired.

- Tether materials testing and research have been accomplished for a very narrow range of applications under the Tethered Satellite System project. Even in that program, tether dynamical properties such as viscous and coulomb damping under various tension and temperatures have not been studied in detail. Testing of tethers is difficult because some measurements require vacuum testing of long lengths implying a long vacuum chamber. Measurements in the presence of gravity also present difficulties when low tension is one of the important parameters. Research into the design of tethers to enhance performance such as achieving large amounts of damping could enhance overall performance of tether systems.
- Measurement of tether dynamics in flight is a difficult undertaking. Real time measurements are required to determine the progress of tether deployment and/or retrieval. Post flight data is required to calibrate dynamics simulations. Running line tension is difficult to measure, especially in low tension deployment profiles. Tether shape measurements using video require high bandwidths for the data and data extraction for real time closed loop control is difficult. Innovation is required to satisfy these requirements.

09.12 Subtopic: A Low Cost, CCD Solid State Star Tracker
Center: GSFC

For the past two decades, image dissector tube star trackers have been used for the fine pointing of sounding rocket payloads by tracking selected stars or by updating the inertial system. Short duration, free flying shuttle payloads such as Spartan have also used this type of star tracker. As a result of the recent advances in CCD technology, an opportunity and a need exist to develop a low cost, CCD solid state star tracker that could be used for pointing sounding rocket payloads, balloon payloads, Spartan payloads, shuttle attached payloads, and SCOUT class explorer payloads.

Innovative approaches are sought for the development of a low cost CCD array star tracker. Areas of interest include but are not limited to the examples listed below. Cost tradeoffs for each of these areas are requested.

- Field of view vs accuracy tradeoffs.
- Noise equivalent angle.
- Sensitivity.
- Sampling time/frame.
- Number of stars simultaneously tracked in field of vision.

09.13 Subtopic: Technologies for Scientific Balloons
Center: GSFC

Innovative methods for lift augmentation for "zero-pressure" balloons are sought that would alleviate the ballasting dilemma faced in all flights. The system design should be capable of operating up to altitudes of 150,000 feet and temperatures ranging from +50C to −80C. The system must be capable of maintaining the balloons altitude within 10,000 feet of its theoretical float altitude for a minimum of two weeks flight duration. The design should be highly reliable and more weight effective than present ballast systems.

Innovative approaches are needed to measure the multiaxial states of stress or strain induced in the membrane skin and loads in the load tapes. These methods of measurement should be non-intrusive to the balloon system and be capable of monitoring the condition of the balloon ascent from dynamic ground launch through the troposphere to final float at altitudes up to 150,000 feet. The sensors must be capable of operating in a temperature range of +50C to −80C and not jeopardize the structural integrity of the balloon. Measurements from the sensors must be retrievable in real time through a telemetry link between the balloon and ground receiving station.

09.14 Subtopic: High Temperature Superconductor Applications for Space
Center: GSFC

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

- Sensors.
- Magnetic levitation.
- Pointing and attitude control system technologies.
- Microwave communication technologies.
- Materials processing aids.
- Thin film high temperature superconductor technologies.
- Power system technologies.
- Cryogenic applications.
- Superconducting electronics and high speed processing.
- Propulsion system technologies.
- Bolometer technologies.

TOPIC 10.00 SPACE POWER

10.01 Subtopic: Spacecraft Electrical Power and Energy Systems
Center: LeRC

Innovations are desired in all aspects of systems for the generation, storage and management of electrical power in spacecraft of all types, including: (1) unmanned small untended, autonomous operation and long lifetimes and for which compactness and high power/energy densities are required, and (2) larger permanent space station installations, orbiting platforms, planetary transfer vehicles or planetary installations, which may be manned or unmanned and which require autonomous operation or minimum astronaut intervention.

Emphasis should be on advanced, innovative concepts which increase efficiency, and decrease size and weight, and which enhance operating lifetimes, manufacturability, and verification testing of systems and components.

Disciplines and technologies of interest are:

- Energy conversion systems:
  —Photovoltaic systems technology; thin film cells, InP cells, multiple bandgap cells, homojunction and heteroface cells, recombination effects, radiation resistant cells and approaches for reducing radiation effects and concentrator array technology;
  —Brayton, Rankine, Stirling cycle technologies; alternator concepts; advanced solar concentrators/mirrors with associated structures.
- Energy storage systems:
  —Electrochemical; advanced fuel cells, primary and regenerative; advanced high energy density rechargeable batteries, (excluding lithium);
  —Thermal storage; receiver and heat storage concepts for solar thermal power systems;
  —Advanced energy storage concepts beyond the present state of the art.
- Power management and distribution systems:
  —Materials for power electronics;
  —Electronic devices; transistors; diodes; transistors for high current, high voltage, high frequency distribution systems;
  —Control of high voltage-high power-high frequency systems.
- Thermal management and control systems:
  —Advanced lightweight heat pipes for high and low temperature systems;
  —Innovative thermal management and control concepts.
- Interactions with the space environment:
  —Interactions of space systems with local plasma field, and neutral environments both natural and generated by the system. Emphasis is on electrostatic/electromagnetic effects including charging, arcing/breakdown, plasma-plasma and plasma-neutral interactions, and dynamic effects;
  —Mechanisms of free oxygen interactions with surfaces, including associated chemical species interactions.

- Automation and control of large space power systems:
  - —Innovative classical/traditional approaches to system control;
  - —Applications of Expert Systems/Artificial Intelligence, (ES/AI) logic to power system operation and control.
- Materials for space power systems:
  - —Materials which enhance the performance and durability of advanced space power systems through reduced degradation due to interaction with the space environment, operate at higher temperatures, and enhance compatibility between materials;
  - —High performance double optical, radiative thermal and electrical materials.
- Systems analysis and design:
  - —Methodologies for the design and analysis of space power systems with emphasis on ease and simplicity of use, and ability to handle all types of realistic constraints;
  - —System and subsystem simulations to analyze design sensitivities, including off-design performance;
  - —Computer codes to assess performance and cost effectiveness of space power systems and applications.

10.02 Subtopic: High Energy Density and Long Life Batteries

Center: JPL

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

10.03 Subtopic: Corona Detection at 20KHz Applied Voltage

Center: GSFC

The current 20KHz power distribution system proposed for the NASA Space Station at voltage levels of 440 volts rms and 208 volts rms is quite revolutionary in terms of behavior of parts and components under certain environmental conditions that might occur. Portions of Space Station where the 208 volts rms 20KHz exist may at times be subjected to partial pressures rather than high vacuum or atmospheric pressure. It is not clear from the literature whether corona or partial discharge might then occur in the electronic parts or subassemblies. Simple Paschen curves of gaseous breakdown voltages versus electrode spacing times pressure taken with 20KHz power do not exist, whereas gas breakdown curves abound at DC, 60HZ, 400HZ and multipactor curves at gigahertz frequencies.

There is a need to perform partial discharge of corona measurements on parts and components in vacuum systems on the ground with 20KHz applied voltages, but the measurement equipment is not commercially available. Current available commercial corona detectors convert the nanosecond partial discharge pulses to microsecond damped shock oscillations by means of an LCR detection network. This is then followed by a high-pass filter to eliminate the power frequency signal and its harmonics. The higher frequency oscillations are then amplified at suitable bandwidths and counted. The necessary development work for 20KHz applied voltage has not materialized because the power frequency pulse width now is of the same order of magnitude as the pulse width of the LCR detection network. Alternatively, RC corona detection networks for the nanosecond partial discharge pulses have not been commercially developed to the uniformity and repeatability of calibration as the LCR detectors. Innovative approaches are required to develop the necessary corona test equipment for 20KHz applied voltage of up to several thousand volts.

10.04 Subtopic: Photovoltaic Laser Energy Converters

Center: LaRC

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

10.05 Subtopic: Space Power Systems Automation
Center: MSFC

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

10.06 Subtopic: Power Transmission and Propulsion Applications of High Temperature Superconductivity
Center: GSFC
JPL
LeRC
MSFC

Opportunities exist in the development of space power and propulsion applications of high temperature superconductors. Research areas in power and propulsion include:

- Large energy storage capacity systems with low specific mass/energy ratios.
- Efficient energy conversion in the form of ac and dc rotating machines, and efficient transmission of electric power.
- Applications in electric propulsion.
- Advanced nuclear propulsion (fusion, antimatter).
- Electromagnetic launchers/mass drivers.
- Electrostatic tethers.

Key innovations are necessary to optimize composite material characteristics in the area of:

- Critical current density.
- Magnetic field tolerance, stress tolerance and radiation tolerance.
- Wire/busbar material processing.
- High strength/mass ratio strengthening materials.
- Low mass active/passive electromagnetic shielding materials and techniques.
- On-board systems interaction with planetary and solar B-fields (torque shielding).
- Biological effects of high fields on humans.
- Long life/low gravity refrigeration (e.g., adsorption) and radiative cooling systems.
- High magnetic energy/field configurations (solenoidal, toroidal, monolithic rings).
- Loss reduction in ac rotating machines.
- Power processing.
- Fast pulse switching.
- Magnetic nozzle design.
- Plasma confinement/control.

TOPIC 11.00 SPACE PROPULSION

11.01 Subtopic: Solid Rocket Motor Technology
Center: MSFC

Several areas of solid rocket motors (SRM) require innovative advances in analysis, production, and testing:

- Test-derived failure criteria for carbon-carbon involute and/or carbon-phenolic materials, implemented in an algorithm for predicting failure, and demonstration of algorithm validity in predicting failure of specimens at high temperature and with stress to failure.
- Alternate and novel methods to reduce the process variability and to reduce fabrication costs of filament wound composite cases.
- NDE methods to detect weak or "kissing" unbonds in the propellant-liner-insulation-case interfaces to a level compatible with acceptance inspection of large SRMs. Weak bonds and kissing unbonds occur occasionally in solid rocket motors ("kissing" unbonds are defined as the condition where the surfaces are in firm contact, but not bonded together). There currently exists no method for detecting them.
- New and/or advanced techniques for the measurement of temperature and strain in or on composite nozzle materials. Existing instrumentation techniques are inadequate in temperature range and response time for evaluation of SRM carbon-carbon and carbon-phenolic nozzle structures and/or validation of analytical models during hot

fired conditions. Current temperature/strain capability is limited to the range of 700F to 1000F, whereas accurate engineering data is needed for temperatures up to 4000F and strain data at temperatures of at least 2000F. New techniques must function accurately and reliability under high heat flux and transient thermal conditions with low strain rates.

11.02 Subtopic: Solid Rocket Performance and Internal Ballistics
Center: MSFC

Current solid rocket performance and internal ballistic codes are based mainly on analytical techniques or simplified one-dimensional methods. The innovative use of two- and three-dimensional computational methods for solid rocket ignition and main-stage performance predictions are sought. Specific areas of interest include:

- Efficient and generalized computational methods for two- and three-dimensional propellant burn back modeling, including generalized methods for defining and displaying propellant geometries and for calculating the time history of the propellant surface geometry accounting for the fundamental propellant grain burn rate parameters. The computational method must be easily integrated into a solid motor performance code which may include a CFD-based flow analysis.
- Advanced, efficient, and innovative CFD methods for the analysis of solid motor ignition transients, including multi-phase flow with liquid and solid particles, two- and three-dimensional grain geometrics, propellant grain ignition thermodynamics and kinetics, compressible and time accurate dynamic (acoustic) effects, and providing an accurate simulation of internal thermal environments, pressure rise rates, and motor thrust buildup.

11.03 Subtopic: Liquid Rocket Engine Combustion Processes
Center: MSFC

Current state-of-the-art CFD-based combustion codes have deficiencies in fundamental physical models as well as in efficient methods for handling multiple two-phase fluid interactions. Enhanced capabilities, innovative methods, and improved efficiencies are particularly sought in the following areas:

- Analytical models which can efficiently predict the atomization or droplet stripping process of an injected liquid jet, with the prediction of droplet size and distribution based on the fundamentals of the fluid flow and injector design parameters and configurations. These model(s) should be applicable to all injectors including coaxial and impinging jet and should be time accurate and provide dynamic solutions for combustion stability analysis.
- Innovative and efficient methods to model liquid spray trajectories, including droplet-wall, droplet-droplet, and droplet-gas interactions. The interaction of two different liquid spray jets is of special interest.
- Analytical models of the physics and chemistry fundamentals involved in spray combustion including droplet vaporization and/or secondary breakup, droplet combustion, dense spray interactions, and flow and combustion turbulence interactions.
- Analytical models of the specific physics and chemistry involved in super-critical combustion.
- Advanced innovative and efficient models of the chemical reactions involved in combustion devices especially including the kinetics and multi-step reactions for LOX/Hydrocarbon reactions.
- Innovative experimental studies, devices, and/or development of flow diagnostics and measurement systems designed to anchor models of the fundamental physical and chemical processes involved in combustion devices. Of special interest are experiments or diagnostics for jet atomization studies, droplet size and distribution assessments, dense and dilute spray combustion processes, super-critical combustion processes, and tri-propellant and metalized propellant combustion kinetics and reactions.

11.04 Subtopic: Liquid Engine Internal Flow Dynamics
Center: MSFC

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

- Computational techniques for coupling 3–D time-dependent flow solvers to 3–D structural models.
- Multiblocking or zonal techniques for obtaining efficient Navier-Stokes solutions in complex 3–D domains.
- Techniques for analysis of incompressible, 3–D flow with phase change for turbopump bearing, seal, injector, and pump analysis.
- Techniques for analysis of unsteady incompressible and compressible flows over vaned elements in turbine and pump environments.
- Techniques for interfacing CAD/CAM IGES files to surface and grid generators used for structured

mesh solvers for complex internal flow geometries.

- Techniques for efficient and accurate prediction of fluctuating quantities for incompressible internal flows in complex domains.
- Improvements to viscous flowfield calculation procedures to account for nonisentropic boundary layers in regeneratively cooled nozzles.
- Techniques of analysis addressing heat transfer and associated radiation levels for reacting and nonreacting flows, with emphasis on heat transfer in liquid engine combustion chambers and nozzles.

11.05 Subtopic: Long-Life, High-Performance, Small Chemical Rockets
Center: LeRC

New space system capabilities, such as spacecraft propellant resupply, use of Space Station waste fluids to augment platform propulsion, and more energetic, longer life, missions have greatly expanded the leverage for improved rocket lifetime and performance. Advanced technologies for small, radiation cooled rocket chambers have promise of extending chamber lifetimes and simultaneously operating at increased specific impulses. Concepts are desired which are compatible with a variety of potential propellants, including H/O, Earth storable, and monopropellants augmented with Space Station waste fluids.

In monopropellant hydrazine thrusters, the life-limiting component is the catalyst bed. Catalyst beds are used in some resistojet thrusters and have potential use when arcjets are ultimately used in space. Electrothermal catalyst beds have long catalyst life, but suffer from nonvolatile residue (NVR) build-up in the injector tube due to heat soak back from the reaction zone. The injector then becomes clogged, ending the beds' useful life. The catalyst bed operates at temperatures that create excessive heat loads on the injector tube. The spontaneous type of catalyst bed (shell 405) operates at considerably lower temperatures, due in part to the decomposition of larger amounts of ammonia (an endothermic reaction). The catalyst, however, is susceptible to thermal shock and poisoning by low purity hydrazine. Thruster duty cycles and the use of nonpurified hydrazine quickly destroy the catalyst. Specific innovations required are:

- Innovative materials, coating technologies, fabrication technologies, and chamber/injector designs for small chemical rockets are sought to achieve long-life, highest possible performance, and propellant flexibility with minimum design changes. Chamber approaches compatible with fundamental diagnostics and which can be tested with minimum costs are especially desired. Government facilities will be made available for proof-of-concept and extended life tests.
- An innovative electrothermal catalyst bed design for hydrazine decomposition is sought that will reduce the heat load on the injector tube by proper sizing and placement of the ammonia decomposition reaction zone to withdraw the heat liberated from the hydrazine to nitrogen and ammonia reaction zone. The goal is to increase the life of an electrothermal catalyst bed by eliminating the NVR problem. Government facilities will be made available for testing the life of this hybrid catalyst bed.

11.06 Subtopic: Space Basing of Rocket Engines
Center: LeRC

Space basing and reusability of rocket engine systems introduce the requirements for long duration compatibility of rocket engine system components with the environment of space automated checkout and condition monitoring systems. Space basing means that rocket vehicles will be stationed in space for years and will accrue many missions to a variety of destinations. Condition monitoring systems will be used to predict the remaining life of major components and subcomponents. In general, algorithms relating to the remaining life of a component are not available. However, it appears likely that, for example, by obtaining accurate measurements of the deformation of the hot gas wall of a thrust chamber, simple and very useful chamber life prediction algorithms can be developed. Innovations are sought, then, in areas such as the following:

- To address the problem of the space environment: Innovative materials, methods of protecting engine components and methods of making engine systems tolerant to exposure induced faults are sought. This includes addressing the following information and technology: Listings of candidate rocket engine components and materials, and the effects of space hazards on them; methods of reducing the effects; methods of fault tolerance; and procedures for ground investigation of the effects and verification of prevention methods. Some suspected space hazards include: Exposure to monatomic Oxygen; radiation effects induced by transit and loitering through the Van Allen Belts; thermal variations; micrometeorites; and contamination of foreign materials such as spacecraft expellants and lunar dust. Some candidate spacecraft components include: Metallic and nonmetallic materials, mechanical structures, joints and flexures, actuators, and electronics instrumentation.

- To address the need for condition monitoring: Concepts are sought for a system that will non-destructively measure the interior deformations of a thrust chamber, process the information, and display it in a useful manner. The measuring system should be readily transportable (it should be taken to the location of the engine).

TOPIC 12.00 HUMAN HABITABILITY AND BIOLOGY IN SPACE

12.01 Subtopic: Medical Sciences for Manned Space Programs
Center: JSC

As the goal of permanent occupancy in space becomes a reality, there exists a need for providing a wide range of medical services to space crew members. There is also a continuing need for maintaining excellent health of astronauts during their preflight periods and for profiling their health characteristics. Many areas of medicine are candidates for innovations:

- Analysis of small volume specimens.
- Determination of decompression sickness before significant symptoms occur.
- Measurement of changes in bone mineral and muscle status over short term intervals (weeks-months).
- Measurement of changes in immune system over short periods and quantify effect of stress and radiation.
- Operational solutions to the problem of Space Adaption Syndrome including effective countermeasures, reliable and predictive tests, and understanding of the mechanisms of space motion sickness.
- Automated portable multi-gas sampling gas chromatograph.
- Ways to estimate circulating red blood cell mass during flight.
- Simple means to measure mass of crew members and of biological samples in microgravity.
- Imaging devices including magnetic resonance, X-ray, and ultrasound.
- Simple rapid determination of a micro-organism causing disease in crew members and/or estimation of its antibiotic sensitivity.
- Constitution and administration of fluids intravenously in a microgravity environment.
- Storage, constitution and administration of blood or blood substitutes.
- Computerized scanning device for diagnosis of disease/trauma in multi-organ systems.
- Oscillatory tooth remover for extracting human teeth. Other innovative zero-g dental hygiene devices.
- Systems for assessment of gastrointestinal function during extended spaceflight.
- Space microgravity bioreactor.
- Automated devices for measuring drug countermeasures in blood, urine, etc.

12.02 Subtopic: Waste Stabilization, Reclamation, and Monitoring for Space Station
Center: MSFC

Habitability and laboratory operations planned for Space Station will lead to the generation of significant quantities of wastes in a variety of states. The safe and efficient operation of the Space Station demands that these wastes be stabilized, reclaimed for reuse if possible, and routinely monitored. As a result of these needs, innovations are required in the following areas:

- Waste stabilization: Technologies are sought which may be applied to the Process Materials Management Systems (PMMS). In particular, effective methods are required to provide adequate containment of hazardous materials used in the various experiment racks and to stabilize the multiphase waste effluents generated therein.
- Waste water reclamation: Technologies are sought which may be applied to the PMMS and life support water reclamation subsystems. In particular, effective methods are required to produce, from appropriate waste experiment fluids, water equivalent to ASTM Electronics Grade E-1 with a pyrogen level not to exceed that defined in USP XX1. Development of technologies to remove trace contaminants to low parts-per-billion levels are required. Minimum weight (fixed and expendable), volume, and power, as well as maximum reliability, flexibility, and commonality is required.
- Monitoring: The development of unique sensors sensitive to specific hazardous contaminants or groups of contaminants are required to effectively detect airborne leaks resulting from laboratory operations. Also, development of an automated, on-line monitor capable of near-real time measurement of microbial contamination in water in the range of 1 CFU/100 ml is required. Emphasis will be placed on reliability and accuracy as well as minimum crew involvement, sample size, and expendable use. Contamination of the processed water supply via the microbial monitor shall be prevented.

12.03 Subtopic: Advanced Mission Environmental Control and Life Support Systems
Center: JSC

Innovations are needed in the following areas of Environmental Control and Life Support to increase human productivity and system performance:

- Carbon Dioxide (CO_2) removal: New technologies are desired for removing and maintaining CO_2 level in habitable atmospheres below 1 millibar. Current technologies based on the well-known oxygen/hydrogen fuel cell and amine resin approaches are not highly efficient and complexities are associated with their operation. The environments to be considered include long-duration manned planetary spacecraft voyages and Lunar/Mars bases. Efficiency, application flexibility, minimum complexity with high reliability and minimal power, size, and volume are ultimate goals.
- Oxygen (O_2) recovery: New technologies are needed for direct recovery of oxygen from CO_2 in habitable atmospheres. In order to obtain O_2 from CO_2 with current regenerative technology, the CO_2 is initially removed from the atmosphere and concentrated by electrochemical and/or amine resin absorption processes. The CO_2 is then reduced with hydrogen over a catalyst at high temperatures to produce water (Sabatier and/or Bosch process), and the water in turn is then electrolyzed to obtain oxygen and hydrogen. For long-term manned missions, newer innovative regenerative life support technologies are required that circumvent one or two of these processes and are more direct in obtaining O_2 from CO_2. A reduction in system complexity, weight and volume are desired goals along with improved system reliability and performance. Additional applications include lunar and Mars bases. Utilization of the resources available in these environments is economically advantageous. The lunar soil is abundant in ilmenite ($FeTiO_3$) mineral. Development of processes for direct extraction of the oxygen from this mineral are important. The Martian atmosphere total pressure is 8 millibar and its makeup is approximately 95% CO_2 and the Martian surface in the polar regions contains dry ice. Development of technology to obtain this O_2 from the CO_2 that is efficient, reliable with minimum complexity and compatible with the Martian environment are ultimate goals.
- Water reclamation: The current technology for purification of waste waters for potable and hygiene usage includes: (1) chemical or heat disinfection pretreatment for providing microbial control; (2) phase change distillation and/or reverse osmosis (hyperfiltration) for removal of organic impurities; (3) sorbent bed filtration for final chemical purification; and (4) heat disinfection followed by addition of residual biocide to provide reclaimed water free of microorganisms. Newer innovative regenerative life support required for long-term manned missions that will reduce the complexity of operation by eliminating and/or circumventing several of these purification steps. Efficiency, flexibility in processing types of waste waters, reliability and minimal power, size and volume are ultimate goals.
- Waste reclamation: Solid waste (both biological and trash) handling and storage represent significant impacts upon planetary bases and missions. New innovative processes are required to economically and reliably convert these materials into useful products. Wet oxidation and super critical water oxidation have been examined in the past.

12.04 Subtopic: Bioregenerative Life Support Systems
Center: ARC

It is anticipated that methods for regenerative human life support will be needed for extended space missions. Regeneration of oxygen, food and potable water will reduce the need for resupply and will increase the potential duration and extent of missions. The ability to regenerate life support materials will depend on the efficient and stable operation of many integrated sub-systems, including those required to grow food, process food and wastes, and maintain system control. Among areas in which innovations are sought are:

- Monitoring and controlling gas composition.
- Separation of gases and recovery of oxygen.
- Evaluating higher plant crop state, including identification of plant pathogens (viral, fungal and bacterial) that are airborne or distributed in liquids.
- Evaluation of volatile and soluble organics produced by plants in air, transpired water and in recirculating hydroponic solutions.
- Methods for processing harvested plant or algal materials into acceptable foods on a small scale.
- Methods of processing inedible biomass into usable food materials.
- Rapid and energy efficient methods of oxidizing organic materials.
- Simple methods for separating and utilizing inorganic soluble and precipitated materials as plant growth nutrients.
- Methods of utilizing low-grade waste heat for regenerative life support processes.

12.05 Subtopic: Human Factors for Space Crews

Center: JSC

To allow crew members to perform all inflight operations, including white and blue collar jobs, inflight maintenance, construction, servicing, both intra- and extravehicular, innovations are required to enhance and augment human capabilities and to optimize human performance and productivity in zero-g and reduced-g environments. Innovations are also required to enable optimum spacecraft layout/arrangement and operations, especially for longer-term and/or reduced-g missions. Examples of desired innovations include:

- Means to acquire anthropometric and biomechanical kinematic and dynamic data to optimize human performance in space and to use in theoretical and applied design models for spaceflight.
- Techniques for providing data and models of human perceptual and cognitive processes for use in the development of intelligent systems for space applications.
- Innovations in the application of new technologies to enhance human/telerobotics and human/automation interfaces.
- Design and development of efficient lighting sources that are lightweight, utilize minimum power, provide high lumen output per watt, and are safe for inflight use.
- Methods to define, reduce and/or control spacecraft noise (e.g., materials, interior arrangements, crew aids) are desired, with consideration given to weight and volume penalties.
- Techniques for display of and interaction with multiple dimension data, such as multiple parameters of triply redundant systems. Volume and weight must be considered.
- Techniques for facilitating the layout and arrangement of spacecraft interiors to promote effective and efficient use of the zero-g environment in carrying out living and working tasks.
- Techniques for optimizing spacecraft interior decor. Consideration must be given to the spacecraft environment and mission/operations constraints, including weight, power, materials and crew time.

12.06 Subtopic: Intravehicular Systems for Space Crews

Center: JSC

The advent of extended duration manned spaceflight and planetary missions has created the need for new systems designs to increase the performance and productivity of the flight crews, and to have a positive influence on their physical and mental well being. Innovations are desired in the following crew equipment areas:

- Crew hygiene: Systems for male and female body and hair grooming, oral cleansing, and shaving under microgravity and closed environmental systems conditions. Included are contaminant removal systems/filters for reducing the loading of solids and other contaminants into water reclamation systems.
- Temporary solid trash handling: Systems for collecting, deodorizing, storing and packaging of paper, food scraps, plastic wrappers and other solid trash for processing onboard manned space vehicles.
- Equipment tracking and management: Systems and components to enhance or augment the tracking, stowage and inventory management of crew equipment and supplies (e.g., tools, food, clothing, wipes, pharmaceuticals, soaps and other expendables) with end goals of reducing crew workload, automating the identification of resupply requirements, rapid location of stowed items and improved housekeeping.
- Still imagery: Electronic still frame recording device for use in microgravity, having high resolution capability and image recording capability on removable/reusable media. Imagery in the visible spectrum with resolution approaching commercial 35mm photographic systems are design goals. Consideration must be given to size, weight and portability for hand held operations.
- Data transmission: Means of providing transmission of data, graphics, photographs and electronic images both uplink and downlink. Included is a recorder/processor capability for reproducing the data on film (either positive or negative) or providing paper copies.
- Visual observation aids: Means to provide high resolution visual observation from intravehicular viewing stations/windows of targets and activities in the proximity of and at some distance from orbiting vehicles.
- Inspace/planetary food production: Techniques and equipment for growing, harvesting and preparation of edible foodstuffs in space and/or in planetary bases will be required for permanent manned presence in extraterrestrial environments. Combinations of production techniques should be investigated to produce an optimized strategy. The impacts of such techniques on closing the life support systems should also be considered.
- Food packaging and service: To enhance the interface between man and the food service system during extended duration space and planetary missions, techniques adaptable to a microgravity environment for packaging, preparation and serving solid and liquid foods are required to provide a functional system. Included are uses of

automation to reduce the amount of crew involvement in food preparation, clean-up, inventory and resupply activities.

- Food storage: Techniques and methods for extending the shelf life of fresh fruits and/or vegetables.

12.07 Subtopic: Extravehicular Activity (EVA)
Center: JSC

With the increased utilization of EVA to support space missions, technological advancement in the following areas is required:

- Speaker independent voice recognizer: Techniques to provide a reliable speaker independent isolated-word voice recognizer in a compact, low-power package that may be used to scroll an information display or activate remote switches. A minimum of 25 words is required with a true recognition efficiency of 98% (no substitution errors, only rejections).
- Vomitus collection device: Techniques to provide a reliable, safe, and compact means for storage of vomitus within the spacesuit assembly that is designed for hands-free operation are needed. The device must be unobtrusive during normal operations, yet easily and quickly available when needed.
- Humidity/CO_2 scrubber: Techniques to remove water vapor and CO_2 within the oxygen environment of the EMU that are low power, reliable, and compact. The device must allow regeneration and reuse without requiring the use of expendables for a period of at least one year in the spacesuit environment.
- Compact chemical oxygen system: Techniques to provide a compact, reliable emergency oxygen backup for either breathing or to sustain pressure integrity of the spacesuit.
- Urine collection device: Techniques to provide an easily reserviceable or low mass, conveniently disposable device from which urine can be extracted for reprocessing. Devices are needed for both male and female use in the spacesuit environment. Since a disposable device is envisioned, concepts which are inexpensive to manufacture, yet reliable, are required.
- Spacesuit insulation material: A lightweight, highly durable, long-term wear, mono-layer insulation material to replace the current multi-layer, aluminized mylar material utilized in spacesuit thermal garments.
- Extravehicular (EV) gloves: Hardware oriented design concept prototypes of EV glove finger/thumb, metacarpal and wrist joint mobility system elements are needed. The gloves must provide a high degree of hand mobility at 8.3 psi operating pressure without loss of hand tactility or at the expense of hand comfort.
- Trace contaminant control: A compact, regenerable, low-power trace contaminant control technique is needed for use in spacesuits. The method must completely remove noxious and toxic contaminants and be easily regenerable to avoid the launch weight cost of an expendable system. Since the free volume of the spacesuit is low (approximately 2 ft^3) the system must be very effective.
- Efficient production of liquid cooling garments: Current concepts of liquid cooled garments are mainly handmade resulting in expensive unit cost. Methods of efficient production which still allow good full-body fit and good thermal performance are needed.
- Exercise suit: Innovative concepts are required to provide an exercise suit which will provide the proper muscle and skeletal loading necessary to reduce the detrimental affects of the zero-g environment on the human body.

12.08 Subtopic: Life Sciences Spaceflight Hardware Development
Center: ARC

Life science payloads provide basic scientific information on the response of living systems to the space environment as well as possible explanations of the human response and adaptation to space. Innovation is sought in areas which will enhance or enable the full flight experiment potential of unicellular organisms, animals and plants through improved care, support, observation and monitoring techniques for the Space Station.

- Implant telemetry for direct biosystem monitoring or control.
- General improvement in physiological monitoring techniques for inflight and ground studies of cardiovascular, skeletal, vestibular, hematological, reproductive, and other changes occurring during spaceflight.
- Automated food delivery and waste management systems for measuring food and water consumption as well as waste product monitoring, volume collection, sampling and storage. Also metabolic holding facilities for rodents to permit complete waste collection and gas exchange measurements.
- Plant research chamber designs incorporating control of irradiance, temperature, humidity, carbon dioxide concentration and nutrient delivery/watering in microgravity.
- Small scale breeding facilities for spaceflight use with animals such as monkeys, rats, mice, and frogs.
- Environmental control and monitoring systems applicable to various species for maintenance of desired temperature, humidity, vibration, atmosphere and other factors during spaceflight.

- Application of various techniques and hardware to zero-g conditions, such as animal holding and husbandry facilities, incubators, surgical techniques, wet chemistry processing, biochemical analysis, and continuous flow processing for aerobic and anaerobic fermentation.
- Centrifugation technology to provide an artificial gravity environment during spaceflight and a research tool for biological studies in microgravity.
- Techniques applicable to contamination, control, contamination monitoring, biosolation, etc. (e.g., cage cleaner).

12.09 Subtopic Physico-Chemical Life Support Systems
Center ARC

It is anticipated that advanced methods for physico-chemical life support systems will be needed for long term human presence in space and on other planetary bodies. Advanced physico-chemical concepts for the regeneration of oxygen, water, and food will increase the duration and extent of future missions and improve the quality of the space environment. Among areas in which innovations are sought include:

- Simulation software to model physico-chemical life support systems processes.
- Techniques to integrate qualitative and quantitative intelligent systems modeling methodologies into an automated modeling tool for physico-chemical life support systems.
- Fusible materials for life support thermal control.
- Materials for mechanical applications in life support.
- Concepts for the processing of waste streams into usable materials.
- Filters and filter technologies for life support.
- Integrated instrumentation systems for monitoring water quality.
- Integrated systems using biological and physico-chemical processes.

12.10 Subtopic Biological Sciences Operations
Center KSC

Innovations are required in a number of areas to support the conduct of research on earth and in space. These areas include:

- Improved methods and techniques of laboratory support for specialized plant and animal studies.
  —Monitoring indicators of stress (i.e., chemical substances, physical parameters) to detect plant and animal stress in sufficient time to treat the problem;
  —Maintenance of animals in specific pathogen-free or gnotobiotic condition while housed in ground facilities;
  —Remote environmental sampling methodologies for biospecimens, microprocessor control systems, software packages for data analyses, and expert interactive system control and system maintenance;
  —Compact, energy efficient subsystems to process waste and inedible biomass into acceptable food products or forms reusable by plants for recycle;
  —Nutrient delivery systems for higher plants using positive supply techniques (i.e., without gravity), both fibrous and tuberous root systems;
  —Robotic subsystems to seed and harvest plants.
- Development of flight hardware for experiments aboard spacecraft.
  —Miniaturized and highly reliable nutrient delivery systems for plants and animals;
  —Automated atmospheric monitors with ultra low level trace contaminant capabilities;
  —Methods to generate and provide lighting for plant growth aboard spacecraft at low levels of power and variable spectral qualities.
- Specialized research to solve specific problems anticipated for space applications, such as:
  —Accurate and continuous control of lighting and environmental variables for plant growth units;
  —Tissue culture techniques, both ground-based and space-based;
  —Genetically improved plant material to maximum yield and minimize non-edible food yield over time and reduce total value required with high energy conversion efficiency;
  —Techniques for growing plants with special capabilities (e.g., evapotranspiration; removal of toxic substances from the atmosphere).
- Specialized instrumentation for remotely monitoring environmental parameters.
  —Miniaturized infrared or other appropriate sensors to detect wildlife movement into and out of an underground burrow;
  —Miniaturized camera systems for penetrations of underground burrows for wildlife inventories (systems should be remotely controlled, completely waterproof, and easy to transport in a field situation);
  —Development of specific sensors (e.g., water level, flow, pH, salinity, turbidity, selected cations, etc.) to remotely monitor parameters and to transmit data to a base data storage system for summary and analyses.

TOPIC 13.00 QUALITY ASSURANCE, SAFETY, AND CHECK-OUT FOR GROUND AND SPACE OPERATIONS

13.01 Subtopic: Ground Operations Instrumentation
Center: KSC

Ground testing and launch of space hardware involves measurement of a large number of parameters in a field operations environment. Following are examples of areas in which new, innovative approaches are sought:

- Contamination detection:
  —Reliable, traceable calibration of commercial Aerosol Particle Monitors for particle counts as well as for particle size. Current methods provide size calibration, but do not provide absolute calibration of particle count.
- Hydrogen/oxygen detection:
  —High reliability, low maintenance H_2 gas detector with range of 0–8% which can operate in air, N_2, He, or changing mixtures of all three. Portable meter and fixed 0-5 VDC sensors are needed;
  —Improved mass spectrometer-based system for detection of trace or % LFL (lower flammability limit) H_2 and O_2 levels (Detect H_2 10 ppm to 4%; O_2 10 ppm to 4%; He 1 ppm to 10%; Ar 1 ppm to 1%). The technical challenge is to meet or exceed present analytical capabilities (computer-controlled quadruple mass spectrometer with triode ion pump) with pumping capabilities which (a) survive launch vibration and (b) do not become saturated with hydrogen within 4–6 months. Improvements are sought in (a) high vacuum pumping techniques, (b) ionizer design and (c) data handling techniques;
  —Multispectral color TV for hydrogen fire detection: Develop color television system capable of imaging and displaying hydrogen fires with normal ambient background, including full day light with open sky background.
- Toxic vapor detection for N_2H_4, MMH, and HCl:
  —Personal dosimeters capable of measuring TLVs with total accuracy of +25% on 5-minute exposure;
  —Portable survey meters with range of 0 to 10 times TLV with total accuracy of +25% and response time to 30 seconds for 90% of change to new value;
  —Length of stain tubes capable of measuring TLVs with total accuracy of +25% of reading in 30–120 seconds;
  —Continuous area monitors capable of operating 30–60 days without maintenance or adjustment, measuring over range of 0–10 times TLV with total accuracy of +25% of reading, and a response time of 30-60 seconds for 90% of change.
- Mass measurement: Innovation leading to the development of a flight weight hydrogen mass measuring device that measures the fluid head (Δp) when fluid is not in a single state. The transducer could possibly use some type of mechanical multiplier (area ratio piston, diaphragm stem, or double diaphragm) which would increase the strain applied to the sensor by the area ratio of the multiplier providing an accurate measurement of loaded triple point hydrogen.
- Electrical path verification within disconnect: The development of remotely operated umbilicals at KSC for future launch vehicles resides in the ability to eliminate the requirement of a liftoff or T-O umbilical. This capability can only exist if umbilicals can be removed some minutes prior to launch but with the ability to reconnect to the launch vehicle in abort situations to unload propellants from the vehicle and/or continue ground servicing. For the case of reconnecting an umbilical to a flight vehicle, innovative approaches are sought to remotely verify electrical continuity between flight and ground connector pin functions without exercising the functions themselves. These may be power supplies, discrete or analog signals, and grounds. When mating electrical connectors contained in a remotely operated umbilical, assurance must be made that no critical pin function is lost, that no inadvertent control function occurs, and that proper measurements can be received.

13.02 Subtopic: Propellant Handling
Center: KSC

Many opportunities exist for innovative concepts to improve the safety and reliability of propellant handling and transfer systems for launch vehicles. These include:

- Ice elimination on cryogenic disconnects: The ability to reconnect a remotely operated, robot controlled umbilical to a flight vehicle after an abort and safely unload cryogenic propellants is directly affected by flashing of frost and ice on the disconnects when the umbilical is separated. Innovative approaches are sought to eliminate frost and ice buildup on the disconnects from the instant of separation. All approaches must include consideration of materials compatibility with liquid oxygen and hydrogen. Electrical approaches which could generate an arc or create enough heat to ignite the propellants cannot be tolerated.

- Remote verification of disconnect seals: Due to the hazardous nature of the hypergolic propellants nitrogen tetroxide and hydrazine, the mating of ground servicing disconnects to flight hardware requires a verifiable leak tight seal between flight and ground halves. To date mechanical means have been used to provide leak tight seals on flight and ground disconnect poppets and between the two halves when mated. This has not proven to be a guarantee of a leak tight seal. Development of a remote capability to test these seals prior to and after propellant flow is essential to the safety of personnel and flight hardware. Innovative approaches are sought to apply pressure to these seals and detect leaks as small as a few sccm or even scch. Innovations for seal redundancy are also desired but seal integrity verification innovations are the primary goal.
- Repair of cryogenic transfer lines: Vacuum jacketed cryogenic transfer lines often develop small leaks in the bellows due to external corrosion. These leaks cause the loss of the vacuum insulating properties. Schedule constraints make it impossible to remove the individual pipe sections for repair or replacement of the bellows. Permanent repairs must be done in place.

Innovations leading to the development of methods and/or materials to clean the affected area, permanently repair the leaks and prevent reoccurrence of surface corrosion are desired. Of specific interest is the development of coatings, materials and/or platings which can be sprayed, brushed or dipped in place.

- Closure for propellant handlers' ensemble: KSC uses a totally encapsulating protective suit called the Protective Handlers' Ensemble (PHE) when working with hypergolic fuels. The user gets into the suit in a manner similar to donning coveralls by fastening the suit with a closure consisting of a zipper for mechanical strength and a ziploc [1] overflap which serves as the toxic vapor barrier.

Innovations leading to the development of an improved closure system are solicited. This closure will serve as a mechanical closure of the PHE and provide a positive seal with a maximum of one tenth (0.1) liters per minute leakage at pressures ranging from 1 to 12 inches of water. Additionally, the closure system must withstand the impingement of a 750 psi, .5 inch diameter water stream for 6 seconds. The external portion of the closure system must withstand a 2-minute exposure to liquid form and a 15-minute exposure to a 50,000 ppm gaseous environment of the following chemicals, with no degradation: N_2H_4, Monomethyl Hydrazine, UDMH, Aerozine 50 and Nitrogen Tetroxide.

The PHE must be able to be de-contaminated using water and mild detergent after exposure and be re-usable after decontamination. The closure assembly must be able to withstand the stresses placed on the closure during multiple normal donning, doffing, transfer, cleaning, and storage operations. The closure must continue to function as designed during and after flexing, liquid impingement, and brushing against objects. Fastening of the closure should be easily accomplished, and it should be obvious to an observer if the closure is improperly fastened. In event of an emergency, the closure must provide a means for the propellant handler to remove the ensemble quickly and without assistance.

13.03 Subtopic: Launch and Ground Processing Weather

Center: KSC

A weather forecasting technology development program is being conducted at KSC. This solicitation encourages innovations that may enhance that program.

- Triggering of lightning by launch vehicles during ascent: Reliable assessment of the threat to a rising vehicle from disturbed atmospheric electric field conditions require innovations in several areas:
  - —Assessing the disturbing effect of the vehicle including exhaust plume;
  - —Assessing the charging of the vehicle by triboelectrification;
  - —Techniques for remotely and directly sensing electrical characteristics of clouds and the neighboring atmosphere;
  - —Correlations between the electrical environment and physical characteristics of clouds, for example: (a) precipitation phase, intensity, distribution; (b) type, altitudes of bases and tops, horizontal and vertical extents; (c) wind shear; (d) transport of charge; (e) temporal variations;
  - —Measurements of physical variables needed to characterize the triggered flash for design purposes.
- Thunderstorm forecasting: Additional and new techniques are needed to generate a probability of thunderstorm forecasts for windows of 1/2 to 24 hours with a lead time of 1 to 72 hours. An accuracy of 90% is sought. The following are some of the concerns that need to be addressed:
  - —Forecasts for specific areas such as work complexes (diameters of 1 to 4 miles) as well as for KSC as a whole;

([1] Ziploc is a copyrighted trademark of the Dow Chemical Company)

—Improved exploitation of existing instrumentation;
—Additional instrumentation.

- Forecasting dispersion of substances: Innovations are needed to provide better forecasting of diffusion, vertical and horizontal transport, and reactions of toxic substances. Specific concerns include improvements in modeling and measuring techniques.
- Facility lightning protection assessment: KSC handles large volumes of ordnance and explosive materials. Existing design specifications cannot be related to specific lightning protection system performance in many cases. The goal is to develop design methods for facility lightning protection systems that assure specific levels of lightning protection related to actual protected system susceptibilities. Innovation is solicited in the area of facility lightning protection assessment tools. These include:

—Computer models of the current flow in facility lightning reduction systems for determining the electromagnetic environment within the facilities as a function of various protection parameters;
—Expert systems for use on CAD/CAE systems for design rules checking and for development of design validation tools;
—Sensors to measure the electromagnetic field environment within facilities for relating that environment to propellant system susceptibilities such as those of electro-explosive devices (EEDs).

13.04 Subtopic: Nondestructive Evaluation of Thermal Protective Tile Bonding

Center: KSC

Innovations are desired in the area of bond evaluation when thermal protection tiles are bonded to the skin of the Space Transportation System orbiter. A non-invasive and non-contact technique is desired to ascertain the condition and dimensions of the multilayer system and associated bonds. One of the two bond lines of silicone RTV is of particular importance. The strain isolation pad is sandwiched between the lower surface of the thermal protection system silica tile and the orbiter skin. After application of the adhesive film on the orbiter skin, the tile with its previously bonded strain isolation pad is placed against the adhesive film and pressure applied during cure. When the pressure is removed, a technique is needed to verify that the strain isolation pad has been sufficiently bonded to the orbiter skin. The technique should be capable of sensing any gaps between the strain isolation pad and adhesive film that may have been caused by installation misalignments or dimensional errors.

13.05 Subtopic: The Use of Heat Pipes For Reheating Conditioned Air

Center: KSC

High energy costs result from operating air conditioning systems designed for unique applications. A typical application at KSC requires high side air pressures of 3 to 5 psig for delivery and low temperatures of 34–38F to achieve low dew points for efficient moisture removal. The normal distributed air temperature requirements typically run above 65F; therefore, it is necessary to reheat the air some 30F after dehumidification. Innovation is sought in the development of heat pipes to operate in high pressure, low temperature air conditioning systems. A goal is to reduce energy consumption by 50%.

13.06 Subtopic: Multi-Position Portable Liquid Air Dewar

Center: KSC

NASA-KSC is developing a liquid air respirator for use by the KSC fire rescue and launch pad closeout crews. Innovations are sought in support of a more reliable Liquid Air Dewar. A major problem is that the present dewar loses system operating pressure when placed in a position such that the outlet is exposed to the ullage gas thus reducing operating pressure and rendering the system unusable. Innovations are solicited which will result in the development of a liquid air dewar that always delivers any liquid air remaining in the system to the regulators and will continue to operate regardless of the position of the user. Additional innovations are sought for development of an indicator that accurately reveals the amount of air remaining in the dewar regardless of its position or use rate.

13.07 Subtopic: Large Magnitude Force Torque Sensing

Center: KSC

Force torque sensors are in large use in the robot industry but fail to provide for loads above a few hundred pounds. The development of a robot-controlled ground-to-flight umbilical is dependent on the ability to sense loads as small as five pounds and as large as several thousand rounds while balancing out large dead loads up to several thousand pounds. An innovative force torque sensor needs to be developed which by itself or in combination with others may be placed on the robot-controlled umbilical so that all loads may be relieved through the use of intelligent robot control systems. Such devices must also be compatible to hazardous fluids such as nitrogen tetroxide, and the hydrazine family of propellants, as well as be compatible with cryogenic oxygen and hydrogen and the temperature extremes they can impart to the sensor.

13.08 Subtopic: Space Component Test Facility Devices
Center: JSC

Testing of flight and ground space components at the NASA White Sands Test Facility requires a number of state-of-the-art devices to monitor test specimens and to provide safety for the test support personnel and facilities. Areas of potential innovation include:

- Contamination detection: Reliable, traceable calibration of commercial Airborne Particle Monitors for particle counts as well as for particle size, including:
  —A non-contact instrument that can quickly determine the quantity of organic contamination on small metal surfaces;
  —A real-time or near real-time method for determining the non-volatile residue or hydrocarbon contamination in Freon 113 after sampling a component for contamination.
- Hydrogen/Oxygen detector for use in high altitude simulation chambers: An innovative system is required for the detection and concentration measurement of hydrogen and oxygen gas under near vacuum conditions established during rocket engine testing.
- Toxic vapor detection in vacuum: Innovative techniques are required for the detection of toxic hyperbolic propellant (hydrazine, monomethyl hydrazine, ammonia, and nitrogen tetroxide) on the surface of astronaut spacesuits and equipment in a vacuum.
- Chemical sensors: Innovative techniques are required to detect real-time changes in the chemical composition of propellants (hydrazine, monomethyl hydrazine, and nitrogen tetroxide) during compatibility testing activities. Changes can include increases in the typical propellant impurities, propellant decomposition products, and concentration of dissolved metal ions.
- Liquid level sensor: An innovative, simple, and reliable liquid level sensing probe is required to remotely measure the level of rocket propellants in a variety of storage and supply tanks.
- Temperature sensors: Innovations leading to the development of a high speed gas thermometer. Pneumatic impact initiated ignitions have been the cause of some serious fires in high pressure oxygen systems. Adiabatic compression of the system gas is one possible cause of the high temperatures leading to ignition. A high speed non-contact means of measuring the gas temperature is needed that is capable of making measurements through small windows or through fiber optics.
- Pressure sensors: Dynamic pressure sensor to measure the near-field dynamic pressure in a free blast environment. Blast intensity will be in the range of 10 kg TNT equivalent. Response time should be in the order of a fraction of a microsecond.
- Pressure sealing compounds: An innovative method of sealing a stainless steel conduit containing signal wires to provide system isolation under temperature and pressure extremes in a vacuum chamber is required.
- Personnel protective equipment decontamination: Innovative techniques are required for the economical and rapid decontamination of Personnel Protective Equipment (PPE) exposed to hypergolic propellants. Salient features include: Complete removal or reduction of concentrations of hypergolic propellants and their reaction products from completely assembled PPE ensembles and single components such as gloves, boots, etc.; and use without detrimental effects on the PPE.

TOPIC 14.00 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS

14.01 Subtopic: Communications for Manned Space Systems
Center: JSC

Innovations are sought for both external and internal communications subsystems in manned space systems. These subsystems are complex from the standpoint of great variety of services (voice, commands, telemetry, video, text, graphics, etc.) and require a large number of interactive links. Multiple, simultaneous links will be required to communicate among the variety of elements within the STS and Space Station including satellites and extravehicular astronauts. Internal communications must accommodate increasing crew sizes, and overall management and control of the communications systems must be highly automated.

- Advanced multiple beam antennas with near-hemispherical coverage and communications systems at Ku-, Ka-, and W-bands for supporting simultaneous multiaccess users are required for future NASA missions. User omni-directional antennas at these frequencies with low power, lightweight detection/switching schemes are needed.

- Personal communications systems for Space Station are needed. Multiple users, user access and remote controls, distributed antenna system, and portable data terminals are some key features for advanced systems implementations.
- Crew communications: Multiple-access wireless communications systems are required to allow simultaneous communication with no restriction on individual orientation within a single enclosure and between various enclosures of the spacecraft. Systems for enclosure to EVA astronauts are also required. Equipment worn by the crewmen must be small and lightweight to avoid interference with crew activities. Electronic noise cancellation is desired.
- Solid-state text and graphics: A solid-state graphics imaging device consisting of at least 4,000 individual light sources capable of illuminating corresponding points along a horizontal scan line is needed for initial application on the Space Station.
- Communication system modeling and simulation: The need exists for development of generalized mathematical models and integrated software packages to allow simulation and evaluation of the performance of candidate one-way and two-way multi-access communications systems, such as those envisioned for the Space Station. These computer simulations allow tradeoffs on the basis of key parameters which include bit error rates, jamming environments, power requirements, complexity, and cost. The models should also include expert system and artificial intelligence implementations.
- Video systems for robotics and automation: Innovative design approaches for small size and lightweight, digital, solid-state imaging, display, and processing systems are needed for robotics and automation applications. Design features include high definition for large scenes, high grey-scale resolution, data compression of higher order with quality imagery, and scene recognition and attitude determination capabilities.
- Automated monitoring and management of communications resources: Innovative approaches for managing communications resources (system scheduling, monitoring, fault diagnosis and fault recovery) to satisfy real-time communications requirements for Space Station are required. Development of techniques for multiple, cooperating expert systems implemented in procedural and non-procedural languages running on multiple processors is required as follows: Development of techniques for distributing expert systems on multiple processors; development of fault detection, isolation, and recovery (FDIR) techniques; development of distributed real-time dynamic data base techniques; development of techniques for efficiently porting expert systems code in non-procedural languages to traditional computer architectures using C or ADA.
- Space-to-space laser communications systems for long range (LEOGEO) and close proximity high data rate operations are required in the Space Station era.
- Communications systems for telerobotic devices: Numerous spaceborne robotic devices will be controlled from earth-orbit or the ground via wireless communications systems. These communications systems must simultaneously provide multiple channels of high quality video, high rate data, and command/control signals with a minimum two-way time delay of information transfer. Trade-off studies of signaling techniques are needed to determine the best candidate design for space-qualified, man-rated equipment.

14.02 Subtopic: Free-Space Laser Communications

Center: GSFC

NASA's next generation geosynchronous (GEO) data relay satellites require multi-access communication capabilities which exceed those currently achievable. Since freespace laser communication technology is rapidly advancing, it is likely to form the basis for NASA's next generation space-to-space communications system. Innovations will be required in several areas.

- Multi-access free-space laser communication system design. This should address both the single GEO data relay terminal and the multiple low-earth orbiting (LEO) terminals. The goal of the conceptual design is to develop a viable multi-access laser terminal to allow rapid acquisition, communication, and tracking. The GEO data relay satellite should be capable of receiving data at rates greater than 1 Mbps simultaneously from at least 10 widely spaced LEO satellites. Its weight per independently accessed channel should not exceed 40 pounds.
- NASA's future free-space communications plans require data to be transmitted between two GEO spacecraft at rates in excess of 1 Gbit/sec. The GEO spacecraft separation can approach 80,000 km. To achieve such communication links, diffraction limited lasers with powers greater than 1 Watt and receivers with sensitivities near the quantum limit are required.
- Recent advances in optical technology have produced laser-diode pumped ND:YAG ring oscillators which are commercially available and have linewidths near 10 KHz and CW powers of 40 mW. Furthermore, it appears that powers approaching 500 mW with linewidths of less than

100 KHz could be available soon. When coupled to a waveguide modulator, such laser sources could be attractive coherent laser communications transmitters. However, in order for such devices to satisfy free-space communications system requirements, both stabilization and electronic tuning of the laser center frequency are required. This task requests innovations in laser technology which will allow both stabilization and tuning of the laser diode pumped ND:YAG ring laser center frequency. Long term stability of 2 KHz and tuning range of 1 GHz are desired. The frequency response of the tuning circuit should exceed 10 KHz. The design should also permit much slower (sub-Hz) tuning of the laser source over a frequency range in excess of 2 GHz.

14.03 Subtopic: Millimeter Wave Deep Space Communications Systems
Center: JPL

Increasingly sophisticated scientific instrumentation aboard advanced deep space missions have generated a demand for the transmission of greater data rates to earth. Most deep space missions operate near 8 GHz but these data rate demands may be more economically met by utilizing the 32 GHz downlink and 34 GHz uplink frequency bands allocated for deep space communications by the FCC. The development of innovative space qualifiable millimeter wave components and subsystems is needed to implement communications systems utilizing these bands.

General areas of interest include development of high efficiency solid state microwave discrete and monolithic integrated circuit transmitter components and subsystems; millimeter wave transponder components and subsystems; and active computer aided design tools for these systems. Array beam control system technology for phased arrays and array feeds is also of interest. In addition, innovative techniques for millimeter wave integrated circuit hermetically sealed packaging, integrated array distribution systems for millimeter wave, digital control and power signals and thermal control concepts are sought. Specific areas of interest include:

- Repeatable, well characterized hermetically sealed packages for microwave integrated circuits at 32 GHz. These packages must be capable of being interfaced with microstrip or co-planar waveguide transmission line at 32 GHz as well as with power and digital control circuitry. Heat sinking and thermal expansion control over −55C to +70C in a vacuum environment is also required.
- Novel concepts for high efficiency, millimeter wave, circularly polarized, radiating elements. These elements must be capable of being readily integrated with millimeter wave, integrated circuit topologies with minimum loss and without complex interconnecting devices.
- Array signal distribution approaches. Approaches such as multi-layer printed circuit boards which integrate millimeter wave, power and digital control signals would be of great value.
- Computer aided design tools for millimeter wave discrete and monolithic integrated circuits. Particular problems include advanced techniques for automated generation of circuit layouts and schematic capture which may, for example, integrate existing powerful PC-based tools such as Touchstone and AutoCAD. Improved device models at millimeter wavelength are also needed as are advanced device parameter extraction techniques using computer aided test equipment for linear and non-linear SPICE and harmonic balance modeling.

14.04 Subtopic: Spacecraft Telecommunication Subsystems
Center: JPL

Innovations in the following areas of spacecraft telecommunication subsystems are sought:

- Beam steering: Innovative advanced concepts are required for implementation of future deep space spacecraft communication systems capable of providing accurate, stable beam steering for phase coherent X- and Ka-band downlink signals (8.8 to 8.5 GHz and 31 to 33 GHz), while using an X-band uplink signal (7.1 to 7.3 GHz) for derivation of the error correcting signals. The beam steering system must provide high stability and accuracy for steering the Ka-band downlink signal within a range of approximately 1/40 the uplink beam width. Typical system antenna sizes are estimated to be in a range of 1/4 m to 1 m, using a common antenna structure for both X and Ka-band. Beam steering concepts will also have potential for use in other communication beam steering applications.
- Receiver monolithic microwave integrated circuit chip set design: Innovative advanced GaAs MMIC concepts are required for implementation of deep space spacecraft communication/beam steering electronics that employ narrow band, double conversion, coherent phase lock receivers. MMIC designs must provide high image rejection, coherent automatic gain control (AGC) function, and high stability phase-gain characteristics. Phase shift as a function of uplink signal variations must be minimal including phase shift of the limiter channel used for the narrow band phase lock loop. Typical performance requirements are:
  —Input frequency 7.1 to 7.3 GHz.
  —Output frequency 50 to 200 MHz.

—Noise figure 2.0 dB.
—Input signal level range −156 to −70 dBm.
—AGC gain reduction 90 dB.
—Temperature range −20C to +75C.
—Overall phase delay variation less than 3 nanoseconds.

- Broadband linear phase modulator: The next generation of spaceborne communication systems require direct phase modulation capability at X-band (8.4 to 8.5 GHz) and Ka-Band (31 to 33 GHz). The phase modulator must be capable of large linear phase deviation, low loss, and wideband operation with good overall performance stability. In addition, the phase modulator and its driver circuit must be capable of linear biphase subcarrier modulation or biphase or quadraphase modulator at data rates up to 10 Mbps. For linear operation +2.5 radians of peak phase deviation is required with a linearity tolerance of 8%. The insertion loss should be less than 7 dB and its variation with phase shift should be within +0.5 dB. The modulators should have a bandwidth of 100 MHz at X-band, and greater than 500 MHz at Ka-band with a modulation sensitivity of 2 radians peak/volt peak. The modulation sensitivity stability vs temperature should be within +10% over the temperature-voltage range, −20C to +75C. The phase delay variation over this temperature range should be demonstrated with analysis and hardware. Technology approaches should include GaAs MMIC implementations.

14.05 Subtopic: Advanced Communications Satellite Systems
Center: LeRC

Innovative advanced concepts are required for devices, components, subsystems, and operating techniques that support advanced NASA and other government missions. These include Mars Rover Communications, science data distribution and remote experiment control by satellite and fault tolerant communication networks for primitive lunar or Mars manned outposts. Applications at all allocated frequencies are of interest but with particular emphasis at Ka band and above, including optical, although many concepts may be frequency independent. General areas of interest include RF/optical devices, components, and subsystems; processing and switching components, subsystems and systems employing digital and analog/digital hybrid concepts; and antenna systems using active arrays in feed and direct radiating configurations. Performance improvements in RF components are sought in bandwidth, power, and efficiency. New technologies for processing and switching should be targeted toward data, packet or message switching/routing; onboard message processing; onboard network control; and associated low-cost ground terminals. Onboard factors to be considered are conflicting but include: implementation complexity, fault tolerance reliability, size, weight, and power. Ground terminal factors to be considered are cost reducing implementations, complexity, ISDN compatibility, fault tolerance, and reliability. Implementations using electronic technologies are being sought for near-term applications (present to 1997). Research in photonic technologies is desired for applications in the longer term (1997 and beyond). Innovative approaches are desired in the following specific areas:

- RF devices and components (solid state or free electron) to improve performance, i.e., higher frequency, bandwidth, power, and efficiency.
- Use of RF devices in advanced satellite communications circuits.
- Concepts for components and subsystems (frequency sources, receivers, amplifiers, mixers, combiners, power dividers, transmitters, etc.) which should stress improvements in bandwidth, power, efficiency, noise figure, gain, reliability, or cost, as well as higher frequency performance, miniaturization, and improved circuit and packaging techniques.
- Combining electronic and photonic technologies where incoming RF signals are converted to photonic information and photonic information is converted to outgoing RF power.
- Flexible, fault tolerant, high speed, onboard data, packet or message switching/routing systems at baseband, or optical frequencies to meet the throughput and interconnectivity needs of efficient high and low-data-rate FDMA and TDMA communications networks.
- Novel digital signal processor or application specific integrated circuit implementation of critical burst modulation and/or coding system functions.
- Very low power, radiation hardened, high density, single chip random access memory with byte wide I/O and access times on the order of tens of nanoseconds.
- Novel digital processing concepts and components that enable simultaneous multiple FDMA channel demodulation and all coding with a single device and switching/routing.
- Advanced concepts for fault-tolerant on-board TDMA communications network control.
- Cost-reducing concepts and components for low-data-rate FDMA uplink, TDMA downlink ground terminal digital systems providing acquisition, synchronization, self-test and fault tolerance, and terrestrial interface.
- MMIC technology for wide angle scan antennas: Monolithic Microwave Integrated Circuit (MMIC) devices are becoming available at Ka band frequencies. Novel approaches are required for wide

angle (up to hemispherical) scanning at Ka band using the large number of degrees of freedom inherent in arrays/array feeds with MMIC devices. Concepts for entire systems or for critical elements of complete systems are desired. Applications include systems for linking LEO satellites/stations to ground terminals, GEO satellites, or maneuvering space vehicles.

- Large phased array antennas using large numbers of MMIC elements in beam forming/control networks pose some unique problems in assembly and integration. Of particular interest are techniques for electrical control and thermal dissipation. Research is desired in optical and photonic technologies for transmitting signal and/or control information to the MMIC devices. Research into packaging and assembly techniques is desired for adequate thermal dissipation and control.
- New and improved devices for any of the above applications, incorporating high temperature superconductor technology are desired.

14.06 Subtopic: Monolithic Distress Beacon Technology

Center: LeRC

Satellite-aided search and rescue distress beacons have saved hundreds of lives through the joint USA/Canada/France/USSR COPAS-SARSAT program. Consisting of a network of polar-orbiting satellites, this system monitors specific frequencies to detect and locate the distress beacon transmitter. Currently available 406 MHz beacons provide greater position determination of the distress beacon than the 121.5 MHz beacon, however the cost is considerably higher. Innovations are needed to develop low cost monolithic circuitry to be used in COPAS-SARSAT 406.025/121.5 MHz beacons. Innovations are sought in (but are not limited to) the following areas:

- GaAs circuit applicability.
- Total monolithic construction of the entire beacon circuit.
- Highly stable 406 MHz oscillators with stability of better than 2 parts per billion.
- Operational temperature range −40C to +65C, minimum.
- Nominal operation should be reached within 15 minutes.
- Must sustain an initial temperature shock of 30C.
- Nominal power output of 5 Watts into 50 ohms.
- Data word is 144 bit, phase modulated at 400 bps rate.
- Duty cycle of 500 milliseconds every 50 seconds.
- Minimum power, cost and weight.

14.07 Subtopic: Emergency Locator Transmitter Batteries and Crash-Sensors

Center: GSFC

The operational use of 406 MHz Emergency Locator Transmitters (ELTs) and Emergency Position-Indicating Radio Beacons (EPIRBs) will make possible detection of aeronautical and marine distresses occurring on the Earth and will provide position information significantly better than previous 121.5/243 MHz systems. Areas of interest are:

- The transmission of beacon identification by 406 MHz beacons will benefit both the distressed parties and search and rescue forces. The energy requirements of 406 MHz ELTs and EPIRBs present a challenge to battery developers and offer a very large potential market. Innovative techniques are required to develop batteries which possess the following minimum criteria:
  —Safe to store, transport, and handle;
  —Five-year minimum storage life;
  —Capable of 2 ampere pulse of ½ second duration every 50 seconds;
  —100 ma steady-state load;
  —Minimum end-of-life voltage. 8v. at −40C;
  —Maximum beginning-of-life voltage. 13 v. at +65C;
  —−40C to +65C operation;
  —24-hour minimum operating life;
  —OEM cost less than $200.
- ELT crash sensors (most often velocity change or "G" switches) within the ELTs frequently fail to activate and equally frequently activate when no crash has occurred. Innovative techniques are required for the development of simple, compact, inexpensive, and reliable velocity-change switches.

14.08 Subtopic: Low Cost Ka-Band Ground Terminals

Center: LeRC

The Advanced Communications Technology Satellite (ACTS) currently under development is an experimental satellite that uses time division multiple accessing (TDMA) together with onboard switching and multiple narrow hopping beam antennas to route communications traffic among a network of small user Earth stations. The master control facilities necessary to manage a network of Earth stations are also currently under development. Innovations are needed to develop low cost, transmit/receive experimenter terminals to function with this satellite. These terminals will initially not need to address the TDMA aspects of the ACTS system but will operate with burst modems and controllers through an IF interface. Innovations should address but are not limited to all of the following:

- 30 GHz transmitters in the 10w to 20w range.
- 2.5 m diameter antennas.
- Upconverters (IF to 30 GHz).
- Downconverters (20 GHz to IF).
- Low noise receivers @ 20 GHz.
- IF interface to burst modems at burst rates of 27.5 and 110 Mbps.
- Beacon receivers at 20 GHz for propagation measurements.

14.09 Subtopic: Communications Applications for Superconducting Materials

Center: JPL

Conductor lasers in transmission lines attenuate signals or degrade signal-to-noise ratios in both RF power sources and in receivers. Low-loss superconducting materials can be used in microwave circuit elements to reduce the power requirements for microwave sources and to improve the noise figure in microwave receivers.

Advanced Deep Space communications systems at X- and Ka-band require highly efficient transmitters and receivers, active phased array and array feed components, microwave monolithic integrated circuits (MMICs), low loss interconnect and switching components, and high reliability in all components over mission life. Innovative applications of the new high Tc superconductors to new components or systems is desired. Suggested areas of innovation would include, among others:

- Methods to fabricate, shape and characterize circuit element shapes in thin or thick film superconductors including microwave transmission line circuit elements.
- Methods to protect thin or thick film microwave circuit elements from degradation by ambient conditions—atmosphere or vacuum—for missions of up to 10 years.
- Low loss ohmic contacts to the high Tc superconductor with mechanical reliability and ease of interconnection with other microwave components.
- Circuit and component applications that use the superconducting properties to advantage in ways that cannot be duplicated by normal materials in another configuration or scheme.
- Reliable fabrication techniques for films and microwave circuits in planar form suitable for integration with MMICs at 8 and 32 GHz.
- High performance sub-mm wave sensors capable of operating at higher temperatures and frequencies than those fabricated with low temperature superconductors.
- Active phased array applications at 32 GHz that includes low loss signal distribution, phase shifters, amplifiers, and antenna elements.
- Fabrication of microwave circuit devices from high Tc superconductors, e.g., High-Q cavities, filters, combiners, amplifiers, receivers, low noise oscillators, high power microwave sources, dividers, couplers, delay lines and sampler circuits.

TOPIC 15.00 MATERIALS PROCESSING, MICRO-GRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE

Commercial utilization of space is a national objective, and the resumption of Space Transportation System (Shuttle) flights will facilitate long-awaited opportunities for private sector access to space. Increased opportunities in the future will be provided by the Space Station and by supplementary space facilities proposed by the private sector.

New Commercial Space Initiatives are now being developed by NASA which will stimulate and encourage greater private sector space involvement. Because of the major role small business entrepreneurs play in the development of technology, new products and services, and in recognizing the importance of that role in the national economy, these initiatives will include new opportunities for small businesses.

Ways to make such opportunities realistic are now being studied. Some approaches would build on previous and current projects in the SBIR program, others would be based on future research innovations. But in every case, success will require supportive policies and institutional arrangements both in Government and in the private sector to overcome existing obstacles to small business involvement in commercial space. Those obstacles are primarily, but not solely, financial in nature.

As NASA's plans mature, and as viable arrangements are developed to increase the probability of success of small business commercial space ventures, it may become appropriate to issue a special SBIR Program Solicitation aimed specifically at projects which have space commercialization objectives. Within this Solicitation, however, Technical Topic 15 continues to invite proposals for research innovations whose ultimate objectives are commercial applications of technology which are either dependent on or enabled by access to the space environment, and which use facilities and services provided by the Shuttle, the Space Station, or other space facilities developed by the private sector.

15.01 Subtopic: Materials Processing in Space
Center: LeRC
MSFC

Opportunities for commercial processing of materials will exist in the low gravity of space. Some of the areas of opportunity, and in which research innovations are sought, are listed below:

- Materials.
  —Electronic Materials: Improved materials for semiconductors and solid-state detectors of high purity, volume or high intrinsic value for use in electronics, computers, communications and medical instrumentation.
  —Metallic Alloys: New alloys made from immiscible components, improved grain structures for alloys of miscible components, directional solidification, and process involving supercooling and rapid solidification from an undercooled state.
  —Glasses and Ceramics: Containerless processing of glasses to eliminate crucible-derived impurities, give better control of nucleation sites, and provide the possibility for dealing with highly reactive melts. Improved optical fibers may result from surface tension forming from melts in a containerless process.
  —Biological Materials: Processes for obtaining specific cell types, cell components, hormones, antigens, proteins and other organic and crystalline substances with greater purity and throughput. Continuous electrophoresis and isoelectric focusing are two separation methods that benefit from the micro-g environment. In addition, the crystallization of proteins in order to determine structure and other properties is a topic of considerable interest.
  —Electro-optical Materials: Processes for obtaining materials for electro-optical applications, particularly in the emerging new field of photonics. Both organic and inorganic materials are of interest.
- Technological Phenomena and Techniques.
  —Fluid dynamic phenomena are involved in a wide range of technologically important processes that are affected by weightlessness. Multiphase flows in a complex regime of thermal and solute gradients are altered by the weightlessness conditions of space. These alterations are applicable to a range of R&D such as crystallization processes, separation processes, phase change phenomena, solidification mechanics, solute-solvent processes, glass processes, etc. Innovation leading to improved understanding for thermodynamic and fluid processes in weightlessness will lead to greater exploitation of materials processing in space.
  —Processing Techniques necessary in the technology and scale-up of specific devices and processes include, for example, acoustic, electromagnetic and electrostatic levitation devices; continuous-flow electrophoresis; isoelectric focusing; cell culture and deposition; furnaces of all types; combustion processes; isotachophoresis; and surface tension manipulation. Approaches to developing new processes, instrumentation and control procedures, and characterization of materials are essential enabling activities.
- Apparatus and equipment, including containerless melting, solidification and fiber-pulling devices, heat-pipe furnaces for directional solidification, efficient furnaces for float zone growth and high temperature containers that can withstand large temperatures differentials (greater than 500C).

15.02 Subtopic: Microgravity Science, Technology and Engineering Experiments
Center: LeRC

Definition and development of in-space experiments: Innovations leading to the definition and development of in-space experiments and the development of basic, core equipment and facilities required for quality space laboratory experimentation are solicited, using unique government research facilities in the study of microgravity processes/phenomena and the definition of space flight experiments which are available at the Lewis Research Center, Cleveland, Ohio. These facilities include several which provide varying degrees and times of simulated microgravity conditions and the Microgravity Materials Science Laboratory (MMSL). MMSL provides easy access and assistance to scientists and engineers from industry and universities wishing to conduct material research using Shuttle flight-type experimental equipment.

Of particular interest are proposals emphasizing innovative commercial applications. Areas of interest in microgravity science and applications are fluid and transport phenomena, combustion, metals and alloys, glasses and ceramics, polymers and electronic materials. Research, technology, and engineering areas include energy conversion and space power systems, fluid and thermal management systems, space environmental effects, and spacecraft fire safety. New concepts in basic laboratory equipment and practices range from fundamental diagnostic and property measurement techniques, data recording and storage to sample preparation and waste product disposal systems.

Space station United States laboratory module experiments: During the definition and preliminary design phase of the Space Station, NASA has defined the functional characteristics of a range of microgravity experiment facilities to be accommodated by the pressurized United States Laboratory (USL) module. The requirements for these user-provided facilities are based on extensive discussions with current and potential users of microgravity facilities. Some of these facilities are in the concept design phase. Many will require advancements in technology to enable or enhance their development and provide the capabilities to satisfy users' requirements.

The microgravity experiment facilities of interest to LeRC are those needed to perform experiments in the Space Station USL module in the microgravity science and applications disciplines of metals and alloys, electronic materials, glasses and ceramics, combustion science polymers and fluid and transport phenomena. General technology areas where innovative advancements are needed to enable or enhance development of these facilities include instrumentation and sensors, unique mechanical devices, high-temperature materials, automation/process control, non-intrusive diagnostics and acceleration/vibration environment control.

15.03 Subtopic: Chemical Vapor Deposition Analysis and Modeling Tools

Center: LaRC

Chemical vapor deposition is one of the key technologies of the electronics industry. To foster development, it is essential that predictive models be developed to compare the results of early microgravity testing with scientific theory and ground-based empiricism. Prediction of the fundamental fluid flow and reaction phenomena taking place under varying gravity fields requires innovations in computational methodology. This subtopic seeks innovative development of a general purpose fluid flow simulation program that predicts in three spatial dimensions the mass, temperature, momentum, energy and chemical species distributions during the chemical vapor deposition of electronic materials and presents the results in both tabular and graphical formats.

15.04 Subtopic: Space Power Generation, Propulsion and Related Technologies

Center: LeRC

While much of the early emphasis on commercial uses of space focuses on use of the microgravity environment, it is recognized that commercial opportunities may exist in other areas. Two of the disciplines regarded as being key to the exploration and exploitation of space are power generation and propulsion. Innovations are therefore being sought in the following areas:

- Unique approaches to the generation, management, distribution, storage and transmission of electric power in space which would create new commercial opportunities. The commercial potential of the research project may be in the development, production and sale of power production equipment to spacecraft builders; licensing of the resulting technology to allow American aerospace companies to gain a competitive advantage in world markets; or, the generation and sale of power produced by new technology to in-space users.
- Unique approaches to providing primary and auxiliary propulsion for spacecraft which have commercial potential as generally described above.
- New concepts for disciplines which support space power generation and/or propulsion. These include, but are not limited to, the storage and handling of propellants (including cryogens), thermal control systems, instrumentation and controls, servicing, repair and resupply, etc.

15.05 Subtopic: Optical Materials and Components

Center: GSFC

Proposals are requested which address new ideas that have commercial application for the general field of optics. The availability of a long-term near zero gravity environment and the natural vacuum environment combined with the long-term presence of people in space are key elements that should be factored into the proposal. Optical elements such as mirrors, filters, beamsplitters, lenses, and polarizers are all items of interest for current as well as eventual use in space as well as on earth. The spectral coverage of proposed optical components or materials is open ended. The proposal must address the potential commercial application of the investigation. Applications may include the space flight market (i.e., those optical elements required for space flight systems which can now be produced on Earth or those optical elements which might be better produced in space for use in space).

15.06 Subtopic: Life Sciences Commercial Research and Applications in Space

Center: ARC

NASA has made a commitment to support extensive life science research activities in orbiting spacecraft, including a life science research laboratory on the Space Station. Innovative research and new advanced technologies are required to exploit these opportunities; proposals emphasizing commercial applications of innovative research will receive special attention. Of particular interest are proposals emphasizing commercial applications. Areas of interest in life science and applications include the following:

- Bioprocessing.
  —Bioreactor technology;
  —Protein crystal growth;
  —Protein separation/identification.
- Space medicine research.
  —Advanced biomedical instrumentation;
  —Countermeasures to effects of space flight;
  —Rehabilitative and geriatric medicine.
- Animal/plant specimen testbeds for long duration space biology.
- Global habitability.

New concepts in basic systems and subsystems include gas, fluids, temperature/relative humidity control, illumination, waste collection, food/water/nutrients, dispensers, robotic manipulators, and video and biotelemetry monitoring systems. Also, specimen-unique habitats for various specimen types including rodents, primates, plants, amphibians, and fish should be considered as critical subsystem elements.

☆U.S. G.P.O. 1988-520-694

APPENDIX E - PROPOSAL CHECK LIST

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION

NASA SBIR 88-1

(Attach Proposal Check List to Original Cover Sheet and Project Summary)

Company: ______________________________

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Proposal Number: __ __ . __ __ __ __ __ __ __

Proposal Title: ____

____

ITEM AND REFERENCE IN SOLICITATION

CHECK

_______ 1. Offeror understands that proposals not meeting all requirements of this Solicitation may be rejected without consideration (Sect. 1.4)

_______ 2. Proposed Innovation is clearly identified (Sect. 1.3-e)

_______ 3. Innovation and Proposal submitted to only one Subtopic (Sect. 5-14-e)

_______ 4. Proposal includes all information required in Section 3.3 and is presented in requested order

_______ 5. Proposal has no more than 25 pages (Sect. 1.2)

_______ 6. No proprietary information included unless in Proprietary Addendum with Proprietary Notice on Cover Sheet indicating its location (Sect. 5.4-a)

_______ 7. Potential Government use, Commercial Applications and Phase III approach identified (Sect.3.3-c.9)

_______ 8. Period of performance does not exceed 6 months and funding request does not exceed $50,000 (Sect. 1.2)

_______ 9. Certification and Signatures on Appendices A and C

_______ 10. Proposal package includes: (Sect. 6.1)
a. Five (5) copies of Proposal
b. Separate original (red) Cover Sheet and Proposal Summary (Appendices A & B)

_______ 11. Offeror understands that proposals must be received in NASA Headquarters by 4 p.m. EDT July 22, 1988 (Sect. 6.4)

NOTE: Send checklist with original (red) Appendices A and B.

APPENDIX E - PROPOSAL CHECK LIST

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION

NASA SBIR 88-1

(Attach Proposal Check List to Original Cover Sheet and Project Summary)

Company: ______________________________

____

____

Proposal Number: __ __ . __ __ __ __ __ __ __

Proposal Title: ____

____

CHECK	ITEM AND REFERENCE IN SOLICITATION
________	1. Offeror understands that proposals not meeting all requirements of this Solicitation may be rejected without consideration (Sect. 1.4)
________	2. Proposed Innovation is clearly identified (Sect. 1.3-e)
________	3. Innovation and Proposal submitted to only one Subtopic (Sect. 5-14-e)
________	4. Proposal includes all information required in Section 3.3 and is presented in requested order
________	5. Proposal has no more than 25 pages (Sect. 1.2)
________	6. No proprietary information included unless in Proprietary Addendum with Proprietary Notice on Cover Sheet indicating its location (Sect. 5.4-a)
________	7. Potential Government use, Commercial Applications and Phase III approach identified (Sect.3.3-c.9)
________	8. Period of performance does not exceed 6 months and funding request does not exceed $50,000 (Sect. 1.2)
________	9. Certification and Signatures on Appendices A and C
________	10. Proposal package includes: (Sect. 6.1) a. Five (5) copies of Proposal b. Separate original (red) Cover Sheet and Proposal Summary (Appendices A & B)
________	11. Offeror understands that proposals must be received in NASA Headquarters by 4 p.m. EDT July 22, 1988 (Sect. 6.4)

NOTE: Send checklist with original (red) Appendices A and B.

APPENDIX E - PROPOSAL CHECK LIST

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SBIR 88-1 SOLICITATION

(Attach Proposal Check List to Original Cover Sheet and Project Summary)

Company: ______________________________

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Proposal Number: __ . __ ______

Proposal Title: ____

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ITEM AND REFERENCE IN SOLICITATION

CHECK

______ 1. Offeror understands that proposals not meeting all requirements of this Solicitation may be rejected without consideration (Sect. 1.4)

______ 2. Proposed Innovation is clearly identified (Sect. 1.3-e)

______ 3. Innovation and Proposal submitted to only one Subtopic (Sect. 5-14-e)

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NOTE: Send checklist with original (red) Appendices A and B.