National Aeronautics and Space Administration

COOPERATIVE AGREEMENT NOTICE

Human Exploration and Development of Space (HEDS) Technology/Commercialization Research & Development Projects

A Cooperative Agreement Notice for the HEDS Technology/Commercialization Initiative

CAN-HEDS-01-1
Released February 5, 2001

Pre-proposal Conference February 9, 2001
Notices of Intent Due March 7, 2001
Proposals Due March 22, 2001

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COOPERATIVE AGREEMENT NOTICE

Human Exploration and Development of Space (HEDS) Technology/Commercialization Research & Development Projects

HEDS Technology/Commercialization Initiative

This NASA Cooperative Agreement Notice (CAN) solicits proposals for cooperative agreements from all sources for research and development (R&D) projects under the Human Exploration and Development of Space (HEDS) Technology/Commercialization Initiative (HTCI). The HTCI is a key element of NASA's implementation of the HEDS Enterprise Strategic Plan. The HTCI, which is administered by the National Aeronautics and Space Administration (NASA), differs from many Federal contract R&D programs that address only agency-specific mission requirements. The program will pursue longer-term exploration and commercial space goals while developing and applying advanced technology in the non-space commercial marketplace and in nearer-term space applications. Proposed projects might include conceptual designs with accompanying analysis, hardware prototypes, ground or space demonstrations, or analytical software for HEDS concepts. R&D projects will focus on precompetitive technologies and novel applications, supporting high-risk and high-payoff opportunities that demonstrate strong potential for commercial space benefits. NASA encourages original and innovative proposals for commercial space and human exploration purposes that will benefit broad and diverse segments of society.

Research projects initiated under this solicitation will have a maximum duration of 24 months, contingent upon availability of funds and adequate progress toward project progress milestones (e.g., identified for each 4 - 6 months). Proposals may be offered by all categories of non-NASA (For purposes of this CAN, the Jet Propulsion Laboratory [JPL] is considered a NASA Center and may not offer proposals) organizations, including for-profit and nonprofit organizations, educational institutions and other Government Agencies. Leadership of teams proposing to this program will typically reside with one U.S. non-government organization. Supporting participation as team members is open to all non-NASA (NASA includes JPL) organizations, including industry, educational institutions, nonprofit organizations, Federal laboratories, and Federal, state, and local government agencies.

<u>Non-U.S. entities that may propose to this Announcement cannot receive funds from NASA as described in Appendix A, Section 5 of this CAN.</u> The direct purchase of supplies and/or services, which do not constitute research, from non-U.S. sources by U.S. award recipients is permitted, however. Also, in general non-NASA (NASA includes JPL) U.S. Federal Government agencies wishing to participate as team members will be expected to supply their own funding; however, national laboratories who participate may, if appropriate, be reimbursed for direct costs in support of a project (including, for example, the use of Government facilities).

A preliminary notice of intent (NOI) to propose is requested from all organizations planning to submit proposals. This NOI shall be submitted by March 7, 2001. Full proposals shall be submitted by March 22, 2001.

A team of specialists consisting primarily of Government personnel will evaluate the proposals from a detailed technical perspective. A NASA team will also integrate detailed reviews to create a single set of recommended rankings. Selections to begin negotiations are planned by May 2001. The selecting official will be the Associate Administrator for the Office of Space Flight.

NASA, through the Office of Space Flight (OSF), is sponsoring this CAN as part of the HTCI. Educational and other non-profit organizations are encouraged to propose cost sharing. For commercial firms, a substantial resource contribution (at least 50% of the total resources) is required. A fifty percent cost sharing is required of any commercial organization participating in a team or consortium as a recipient of the Cooperative Agreement only to the extent of its specific contribution to the overall project. For more information regarding cost sharing for NASA Cooperative Agreements, please refer to the Code of Federal Regulations Title 14, Chapter 5, Part 1274.202, Section c (14CFR Part 1274.202). This document can be found at:

http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1274_00.html

Electronic versions of this CAN and other HTCI documents in RTF, PDF, and HTML formats are available via the World Wide Web at the following address:

http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

The appendices to this announcement include further relevant details:

- Appendix A contains specific information on this program opportunity including solicited R&D emphases, evaluation criteria, and other considerations
- Appendix B provides instructions for NOI and proposal preparation including required forms
- Appendix C contains detailed technical theme descriptions for this HTCI CAN
- Appendix D provides a glossary of acronyms pertinent to this CAN

OSF policy strongly encourages participation by the HEDS R&D community in education and public outreach activities with the goal of contributing to the broad public understanding of NASA's strategic plans for human exploration and development of space. Therefore, proposers to this CAN are encouraged to review information concerning HTCI Education/Public Outreach (E/PO) activities as provided in Appendix A of this Announcement.

Recommendations for funding will be based on the evaluation of each proposal's relevance to the objectives as described in Appendix A of this CAN, its technical merit, and its requested budget. In all cases, the Government's obligation to make awards is contingent upon the availability of appropriated funds from which payment can be made and the receipt of proposals that NASA determines are acceptable for award under this CAN.

Funds are available for awards under this CAN. NASA's ability to continue funding the cooperative agreements selected under this CAN and any future cooperative agreements are contingent upon future appropriated funds.

The following information applies to this CAN:

NASA Identifier: CAN-HEDS-01-1

Date of Issue: February 5, 2001

Notice of Intent (NOI) to propose:

- Due date March 7, 2001

Notices of intent should be submitted via the World Wide Web (www) at:

http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

If you do not have access to the www, you may submit a notice of intent via email to:

noi@hq.nasa.gov

The subject heading of the e-mail message should read "Notice of Intent CAN-HEDS-01-1." If you do not have access to e-mail, you may submit a notice of intent by U.S. Postal Service or commercial delivery to the address listed below for proposal submission.

Submission of Proposal:

- Required number 20 copies plus signed original
- Due date 4:30 PM Eastern Standard Time, March 22, 2001

Address for delivery by U.S. Postal Service, personal courier, or commercial service:

NASA Peer Review Services
Subject: CAN-HEDS-01-1
500 E Street SW, Suite 200
Washington DC, 20024

Proposals (and NOIs) that are hand delivered or sent by commercial delivery or courier services are to be delivered to the above address between 8:00 AM and 4:30 PM. The telephone number, 202-479-9030, may be used when required for reference by delivery services. NASA Peer Review Services (NPRS) cannot receive deliveries on Saturdays, Sundays, or federal holidays. Upon receiving a proposal, NPRS will send notification to the proposer confirming its arrival; however, there will not be a response from the HTCI Program office.

Selecting Official: Associate Administrator
Office of Space Flight

Announcement of selection: May 2001

Initiation of funding: June 2001

Program Manager for further information:

Mr. John C. Mankins
Manager, HTCI
Advanced Projects Office / Code MP
NASA Headquarters
Washington, D.C. 20546
E-mail: **jmankins@hq.nasa.gov**
Telephone: (202) 358-4659

Your interest and cooperation in participating in the HEDS Technology/ Commercialization Initiative and this NASA Cooperative Agreement Notice process are appreciated.

Original signed by

John C. Mankins
Manager, HEDS Technology/Commercialization Initiative
Advanced Projects Office

Gary Martin
Director, Advanced Projects Office
Office of Space Flight

Joseph H. Rothenberg
Associate Administrator,
Office of Space Flight

DESCRIPTION OF PROGRAM OPPORTUNITY

In FY 2001, NASA's Human Exploration and Development of Space (HEDS) Enterprise began implementation of the HEDS Technology/Commercialization Initiative (HTCI).

NASA has consistently investigated options and technologies for future human (and robotic) exploration beyond low Earth orbit (LEO). Dramatic advances in a wide range of space technologies are needed in order to achieve breakthrough improvements in diverse future HEDS systems. Moreover, new systems concepts must be created and refined which incorporate existing and new technologies in revolutionary ways that better support safe, affordable and effective future initiatives, programs and projects for the human exploration and commercial development of space.

Toward that end, the goal of the HTCI will be to identify, develop and validate highly innovative technologies and systems concepts that open up new options for future human/robotic exploration and commercial development of space. The HTCI will result in the identification, refinement, analysis and validation of innovative architectures, infrastructures and systems concepts that can advance the emergence of key capabilities needed for future human exploration and commercial development of space activities, with particular emphasis on infrastructures that might meet the needs of both.

The HTCI will also validate the key results of studies through the identification, development and experimental testing of critical – sometimes competing – technologies needed by those systems and capabilities. Where possible, these efforts will be implemented in partnership with industry to accelerate or enable the successful commercial application of these technologies. Finally, the Initiative will pursue flight experiments and major technology flight demonstrations to acquire key data and to test critical technologies on the ground and in space, including both conduct of small-scale experiments and the definition of potential larger-scale technology flight demonstration missions.

By achieving these objectives, the Initiative will provide needed information to key stakeholders in support for future decisions regarding the human exploration and commercial development of space, while achieving meaningful progress in selected key areas of technology. The HTCI will also advance several important HEDS strategic goals and objectives. This includes the objective of establishing by the 2010 timeframe those capabilities needed to enable safe, effective and affordable 50-100 day class human missions beyond LEO. The HTCI will also advance the objective of establishing by the 2015-2020 timeframe those capabilities needed to enable comparable 300-1000 day class missions beyond LEO. Moreover, the HTCI will advance the HEDS strategic goal of enabling the commercial development of space.

This program opportunity intends to explore options for — and the viability of — highly innovative new concepts and technologies that might dramatically lower the cost and increase performance of critical human exploration and commercial development of space technologies and/or system concepts.

Approximately $15M is available in FY 2001 and approximately $15M is anticipated to be available in FY 2002 to support this effort.

1. Proposal Categories

Types of activities that are solicited by this CAN include the three categories listed in this section. It is anticipated that the allocation of FY2001 resources between the first and third of these three high-level categories will be approximately equal (i.e., over no more than 24 months, approximately $7M-$8M in Government funding for each category); and over no more than 24 months, approximately $15M in the category of HEDS-enabling advanced research and technology development. However, non-NASA cost sharing is required by commercial firms (see Appendix B, Section 2.1.3), increasing the total value of funded projects beyond the Government-only limits cited above. Specific solicited activities include:

- Systems Integration, Advanced Concepts, Analysis and Modeling (up to $7M-$8M over no more than 24 months)
- HEDS-Enabling Advanced Research and Technology Development (up to $15M over no more than 24 months)
  - Space Resources Development
  - Space Utilities and Power
  - Habitation and Bioastronautics
  - Space Assembly, Inspection and Maintenance
  - Exploration and Expeditions
  - Space Transportation
- HEDS Technology Flight Demonstrations (up to $7M-$8M over no more than 24 months)

Categories and Technical Themes, as listed above, are described in greater detail in Appendix C.

2. HTCI Education / Public Outreach (E/PO)

OSF policy strongly encourages participation by the HEDS research and technology (R&T) community in education and public outreach (E/PO) activities with the goal of enhancing the Nation's formal education system and contributing to the broad public understanding of science, mathematics and technology. OSF's demonstrated commitment to E/PO goals should become an important part of the broader justification for public support for human exploration and development of space.

Based on NASA experience of the past few years, OSF will solicit E/PO proposals only from those offerors whose research proposals have been already selected for negotiation. This approach should minimize the overall workload on the community, increase the likelihood that more E/PO proposals of merit will be funded, and effectively encourage successful proposers to add an E/PO component to their research effort.

At the time of the release of this CAN, it is anticipated that selected Principal Investigators (PIs) will have an opportunity to submit a supplemental E/PO proposal <u>no later than 45 days after the date of the letter of selection of their parent research proposal</u>, with the anticipation of starting the proposed E/PO activity within the first third of the first year of the parent activity. Consistent with

NASA E/PO policies and to ease the burden of NASA's administration of these supplemental awards, the total period of performance of an E/PO award will be restricted to that of its parent research award.

The specific policies and procedures for writing and submitting supplemental E/PO proposals in conjunction with proposals selected through this HTCI CAN will be posted no later than the end of May 2001, which will be sufficiently early to allow those selected for the program to organize and submit an E/PO proposal. Questions and/or comments about this OSF E/PO program are sincerely welcomed and may be directed to Mr. John C. Mankins, HTCI Program Manager.

3. HTCI Technical Proposal Evaluation and Awards Selection Process

All proposals must comply with the general requirements of this Announcement. Upon receipt, proposals will be reviewed for compliance with the requirements of this Announcement. The general requirements include:

- Submission of complete proposals as specified in this Announcement. HTCI Proposals must be responsive to the technical areas described in this Announcement, and the project description must be no longer than 15 pages.
- Submission of a budget that is within the guidelines specified in this Announcement and for a funding period not exceeding 24 months in duration
- Submission of all other appropriate forms and supporting documentation as required by this Announcement
- Identification of non-NASA investigators (NASA includes JPL)
- Letter of Assurance of Foreign Support, if applicable
- Articles of Collaboration for a proposing Team/Consortium and/or NASA Letter(s) of Commitment, if applicable

Note: At NASA's discretion, non-compliant proposals may be withdrawn from the review process and returned to the proposer without further review.

Compliant proposals submitted in response to this Announcement will undergo an intrinsic technical merit review.

3.1. Technical Merit Review

The first review tier will be a merit review by a panel of scientific and technical experts consisting primarily of NASA personnel. The number and diversity of experts required will be determined by the response to this CAN and by the variety of disciplines represented in the proposals relevant to the research emphases described in Sections 1 and 2 of this Appendix. The merit review panel will assign *a score from 0-100* based upon the intrinsic technical merit of the proposal. This score will reflect the consensus of the panel.

The technical merit review will be an evaluation of the ability of the proposed research and development to enhance U.S. competitiveness. The following factors will be considered in the evaluation and scoring of a proposal:

- Relevance and potential to support the goals of the HEDS Strategic Plan and the HTCI Program, including the potential to result in broad benefits/impact to foster U.S. leadership, including human space exploration, commercial development of space, and potential terrestrial applications. (This factor will carry great weight in the scoring of HTCI proposals.)
- Technical quality and appropriateness of the proposed effort, including the technical approach and the clarity and appropriateness of technical milestones and proposed accomplishments, and identification of appropriate technology metrics characterizing advances to be achieved. (This factor will carry considerable weight in the scoring of HTCI proposals.)
- Appropriateness of the proposed team and management, including relevant experience, including qualifications and depth of management and technical staff and past performance, and including Articles of Collaboration (if required; see Appendix A, Section 7).
- Reasonableness of proposed project resources and implementation planning, including the business approach, proposed cost to NASA (in terms of realism, reasonableness, allowability and allocation), and the quality and appropriateness of proposed resources sharing (if any) committed to the project.

3.2. Integration Panel

Upon completion of the technical merit review panels, an integration panel consisting of representatives from each of the individual panels as well as NASA program management will meet. The integration panel will consider the findings of the technical merit panels, as well as overall program balance and budget, in the preparation of selection recommendations.

3.3. Selection

The selection recommendation prepared by the integration panel will be submitted to the Associate Administrator for the Office of Space Flight who will serve as the selecting official.

4. Eligibility

Proposals may be offered by all categories of non-NASA (NASA includes JPL) organizations, including for-profit and nonprofit organizations, educational institutions and other Government Agencies. Leadership of teams proposing to this program will typically reside with one or more U.S. non-government organizations. Supporting participation as team members is open to all non-NASA (NASA includes JPL) U.S. organizations, including industry, educational institutions, nonprofit organizations, Federal laboratories, and Federal, state, and local government agencies. All types of non-NASA (NASA includes JPL) institutions are eligible to submit proposals in response to this CAN, but only approved proposals from U.S. institutions will be eligible for NASA funding. In general, U.S. Federal Government agencies wishing to participate as team members will be expected to supply their own funding; however, national laboratories who participate may, if appropriate, be reimbursed for direct costs in support of a project.

The applying entity should document any ongoing high quality research in technology or in those areas of engineering clearly relevant to the specific programmatic objectives and research emphases indicated in this CAN. Present or prior support by NASA of research or training in any institution or for any investigator is not a prerequisite to submission of a proposal or a competing factor in the selection process.

5. Foreign Participation

NASA cannot fund activities performed by non-U.S. entities. However, proposals containing participation by non-U.S. entities may be reviewed under this CAN.

Proposals from non-U.S. entities must be accompanied by a Letter of Assurance from the respective government agency or funding/sponsoring institution in that country from which the non-U.S. participant is proposing. Such endorsement should indicate that the proposal merits careful consideration by NASA, and if the proposal is selected, sufficient funds will be made available to undertake the activity as proposed. U.S. co-investigators who are collaborating on proposals submitted by non-U.S. entities must ensure that their scientific role is clearly delineated in the proposal, that their expertise is shown to make a substantial contribution, and that their funding requirements are included in the proposal.

Proposals from U.S. entities containing non-U.S. collaboration must include a Letter of Assurance, as described above, for the portion of the project to be completed by the non-U.S. entity.

All proposals from non-U.S. entities must be typewritten in English and comply with all other submission requirements stated in this CAN. These proposals will undergo the same evaluation and selection process as those originating in the U.S. Sponsoring foreign government agencies or funding institutions for proposals from non-U.S. entities meeting the above guidelines may, in exceptional situations, forward a proposal without endorsement to the above address if endorsement is not possible before the announced closing date. In such cases, the NASA sponsoring office should be advised when a decision on endorsement can be expected.

Successful and unsuccessful non-U.S. principal investigators will be contacted directly by the NASA sponsoring office.

Should a proposal containing both U.S. and non-U.S. participation be selected, NASA's Office of External Relations will arrange with the foreign sponsoring agency or funding institution for the proposed participation on a non-exchange-of-funds basis, in which NASA and the non-U.S. sponsoring agency or funding institution will each bear the cost of discharging their respective responsibilities.

Depending on the nature and extent of the proposed cooperation, this arrangement may entail:

a. A letter of notification by NASA;
b. An exchange of letters between NASA and the sponsoring foreign governmental agency; or
c. A formal Agency-to-Agency Memorandum of Understanding (MOU).

<u>Export Control Guidelines Applicable to Foreign Proposals and Proposals Including Foreign Participation.</u>

Foreign proposals and proposals including foreign participation must include a section discussing compliance with U.S. export laws and regulations, e.g., 22 CFR Parts 120-130 and 15 CFR Parts 730-774, as applicable to the circumstances surrounding the particular foreign participation. The discussion must describe in detail the proposed foreign participation and is to include, but not be limited to, whether or not the foreign participation may require the prospective proposer to obtain the prior approval of the Department of State or the Department of Commerce via a technical assistance agreement or an export license, or whether a license exemption/exception may apply. If prior approvals via licenses are necessary, discuss whether the license has been applied for or if not, the projected timing of the application and any implications for the schedule. Information regarding U.S. export regulations are available at:

http://www.pmdtc.org/

and

http://www.bxa.doc.gov/

Proposers are advised that under U.S. law and regulations, spacecraft and their specifically designed, modified, or configured systems, components, and parts are generally considered "Defense Articles" on the United States Munitions List and subject to the provisions of the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120-130.

6. Program Reporting

NASA reserves the right to make public any technical data produced in the course of any cooperative agreements resulting from this CAN, for those that may not involve cost sharing. For those cooperative agreements resulting from this CAN that involve cost sharing, NASA strongly encourages the recipient to provide appropriate information about the project to enable program-level integration, advocacy, etc., consistent with the rights in data provision section of the cooperative agreements regulation (Reference: Section 1274.905 of the NASA Grants and Cooperative Agreements Regulation). This does not include any proprietary data such as that which is identified in the notice in Appendix B, Section 2.1.6.

Details concerning the disposition of detailed technical data will be negotiated prior to any final agreement. However, all winning proposers will be required to submit a semi-annual report that describes program accomplishments and technical status. Consistent with the paragraph above, NASA strongly encourages offerors to publish final results of the investigation at an appropriate level in recognized professional journals. Also, consistent with the paragraph above, NASA strong encourages investigators to participate in one or more appropriate annual NASA HTCI technical interchange meetings (TIMs). Summary descriptions of the investigations selected by NASA may be posted on the World Wide Web (WWW) and in conjunction with future solicitations for HEDS investigations.

NASA has developed a WWW-based information system known as the Virtual Research Center (VRC) for archiving and information management of study products. Winning proposers will be offered the use of the VRC as a means of archiving documents, data, and software products. Information regarding the VRC can be found at:

http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

NASA intends to use the results of the HTCI to inform ongoing integrated systems analysis and mission architecture studies for future human exploration and development of space – including important systems engineering information pertaining to conceptual designs. Winning proposers will be required (if there is no cost sharing) or strongly encouraged (if there is cost sharing) to submit systems engineering data such as requirements, functional decompositions, mission descriptions, systems analysis data, technology evaluations, etc., to the HTCI program office for incorporation in ongoing HEDS study activities.

7. Joint Proposals and Technical Collaboration

Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards could be made. Proposals involving more than one non-NASA (NASA includes JPL) institution (i.e., a consortium) must include an outline of the consortium's Articles of Collaboration. This outline must be signed by appropriate representatives of each involved institution. Please refer to the Code of Federal Regulations Title 14, Chapter 5, Part 1274.202, Section d (14CFR Part 1274.202) for more information regarding Articles of Collaboration. This document can be found at:

http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1274_00.html

Technical collaboration with NASA Field Centers is required in Cooperative Agreements. Proposals should describe the contributions expected from each participating NASA Center, including agency facilities / equipment which may be required. The proposal must be confined only to that which the proposing organization(s) can commit itself. Proposals that specify the internal arrangements that NASA will actually make are not acceptable as a means of establishing an agency commitment. Where proposed collaboration with NASA includes the use of unique assets (e.g., use of specific facilities), a Letter(s) of Commitment from the appropriate NASA Center(s) must be included in the proposal submission (see Appendix B).

The following individuals may be contacted at each of the several NASA Field Centers as appropriate initial points of contact (POCs) for the HTCI to discuss potential areas for collaboration, available facilities, available tools, and related matters.

HTCI / NASA Field Center	Point of Contact	Phone Number/E-mail Address
Ames Research Center Moffett Field, California	Anthony Gross	650-604-2727 agross@mail.arc.nasa.gov
Glenn Research Center Cleveland, Ohio	Steven Johnson	216-433-5370 Steven.D.Johnson@grc.nasa.gov
Goddard Space Flight Center Greenbelt, Maryland	Rud V. Moe	301-286-2180 Rud.V.Moe.1@gsfc.nasa.gov
Jet Propulsion Laboratory Pasadena, California	Neville I. Marzwell	818-354-6543 Neville.I.Marzwell@jpl.nasa.gov

Johnson Space Center Houston, Texas	Al Conde	281-483-1388 al.conde1@jsc.nasa.gov
Kennedy Space Center Florida	Carey McCleskey	321-867-6370 Carey.McCleskey-1@ksc.nasa.gov
Langley Research Center Hampton, Virginia	Mark Saunders	757-864-9862 M.P.Saunders@larc.nasa.gov
Marshall Space Flight Center Huntsville, Alabama	Joe Howell	256-961-7566 joe.howell@msfc.nasa.gov
Stennis Space Center Mississippi	Kirk Sharp	228-688-1914 Kirk.Sharp@ssc.nasa.gov

8. Proposal Withdrawal

Proposals may be withdrawn by the proposer at any time. Offerors are requested to notify NASA in writing if the proposed work is funded by another organization after submission to this Announcement or of other changed circumstances which dictate termination of evaluation.

9. CAN Cancellation

NASA reserves the right to make no awards under this CAN and to cancel this CAN. NASA assumes no liability for canceling the CAN or for anyone's failure to receive actual notice of cancellation. Cancellation may be followed by issuance and synopsis of a revised CAN.

10. Bibliography

- **Code of Federal Regulations Title 14, Chapter 5, Parts 1260 and 1274 (NASA Grants and Cooperative Agreements and Cooperative Agreements with Commercial Firms, respectively)** are available on-line at the following World Wide Web addresses:
  http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1260_00.html
  http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1274_00.html

  Applicable regulations include: (a) for non-profit and educational organizations, 14CFR 1260, and (b) for commercial organizations, 14CFR 1274.

- **NASA 2000 Strategic Plan**. This document is available on-line at the following World Wide Web address:
  http://www.hq.nasa.gov/office/codez/plans.html

- **Human Exploration and Development of Space Strategic Enterprise Plan, 2000**. This document is available on-line at the following World Wide Web address:
  http://www.hq.nasa.gov/office/codez/plans.html

- **HTCI Strategic Technical Challenges White Paper** is available on-line at the following World Wide Web address:
  http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

- Information concerning the **NASA Virtual Research Center** is available on-line at the following World Wide Web address:
  http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

- **NASA's Small Business Innovation Research & Small Business Technology Transfer Programs**. Information regarding these programs is available on-line at the following World Wide Web address:
  http://sbir.nasa.gov/

INSTRUCTIONS FOR HTCI NOTICE OF INTENT AND PROPOSAL PREPARATION

This Appendix contains specific requirements, instructions, and considerations for the preparation of HTCI notices of intent and proposals. Forms required for proposal submission are also included at the end of this Appendix. Please read this Appendix in its entirety before preparing your submission.

The information in this Appendix is specific to this CAN and is meant to compliment the general guidelines described in Code of Federal Regulations Title 14, Chapter 5, Parts 1260 and 1274 (14CFR Parts 1260 & 1274). In case of conflict between this Appendix and 14CFR Parts 1260 & 1274, the latter takes precedence. These documents can be found at:

http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1260_00.html

and

http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1274_00.html

1. Notice of Intent Content and Preparation

To facilitate proposal processing, potential Principal Investigators are requested to confirm plans to submit a proposal responding to this Announcement by sending a Notice of Intent (NOI) to propose. As stated previously (see Cooperative Agreement Notice, Page 3), the NOI, which is not binding, should be submitted electronically by March 7, 2001. If you do not have access to electronic submission, you may submit an NOI by U.S. Postal Service or commercial delivery in the same manner as proposals.

As detailed on the electronic notice of intent submission form, the NOI should contain:

- A descriptive title of the research or technical proposal
- The names, affiliations, addresses, and telephone numbers of a single Principal Investigator and all Co-Investigators
- The participating institutions
- A brief summary describing the proposed research and clearly indicating the research area defined in this Announcement that is most relevant to the proposal
- The applicable proposal category and technical theme(s) as described in Appendix C.

2. Proposal Content and Preparation

Proposals are to be received by NASA Peer Review Services (NPRS) in printed copy by 4:30 PM Eastern Standard Time (EST), March 22, 2001 (see Cooperative Agreement Notice, Page 3).

Proposers are to submit a signed original plus 20 printed copies of each proposal. Submissions received by NPRS after 4:30PM EST, March 22, 2001 will be considered late, will **not** be reviewed, and will be returned to the principal investigator. However, NASA does reserve the right to review a late submission when it is in the best interest of the Federal Government.

Please note that the proposal must specify the period of performance for the described work. Periods of performance may be up to 24 months but should be suitable for the proposed project.

The technical merit review criteria by which HTCI proposals will be judged are included in Appendix A, Section 3.1. Applicants should find this information helpful for constructing proposals.

Applicants are encouraged to write thorough but concise proposals. Applicants are encouraged to print HTCI proposals double-sided, single-spaced, in a 12 point text font, and on 8.5" x 11" plain white paper. Proposal forms, however, should be printed single-sided, following the provided formats. Proposals should be bound using only metal staples or metal binder clips.

Each proposal copy shall contain all materials listed below and in the order presented. These materials are needed to permit consideration in an objective manner. In addition to these materials, one and only one copy of Form E, Proposal Checklist, needs to be included in the submission of the signed proposal and copies. The purpose of Form E is to assist the proposer in assuring a complete submission.

2.1. Proposal Forms and Supporting Documentation

Each proposal shall contain a complete set of forms as described below and included at the end of this Appendix. Please note that proposals which include participation by non-U.S. entities should not include Budget Summary Forms for the portion of the proposal to be completed by the non-U.S. entity. Proposers are encouraged to use the electronic form submission system provided at the following website:

http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

Electronic submission of forms will help facilitate proposal processing. Also, a full set of printed forms and supplemental documentation as described below must be submitted at the beginning of each proposal copy.

Please refer to each of these forms for further instruction.

2.1.1. Form A, Cover Page

This form includes general information required for the review of a proposal. It also includes certification of compliance with U.S. code (if applicable). One signed original is required.

2.1.2. Form B, Proposal Summary

On this form, please include a concise proposal summary describing:

- The objectives and specific aims of the proposed research and development, including all major programmatic and technical milestones
- The research design and methods for achieving these objectives and aims
- The potential applications and benefits of the proposed work to the exploration and development of space.

Please limit this summary to 400 words or less. The proposal summary and other information on Form B are essential to the review of the proposal. Form B helps to determine how the application will be evaluated.

2.1.3. Form C, Budget Summary

Please provide on this form the budget for each Fiscal Year (Oct. 1 - Sept. 30) of proposed research as well as for the entire proposed period of performance. For example, a 24-month project with a period of performance of June 2001 - May 2003 would require data in all four columns of Form C: one for FY 2001, one for FY 2002, one for FY 2003, and one for the entire period of performance.

Educational institutions and other non-profit organizations are encouraged to propose cost sharing. For commercial firms, a substantial resource contribution (at least 50% of the total resources) is required. A fifty percent cost sharing only to the extent of its specific contribution to the overall project is required of any commercial organizations participating in a team or consortium as recipient of the Cooperative Agreement. Contributions should be entered on line 7 of form C. This cost sharing contribution may be cash and or non-cash. Contributions from commercial proposers of less than 50% must be approved by the NASA Associate Administrator for Procurement (Code HS) prior to award. For more information regarding cost sharing for NASA Cooperative Agreements, please refer to the Code of Federal Regulations Title 14, Chapter 5, Part 1274.202, Section c (14CFR Part 1274.202). This document can be found at:

http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1274_00.html

Cooperative Agreement recipient estimated costs should be entered on Form C (except for Line 2, which represents Total Direct Labor Hours).

2.1.4. Supporting Budgetary Information

This section must include information supporting the costs submitted on Form C. In this solicitation, the terms "cost" and "budget" are used synonymously. Sufficient proposal cost detail and supporting information are required; funding amounts proposed with no explanation (e.g., Equipment: $1,000, or Labor: $6,000) may cause delays in evaluation and award. Generally, costs will be evaluated as to realism, reasonableness, allowability, and allocation. The budgetary forms define the desired detail, but each category should be explained in this section. Offerors should exercise prudent judgment in determining what to include in the proposal, as the amount of detail necessarily varies with the complexity of the proposal.

The following examples indicate the suggested method of preparing a cost breakdown:

Direct Labor

Labor costs should be segregated by titles or disciplines with estimated hours and rates for each. Estimates should include a basis of estimate, such as currently paid rates or outstanding offers to prospective employees. This format allows the Government to assess cost reasonableness by various means including comparison to similar skills at other organizations.

Other Direct Costs

Please detail, explain, and substantiate other significant cost categories as described below:

- Subcontracts: Describe the work to be contracted, estimated amount, recipient (if known), and the reason for subcontracting. Subcontracting is limited to vendors of supplies and commercial services; all those doing research and development as part of the project must be formal team members.
- Consultants: Identify consultants to be used, why they are necessary, the time they will spend on the project, and the rates of pay (not to exceed the equivalent of the daily rate for Level IV of the Executive Schedule, exclusive of expenses and indirect costs).
- Equipment: List separately. Explain the need for items costing more than $5,000. Describe basis for estimated cost. General purpose equipment is not allowable as a direct cost unless specifically approved by the NASA Grant Officer. Any equipment purchase requested as a direct charge must include the equipment description, how it will be used in the conduct of the basic research proposed, and why it cannot be purchased with indirect funds.
- Supplies: Provide general categories of needed supplies, the method of acquisition, and estimated cost.
- Travel: Describe the purpose of the proposed travel in relation to the grant and provide the basis of estimate, including information on destination and number of travelers where known.
- Other: Enter the total of direct costs not covered by a) through e). Attach an itemized list explaining the need for each item and the basis for the estimate.

Indirect Costs

Indirect costs should be explained to an extent that will allow the Government to understand the basis for the estimate. Examples of prior year historical rates, current variances from those rates, or an explanation of other basis of estimates should be included. Where costs are based on allocation percentages or dollar rates, an explanation of rate and application base relationships should be given. For example, the base to which the General and Administrative (G&A) rate is applied could be explained as: application base equals total costs before G&A less subcontracts.

While proposals submitted by “for profit” organizations are encouraged, proposals to Cooperative Agreements cannot include profit (i.e., a “fee”) to the recipient organization.

Other Applicable Costs

Offerers proposing other applicable costs should provide an itemized list explaining the need for each item and the basis for the estimate.

Resource Sharing

If resource sharing is based on specific cost items, identify each item and amount.

2.1.5. Form D, Other Support

Please use this form to list current and pending support for the principal investigator and each co-investigator.

2.1.6. Confidentiality Notice (if necessary)

Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on a single page and specify the information subject to the notice by inserting appropriate identification, such as page numbers, in the notice. This page should also include the complete proposal title as well as the first and last name of the principal investigator. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

Notice

> **Restriction on Use and Disclosure of Proposal Information**. The information (data) contained in [insert page numbers or other identification] of this proposal constitutes 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, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

2.1.7. Table of Contents

This page should include an outline of the proposal body described in the next section.

2.2. Technical Proposal Body

The proposal body shall include each of the following components.

2.2.1. Project Description

The project description **shall not exceed 15 pages** in length (i.e., 15 sides of paper). The proposal shall include a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the design of research to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in Appendix A, Section 3.1. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is not permitted. See Paragraph 2.1.4, Appendix B. The project description should contain sufficient detail to enable a reviewer to judge the scientific and technical merit of the proposed research.

When it is expected that the effort will require more than one year, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years. Also, the project description should include a detailed schedule and description of scientific/technical milestones. For guidance concerning the structuring of these milestones, refer to 14 CFR 1274.202(c)(4).

All materials described in the sections that follow are in addition to the 15 pages allowed for the project description.

2.2.2. Scientific / Technical References

The proposal body may include a bibliographic list of scientific / technical references directly relevant to the project description

2.2.3. Management Approach

For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described. Anticipated working relations with NASA field centers should be described in general. Also, for the proposed collaboration with NASA, a Letter(s) of Commitment from the appropriate NASA Center(s) should be included in the Management Approach section of the proposal body. A Letter of Commitment should clearly confirm and describe tentative arrangements made between the proposer and NASA regarding the use of NASA personnel in the proposed research and development.

Proposals involving more than one non-NASA (NASA includes JPL) institution (i.e., a consortium) must include an outline of the consortium's Articles of Collaboration in the Management Approach. This outline must be signed by appropriate representatives of each involved institution. Please refer to the Code of Federal Regulations Title 14, Chapter 5, Part 1274.202, Section d (14CFR Part 1274.202) for more information regarding Articles of Collaboration. This document can be found at:

http://www.access.gpo.gov/nara/cfr/waisidx_00/14cfr1274_00.html

2.2.4. Personnel (Biographical Sketches)

The principal investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch (approximately 1-2 pages) of the principal investigator must be included. The sketch should include professional qualifications and a list of pertinent recent (within 5 years) publications. Omit personal items that do not merit consideration in evaluation of the proposal. Give similar biographical sketches on each co-investigator identified in the proposal. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Proposers should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

2.2.5. Facilities and Equipment

Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use. This includes NASA ground-based research facilities, space flight hardware, and flights aboard the KC-135 aircraft or sounding rockets. When use of NASA facilities and/or equipment is proposed, a Letter(s) of Commitment from the appropriate NASA Center(s) must be included in the Facilities and Equipment section of the proposal body. A Letter of Commitment should clearly confirm and describe tentative arrangements made between the proposer and NASA regarding the use of NASA facilities and/or equipment in the proposed research and development.

Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

2.2.6. Letter of Assurance of Foreign Support (if applicable)

Proposals specifying research activities by non-U.S. entities must include a Letter of Assurance of support from the respective government agency or funding/sponsoring institution in the country from which the non-U.S. participation is being proposed. Such endorsement should indicate that the proposal merits careful consideration by NASA, and if the proposal is selected, sufficient funds will be made available to undertake the activity as proposed. For more information regarding participation by non-U.S. entities, please see Appendix A, Section 5.

Required Forms for this CAN are available on-line at:

http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

TECHNICAL AREA DESCRIPTIONS

IMPORTANT: Added on 2/21/01:

The following statement is a clarification and modification of the FY 2001 Human Exploration and Development of Space (HEDS) Technology and Commercialization Initiative (HTCI) Cooperative Agreement Notice (CAN), posted on February 5, 2001.

In order to better align with current Agency budget priorities, in FY 2001 the HTCI will be focused largely on nearer-term goals within the overall strategic framework that has been defined for HEDS. The HTCI will consider commercialization in a broader context than the more focused efforts to date involving commercialization of the International Space Station (ISS) or the Space Shuttle. Through the HTCI CAN, NASA intends to examine architectures that take advantage of a potentially robust future commercial infrastructures that could dramatically lower the cost of future space activities.

Categories of activities will include (1) systems analysis, concepts and modeling, (2) enabling research and technology (R&T), and (3) technology flight demonstrations. Within this framework, the emphasis will be on technology development and demonstrations that engender safer, more affordable and more effective infrastructures and operations in Earth orbit and near-Earth space, including technology developments and demonstrations that may lead to evolutionary advances in ISS capabilities.

It is anticipated that these developments will provide a foundation for a broad range of future exploration missions. However, activities that are exclusively oriented toward farther-term human exploration of Mars (or other interplanetary targets) will not be selected at this time. Proposed activities should identify what potential nearer-term applications are anticipated for concepts and/or technologies to be studied. Following the successful conclusion in the next two years of the activities initiated this year, funding of longer-term activities related to science-driven / technology-enabled human interplanetary exploration (for example, of Mars) will be considered.

NASA's HEDS Enterprise seeks to advance the identification, development and validation of highly innovative technologies and systems concepts that open up new options for future human/robotic exploration and commercial development of space. A family of strategic research and technology (R&T) road maps addressing technology for the human/robotic exploration and development of space (THREADS) have been developed. Within the THREADS framework, the HTCI will pursue specific technology areas, not otherwise addressed by NASA's various R&T programs, and will result in the identification, refinement, analysis and validation of innovative architectures, infrastructures and systems concepts that can advance the emergence of key capabilities needed for future human exploration and commercial development of space activities, with particular emphasis on infrastructures that might meet the needs of both. Summary information concerning the overall family of THREADS strategic R&T road maps, and the strategic technical challenges that must be solved to enable ambitious future human exploration and development of space, can be found on the Internet at:

http://research.hq.nasa.gov/code_m/nra/current/CAN-HEDS-01-1/index.html

Types of activities that are solicited by this CAN include the categories listed in this section. It is anticipated that the allocation of FY2001 and FY2002 resources between the first and third of the three high-level categories will be approximately equal (i.e., over 2 years, approximately $7M-$8M in Government funding for each area); and over 2 years approximately $15M in the area of HEDS-enabling advanced research and technology development. However, non-NASA cost sharing is required by commercial firms (see Appendix B, Section 2.1.3), increasing the total value of funded projects beyond the Government-only limits cited above.

1. Systems Integration, Advanced Concepts, Analysis, Modeling and Related Topics (SIM)

SIM activities address the definition and assessment of specific system concepts and/or applications. These systems concepts should address one or more prospective exploration, commercial space development or space science. Efforts in this area could include system preliminary design or architecture definition, among others. In addition, economic factors (costs, revenues, cost savings, etc.) should be analyzed where appropriate – for example concerning prospective commercial space applications. High-level modeling and analysis tools (system and architecture level) could be included. Finally, integrated technology assessment and analysis activities could be included, including high-level assessments of relevant system, application or technology opportunities in other, non-NASA programs. To the greatest extent practical, modeling, tool development or analysis activities will be required to be coordinated with other such HTCI or Agency efforts. Specific tools or similar products should be capable of distribution over the Internet for possible use by various team members.

This category includes definition, modeling and analysis of advanced HEDS systems concepts and architectures or supporting infrastructures, including potential space mission applications (e.g., human exploration or the commercial development of space). Efforts could include market/economic analyses to address the potential economic viability of concepts, as well as environmental issue assessments, for various potential terrestrial and space markets. These activities are likely to be interdisciplinary in character, incorporating aspects of one or more of the technical themes cited in Section 2 of this Appendix. Efforts could also include technology applications definition activities addressing either exploration missions or commercial markets, or both. In this category, individual proposals requiring government funding of up to $250K in FY 2001 will be considered; there is no lower limit. Projects of this type should be proposed to be implemented in 24 months or less. Total government funding of up to $1,000K over 24 months (including FY2001) will be considered; there is no lower limit. The anticipated number of awards is up to approximately 15, with an average value of $500K over 24 months.

Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

1.1. Applications Definition Studies

The area includes human exploration mission applications definition studies and goal identification with the science community, as well as commercial space market studies and goal identification with the private sector. Efforts could include studies, workshops, and related activities. Exploration mission options could include servicing space observatories at locations beyond low Earth orbit (LEO), such as Sun-Earth Libration Points, as well as lunar and planetary science-driven mission options, such as missions to Mars. Commercial space market opportunities including LEO commercial markets, Earth neighborhood possibilities, including geostationary Earth orbit (GEO), and commercial space opportunities arising from space exploration mission activities.

1.1.1. Applications for Human/Robotic Exploration

Studies are needed concerning application of HTCI technologies for evolutionary capabilities in LEO, including potential enhancements of the International Space Station and related infrastructure. Studies are needed concerning application to lunar surface activities and related infrastructure, including transportation, surface power, and other areas. These might include examination of the use of lunar or other extraterrestrial materials in space systems (e.g., lunar surface manufactured solar arrays). Studies are also needed that address potential human exploration mission applications beyond the Moon, including both asteroids and Mars. Such studies might address systems concepts or architectures concerning large-scale systems for interplanetary transportation, integrated concepts involving transportation systems and surface operations, or other applications.

1.1.2. Applications for Commercial Space Development

The emphasis of HTCI efforts in this area should address the application of HTCI technologies and/or systems to enhance current commercial space markets or to enable prospective future new space industries. Such applications studies might address nearer-term options (e.g., large GEO communications satellites, commercial evolutionary development associated with the International Space Station (ISS), etc.), mid-term options (e.g., space business parks, public space travel and tourism, etc.) or far-term options (e.g., in-space manufacturing, solar system resources development, etc.). Analysis of market, cost and economic factors would be particularly important in these cases. Technical studies, including engineering and economic analyses, are of interest, as well as the definition of concepts or methodologies to develop commercial enhancement of NASA missions. HTCI funding will not support directly competitive commercial activities, such as preparation of business plans, etc.

1.1.3. Applications for Space Science

Studies are needed concerning enabling science applications of HTCI technologies in a range of areas, including applications at both the systems-level (e.g., for space propulsion – such as solar electric power and propulsion) and the architecture-level (e.g., assembly and maintenance of large-scale observatories). Potential systems-level technologies, applications that could be studied include planetary surface applications (e.g., for surface rovers and operations), propulsion applications for deep space missions (e.g., multiple asteroid rendezvous), and others.

1.2. Advanced Concepts Definition Studies

HTCI advanced systems concepts definition studies should be focused on solving the strategic technical challenges associated with safe, affordable and effective, science-driven human/robotic exploration and development of space over the coming several decades. (See page C-1 above for the web site reference for these challenges.) The emphasis may be on either the application of breakthrough or other advanced technologies or on new and potentially revolutionary systems concepts (including architectures) of potentially great future importance in the near-, mid- and far- term. HTCI advanced concepts studies may address applications of any HTCI R&T themes/areas singly or in combination.

These studies should result in the preliminary definition of new design concepts – including systems, infrastructures, architectures, etc., or new approaches to applying existing concepts to HEDS challenges. Innovative solutions that meet multiple exploration and/or commercial space mission needs are of particular interest.

1.3. Technology-Systems Analysis Studies

Technology-systems analysis (TSA) studies within the HTCI will involve independent and cooperative refinement of the trade space for exploration and commercial development of space. These efforts may address either already existing or new advanced systems concepts for HEDS.

Activities of particular interest for HTCI TSA activities include: (1) preliminary modeling and sensitivity studies of innovative new options (including determination of sensitivity of system-level parameters and characteristics to changes in technology-level metrics), and (2) integrated assessments of concepts emerging from various sources in a common context (including the NASA Institute of Aerospace Concepts (NIAC)), and (3) activities to update strategic research and technology (R&T) road maps for HTCI (including technology assessments, technology forecasting, etc.).

1.4. System and Infrastructure Modeling

HTCI system and infrastructure modeling activities should focus on translating preliminary models that already exist (for example, those that may be developed as part of TSA activities described above) into more detailed models that may be used in integrated mission architecture studies. Activities of particular interest include the development of analytical models of new systems, the development and use of databases to support modeling, and dynamic simulations of new system concepts.

1.5. Mission Architecture Studies (MAS)

HTCI MAS will synthesize and evaluate the results of advanced concepts studies and technology-systems analysis (including those funded through the HTCI – see paragraphs 1.2-1.4

above) in the context of integrated end-to-end mission architectures. The particular focus of MAS efforts will be human/robotic exploration mission options, including 50-100 day class human missions in the Earth's neighborhood, 300-1000 day class human/robotic missions including interplanetary targets, and sustained interplanetary human/robotic presence.

HTCI MAS of particular interest include those involve potential human/robotic missions to the Moon, Earth-Moon/Sun-Earth Libration Points, Mars and asteroids.

1.6. Operations Concepts and Modeling

HTCI operations concepts and modeling activities will involve focused consideration of new HEDS concepts and mission architecture study results in terms of operations – with the goal of feeding results from operations studies back to MAS (and other) efforts early in the design process. Activities of particular interest include those that could result in dynamic modeling of advanced HEDS operations concepts.

1.7. Other Areas of Potential Interest

Other, lower priority, topics of potential interest in this area include training concepts and architectures, and technology validation testing requirements and architectures.

2. HEDS-Enabling Advanced Research and Technology Development

This category includes tightly focused exploratory research and technology development targeting "tall poles" and rapid analysis to identify promising systems concepts and establish technical viability to "first-order" of technologies at the breadboard level. These proposals would typically address only one or two of the individual HTCI technology themes cited below in this Appendix. If appropriate, proposers are encouraged to identify and make arrangements for testing, validation of the performance, or demonstrations of their technology developments by means of test beds or other facilities at NASA Field Centers. Such proposed activities must be documented per Appendix B. A representative model or prototype which goes well beyond *ad hoc*, 'patch-cord,' or discrete component level bread-boarding should be tested in a relevant environment. This demonstration might represent an actual system application or might only be similar to the planned application using the same technologies.

In this category, individual proposals requiring government funding of up to $400K in FY 2001 will be considered; there is no lower limit. Projects of this type should be proposed to be implemented in 24 months or less. Total government funding of up to $1,000K over 24 months (including FY2001) will be considered; there is no lower limit. The anticipated number of awards is up to approximately 20, with an average value of $750K over 24 months.

Proposals in each of the three categories described in this Appendix shall focus on specific HTCI technical themes. Descriptions of each of the technical themes are included below.

2.1. Space Resources Development (SRD)

The SRD theme includes material resource extraction and processing, as well as manufacturing of finished items from *in situ* materials. This area encompasses lunar, asteroid, and Martian types of materials.

HTCI is seeking proposals that would in the nearer-term mature and validate innovative SRD technologies at the breadboard or higher level, consistent with longer-term goals and strategic technology for human / robotic exploration and development of space (THREADS) road maps. Concepts that can be applied to high-payoff commercial applications are of particular interest. Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

2.1.1. *In Situ* Resource Excavation and Separation

Use of space resources is highly dependent on extracting, separating, and transporting available resources efficiently. *In situ* resource excavation, and separation includes the simple extraction and separation of desired resources from the bulk resources available. Resource collection processes of interest include: atmospheric resource acquisition, and fine-regolith, hard material/ore, and subsurface resource excavation, drilling and acquisition. Separation processes of interest include physical/mechanical separation, electro/thermal separation, and gas/volatile separation. Challenges for resource excavation, drilling, acquisition, and separation include minimizing equipment mass and power needs, while operating autonomously, over long periods of time, and in extremely cold (e.g. permanently shadowed lunar craters), dusty/abrasive, and/or micro-g environments. Potential locations for resources of interest include the moon, Mars and it's moons, and Near Earth asteroids and dormant comets. Resources of interest include: bulk regolith for processing and radiation shields, bulk or processed regolith for cement, Mars atmospheric gases, lunar solar wind deposited volatiles, lunar polar hydrogen/ice, Mars regolith/subsurface water, and asteroid/comet water and volatiles. Proposals with technologies and concepts that are applicable to multiple destinations/resources will receive higher priority.

2.1.2 Resource Processing and Refining

Resource processing and refining involves single or multi-step thermal, chemical, and/or electrical processing of extracted resources into products with immediate use or as inputs into *in situ* Manufacturing and/or Surface Construction activities. Challenges for resource processing and refining include minimizing processing hardware size, mass, and power needs, and minimizing processing reagent losses and Earth supplied consumables, while operating autonomously over long periods of time. Resource processing and refining concepts and technologies of interest include the extraction of oxygen and feedstock materials (silicon, metals, etc.) from extracted mineral resources, and concepts and technologies associated with the processing of water and/or carbon dioxide into oxygen, fuels, and/or feedstock for plastic and biological support applications.

2.1.3 *In Situ* Manufacturing

In situ manufacturing of engineering components will require highly versatile processes capable of producing near-net-shape parts from a variety of materials including metal alloys, plastics, ceramics, and composites as well as the production of solar cells and other electrical power generating system elements. *In situ* manufacturing is expected to evolve from the use of feedstock materials brought from Earth to the use of feedstock materials generated from indigenous resources on the moon, Mars, asteroids, or other bodies. Concepts and technologies of particular interest include additive fabrication processes, such as those in the family of emerging processes known as solid freeform fabrication with emphasis on adaptation of state-of-the-art technologies and the development of innovative concepts and approaches. Challenges to be addressed include practical materials processing in reduced-gravity environments, efficient use of energy and feedstock materials, and minimization of the mass and volume of fabrication system equipment.

2.1.4. Other Areas of Potential Interest

Other, lower priority, topics of potential interest in this area include surface construction, storage and transport of consumables in a planetary environment, and others.

2.2. Space Utilities and Power (SUP)

The SUP theme includes space solar power (including wireless power transmission), space nuclear power, and cryogenic propellant depots. This area addresses space, lunar, and planetary surface power and includes research and technology development directed toward proof-of-concept breadboards for several types of space utilities and/or power systems as well as supporting areas related to development (such as spectrum management-related R&D).

HTCI is seeking proposals that would in the nearer-term mature and validate innovative SUP technologies at the breadboard or higher level, consistent with longer-term goals and strategic THREADS road maps. Concepts that can be applied to high-payoff commercial applications are of particular interest. Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

2.2.1. Solar Power Generation (SPG)

For in-space and surface applications, technologies that are of particular interest for validation during the next several years are those that can enable affordable, light-weight SPG systems at power levels greater than 100 kW to 1 MW. For the longer term, technologies that could enable systems at power levels in the range from 1 MW to 10 MW are also of interest. Of particular interest are SPG concepts that can achieve dramatic increases in efficiency and reductions in overall system mass per unit power compared to current arrays. For in space systems, significantly higher voltages are also important. Research and technology development is needed to enable large-scale (e.g., MW to 10 MW and greater solar power generation systems. Systems analyses of innovative concepts are also needed. This technology area encompasses photovoltaics (PV) arrays, multi-bandgap approaches, concentrators, solar dynamic conversion, superconducting power distribution, and other areas.

Solar power requirements for surface applications will be different from in-space applications. For example, concentrator PV arrays are not effective during Mars storms. Surface power generation, management and distribution concepts that can achieve dramatic increases in efficiency are being sought. System analyses of innovative concepts are also needed.

Photovoltaic Arrays

Concepts are sought which in the near term, at the 10s of kilowatt level and greater, could enable an array power-to-mass ratio exceeding 300W/kg. High voltages are required (e.g., sustaining operating voltages up to 1000 volts dc). Array designs should have the potential to achieve total array specific powers of 1000 W/kg or more at the multi-hundred kW to MW output level, with potential for significant cost reduction compared to state-of-the-art space qualified arrays at these sizes.

High-Voltage Arrays/Arc Mitigation

Lightweight, high power, high efficiency solar arrays are absolutely necessary for large, high-power solar power generation. However, high voltage, high power arrays in various Earth orbits are subject to continuous arcing, which can destroy lightweight substrates. Therefore, R&D is needed that leads to improved spacecraft charging computer codes, to provide lightweight, fully encapsulated arrays, and to design concepts/guidelines for very high voltage power generation and power distribution systems in GEO and other environments. Voltages up to 500 kV should be considered. Arc mitigation strategies in the space plasma should have highest priority.

Solar Dynamic (SD) Power Modules

Conversion systems are required to provide large (e.g., MW) electrical power systems. Long term goals are for low mass and low cost with long life. One potential option is the use of solar dynamic power modules. R&D is needed assess the performance, mass and cost of SD power conversion units and to provide and evaluate SD designs for high temperature operation along with performance evaluation and materials selection. Conceptual SD systems designs will include the solar concentrator, SD engine and radiator subsystems for various size power modules.

2.2.2. Wireless Power Transmission (WPT)

The availability of abundant, affordable power where needed is a key to future exploration and development of space. In addition, wireless power transmission (WPT) technologies, particularly the utilization of solid-state technology in electromagnetic power generation systems (radio frequency and microwave) will play an important role in high power space communications, radar mapping of planetary surfaces and electric propulsion. Power utilities could prove to be one possible commercial space development as activities expand in Earth orbit and near-Earth space. One innovative approach to providing such power is the use of WPT. Alternatives include the use of radio frequency (RF) phased array power beaming as well as solid state laser power WPT in visible/near-visible frequencies. Also, high power, solid-state radio frequency amplifiers have important applications in electric propulsion as they enable plasma generation without the need for physical electrodes that tend to erode away in the harsh environment.

Specific WPT research and technology areas of interest include, but are not limited to the following areas: (a) Energy conversion efficiency, device and system cost, specific mass, polarization, element size, electronic beam-steering ranges, pilot signal acquisition and pointing, breakdown margins, side lobe levels and losses, radio frequency interference (RFI) and electromagnetic compatibility (EMC) spectrum issues such as required filtering and insertion loses, (b) high power, solid-state radio frequency amplifiers have important applications in electric propulsion, (c) techniques of estimating the cost of non-recurring and recurring engineering for manufacturing, packaging, erection, alignment, and disposing of waste heat to promote lifetime with minimum mass, (d) efficiently distributing the DC power or sunlight over the WPT transmitter array, (e) providing for beam safety and phase references, phase conjugation, phase shifting and the phase error corrections of structural motions, and (f) a NASA-Industry teamed demonstration is desired of an end-to-end scaled system of microwave WPT technology.

2.2.3. Power Management and Distribution (PMAD)

Achieving low-mass and low-cost, large-scale space power systems depends upon modular, high-voltage PMAD systems. Specific technology areas of interest also include intelligent power controls and low-voltage, superconducting PMAD systems. NASA is interested in industry partners to develop components and systems for distributing up to megawatt levels of electric power in large space systems. Technology studies and demonstrations are needed in the following areas: (1) remotely controlled high-voltage switches and distribution units, (2) high-voltage DC-to-DC converters, and (3) high-temperature semiconductors. These systems should be capable of operating at levels of up to 100,000 to 500,000 volts in space and be amenable to evolutionary development. The maximum use should be made of *Power Electronic Building Block* (PEBB) technology.

Reducing surface PMAD system mass and volume (perhaps with high voltages), especially in cases where remotely emplaced power generation systems are used, is of particular importance. In the case of Mars, where high voltage (5,000 to 10,000 volts) would exceed the Paschen discharge threshold, innovative options (e.g., some means of protecting cables) are needed.

2.2.4. Cryogenic Propellant Depots (CPD)

The long-term management, storage and transfer of cryogenic (and non-cryogenic) propellants is one potentially important architecture-level approach to reducing the cost while expanding the operational robustness of future exploration and commercial space activities. Basic research into the behavior of fluids in zero-gravity is the responsibility of NASA's Office of Biological and Physical Research (OBPR). R&D supported by the HTCI will focus on systems level applications of this knowledge as well as associated technologies (such as those mentioned in other paragraphs in this section).

2.2.5. Structural Concepts, Materials and Controls (SCMC)

Low-mass, deployable ultra-large structural systems are important to achieving system-level objectives for a variety of prospective HEDS space utilities and power systems. NASA has a variety of programs (current and planned) that are making significant investments in basic technologies for so-called "gossamer" structures and in systems-level applications for space science missions. The latter include large, thin-film solar sails for use in space transportation and smaller, more precise optical systems for use in future space telescopes. This CAN solicits technology development in SCMC to enable large-scale space utilities and power systems. Concepts and materials enabling systems analyses of innovative structural concepts are also solicited. Note that technology R&D in this area may also be applicable to other technology needs (e.g., large solar concentrators may also be applicable to space telescopes). Technology developments and systems analyses that relate to this thrust area may include, but are not limited to: structural concepts, deployable and inflatable structures, solar concentrators, concepts that integrate primary structure with other system functions (e.g., thermal management, PMAD, etc.), modular assembly, and distributed controls.

2.2.6. Other Areas of Potential Interest

Other, lower priority, topics of potential interest in this area include nuclear power generation, energy storage (including long-life (>10,000 hrs), high energy density (>400 whr/kg) and low volume options), thermal materials and management, and space environmental effects.

Concerning space nuclear power: for a variety of applications, solar power may prove inadequate to meet the needs of future exploration missions (including both nearer term government missions, as well as potential commercial missions in the long term). Space nuclear power generation (SNPG) is a potential alternative. During the next several years, NASA R&D in the area of SNPG will be conducted largely through funding in other Offices. These include the Office of Space Science in the area of radioisotope power systems for planetary surface robotic mission applications. Another potential funding source could be the Office of Aerospace Technology, concerning nuclear reactor power systems for nuclear electric propulsion (NEP). HTCI funding, if any, will be focused on systems studies concerning the identification of innovative approaches to the use of SNPG for human exploration missions and on technological approaches to non-isotope elements of an SNPG system (e.g., energy conversion) that are not addressed by other NASA or non-NASA programs.

2.3. <u>Habitation and Bioastronautics (HAB)</u>

The HAB theme places particular emphasis on systems-level technology development and validation in the areas of extravehicular activity (EVA) systems and human habitation systems (including structural concepts). HTCI is seeking proposals that would in the nearer-term mature and validate innovative HAB technologies at the breadboard or higher level, consistent with longer-term goals and strategic THREADS road maps.

A number of the key technology research topics that must be pursued to address the challenges cited above are the programmatic responsibility of NASA's OBPR. (These are often at lower levels of technology maturity than topics to be addressed within HTCI.) Applicants who wish to propose research or technology development in these areas should refer to other NASA Research Announcements (NRA) issued by the Office of Biological and Physical Research (OBPR), particularly the Advanced Human Support Technology Program NRA (01-OBPR-01). These announcements are available on the web at:

http://peer1.idi.usra.edu

Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

2.3.1. Advanced Habitation Systems (AHS)

Integrated validation is needed of diverse innovative approaches employing various new technologies to enable affordable, long-duration human habitation in space environments ranging from Earth orbit to deep space to lunar and planetary surfaces. Areas of interest for integration included environmental monitoring, life support, structural systems, radiation shielding and others. Deployment and/or construction of AHS are other areas of interest. Concepts that can be applied to high-payoff commercial applications are of particular interest.

Advanced habitation technology is sought to enable future orbital, planetary and deep space applications. This research and development will permit crewmembers (in conjunction with other mechanical and information aids) to accomplish mission objectives safely, reliably, comfortably and efficiently in a diversity of exploration environments and applications. NASA's goal is the understanding of architectural problems and thus solutions to enhance crew morale and productivity. An open architecture is envisioned which can be readily adapted via flexible and modular systems utilizing common solutions and standardized interfaces. Technology research challenges, or problems, of advanced habitation include ways to fully-integrate habitat systems, to protect the crew and hardware from the harsh external environment of space, how to protect the crew from internal systems, development of larger, light weight, and durable habitat pressure vessels, and how to minimize the crews required service, maintenance and repair of equipment in order to keep the habitat functioning. Advances in material developments and manufacturing techniques that enable the structure to "self-heal," and the emplacement, erection, deployment or manufacturing of habitats in space or on the Moon and Mars are considered enabling technologies for the evolution of humans into space and the eventual settlement on Mars. Teaming between the selected PI's and NASA architects/engineers is encouraged to help focus and promote technology that can be practically integrated and tested with existing habitation designs. The following topics are of prime interest and are listed in approximate order of priority.

Habitat Structures

Space and planetary habitation pressure structures and unpressurized shelters are being sought for innovative design and technology solutions that combine high strength and light weight materials, along with the reliability, durability, repairability, radiation protection, packaging efficiency and life-cycle cost effectiveness. Novel methods for underground development of habitable planetary structures that meet human space flight requirements are also being sought. Advanced technology solutions for advanced composite structures, inflatable structures, *in situ* derived structures, and internal structures and mechanisms are being sought.

External Environment Protection

The next generation habitat will need to enhance its external protection capability in order to better protect humans and systems for long duration space missions. Advanced technology solutions for radiation, micrometeoroid and ejecta, vibration, noise, ultraviolet (UV), atomic oxygen (AO), thermal and surface dust protection are being sought. Low bulk thermal insulation for both vacuum and non-vacuum environments needs to be developed. Dust, chemical contamination and self-sealing puncture resistant materials are also extremely important. Protection from radiation, micrometeoroid, orbital debris, and surface ejecta are very important.

Protecting human crews from galactic cosmic radiation will be critically important in conducting safe interplanetary space flights. Shielding is also needed for protection of people and equipment from solar particle events and trapped radiation in the near-Earth environment. There is potential for innovations in conformal tank design and the use of new tank materials that could benefit a wide range of air and space transportation applications. The use of propellants, such as hydrogen, for radiation shielding might prove useful for satellites and spacecraft operating in and above the radiation belts of Earth. It remains a technical challenge to design a lightweight, structurally efficient propellant tank or configuration of tanks, which can provide effective radiation shielding by surrounding a large habitation module with propellant. Innovative propellant storage concepts such as inflatable tanks or the use of solid hydrogen as a radiation shield are of interest but study results should emphasize practical engineering considerations, realistic mass estimates, and feasibility of manufacturing for all concepts.

Integrated Habitation Systems

Research on architectural functional and spatial arrangement, color, patterns, temperature, gravity, and social interaction are being sought. Integration of sensors, circuitry and automated components to enable self-deployment, “smart” structures and “smart” habitats are considered necessary to allow the habitat to operate autonomously. The vision of this technology research is to create an advanced habitat that becomes a “living” structure that not only runs autonomously, but also has self-healing capability. Surface base design, development and evolution are being sought out as well as a number of technologies and techniques that allow the delivery of deployable habitats to space/planet surface. Technological advances in smart habitats, integrated detection, monitoring and control, internal systems and outfitting, and advanced habitat evolution are being emphasized.

Logistics, Maintenance & Repair

Novel methods and techniques for fully integrated skin and sensors/circuitry that enables "smart" structures that autonomously detect, analyze, and correct (repair) structural failure are being sought. Methods of integrating miniaturization technology into the habitat skin that reduces weight and increases self-autonomy are considered important. Life support systems are needed for recycling water, CO_2, controlling trace gas contaminants in human habitation areas, processing solid wastes, provisioning of food, and controlling the thermal environment. Technologies are sought which minimize mass, volume, power, thermal requirements, crew time, and are highly reliable over extended periods of operation; and can operate in both the microgravity and hypogravity environments of space. Concepts and technological advances of particular interest include zero-g clothes washing technology, trash reduction, recycling of plastics, etc. and stowage systems. Technological advances in habitation automated servicing, repair, contamination control and housekeeping are being emphasized.

2.3.2. Extravehicular Activity (EVA) Systems

Extravehicular Activity (EVA) Systems technology is sought to enable future orbital, planetary and deep space applications. This research and development will permit EVA crewmembers (in conjunction with other mechanical and information aids) to accomplish mission objectives safely, reliably, comfortably and efficiently in a diversity of exploration environments and applications. Portable life support system (PLSS) concepts are of interest. An open architecture is envisioned which can be readily adapted via flexible and modular systems utilizing common solutions and standardized interfaces. Teaming between the PI's and NASA engineers is encouraged to help focus and promote technology which can be practically integrated and tested with existing advanced hardware designs. The following topics are of prime interest and are listed in approximate order of priority.

Atmosphere Revitalization

Life support systems suitable for suit mounted portability in a variety of gravity and pressurized environments are sought. Suit, habitat and mobile pressurized transportation devices should use common elements where possible. Components should strive for high reliability, ease of maintenance, low mass, minimal volume, low power, long life and full regeneration without consumables. Efficient removal of CO_2, humidity and trace contaminants is a major challenge. Compact, long lasting storage, supply and recharging of O_2 and power are of concern. Closed loop thermal heating and cooling devices are needed which do not consume scarce resources and which consider improved means of heat transfer.

Environmental Protection

The next generation EVA pressure suit will need to be lightweight, highly mobile and robust while fitting a wide range of sizes. Low bulk thermal insulation for both vacuum and non-vacuum environments have to be developed. Dust, chemical contamination and self sealing puncture resistant materials are also extremely important. Passive and/or active portable radiation protection is needed to enable work beyond LEO. Garments and gloves which compensate for vacuum levels conditions via mechanical counter pressure and pneumatic pressure are to be considered. Lightweight and high strength structural materials readily integrated into the suit backpack, pressure garment, and bearings are sought.

Human Integration

System level integration, modeling and prototyping is encouraged to aid cost effective and efficient design of EVA crew interfaces. Development of conceptual designs and mockups for airlock/hatch/controls should allow mobility testing of healthy and incapacitated crewmembers, isolate contamination and feature minimal gas/power loss for frequent crew and equipment transfer. Computer based instrumentation and data processing is sought for rapid quantification of suit mobility dynamics and sizing/fit/comfort. Portable multi-sensory information displays and controls are needed which work in harsh environments and are compatible with hands free input/output. Robotic interfaces are essential. Handling aids are desired for delicate materials, extreme temperatures and reduction of fatigue.

2.3.3. Other Areas of Potential Interest

Other, lower priority, topics of potential interest in this area include advanced medical care systems, and others.

2.4. Space Assembly, Inspection and Maintenance (SAM)

This theme includes in-space assembly and construction, in-space inspection and/or servicing. This area includes studies to better define technology needs and tests to rapidly validate "on the laboratory shelf" technology.

HTCI is seeking proposals that would in the nearer-term mature and validate innovative SAM technologies at the breadboard or higher level, consistent with longer-term goals and strategic THREADS road maps. Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

2.4.1. In-Space Assembly and Construction

The ability to assemble large, potentially ultra-lightweight, systems in space is a key requirement for many future human/robotic exploration and commercial development space applications. Key areas for development could include system element assembly in space, including structural mechanisms and fluid interconnections. Concepts that can be applied to high-payoff commercial applications are of particular interest.

The International Space Station initiated an era of large-scale in-space assembly activities. As systems move away from LEO, a variety of technology advances will be necessary to improve on current approaches towards system assembly. Robotic systems will be necessary for all stages of assembly and construction. Examples include:

- A variety of interconnection capabilities must be simplified or automated. Methods for fluid coupling and robotic systems for pipe/hose handling need development. Electrical connectors with interface guidance and robotic handling methods need to be developed.
- New structural assembly approaches must be defined. These include assembly mechanisms, both manual and remote. Grapple fixtures, hard points, and other methods for construction robots to maneuver and handle assembly components need refinement.
- Methods that allow robotic assembly devices to 'walk softly' without damaging structural elements (such as inflatable components) and minimize the need for special purpose fixtures.
- Robots or other devices for manipulating large payloads (construction components) such as 'cranes' or 'fork lifts'
- Robotic components that enable very fine-scale manipulation for connection work, detailed hookup, and location adjustment while working in tightly constrained areas.

Proposals are sought to explore the enabling aspects of astronauts in deployment, assembly, checkout, maintenance and upgrade of very large gossamer structures. All the activities should use an optimal combination of robotics, teleoperation and extravehicular activity. The gossamer structures considered are large telescopes, antennas and sunshields - tens to hundreds of meters in diameter - and solar sails extending from hundreds of meters to kilometers. These gossamer structures are based heavily on membranes, inflatables, rigidizables and other ultra-low-mass materials and structures.

2.4.2. In-Space System Deployment

Not all space systems must be assembled. Launch vehicle constraints limit size and payload packaging, but some systems will deploy themselves into much larger configurations once on-orbit. Concepts that can be applied to high-payoff commercial applications are of particular interest. Technology development areas of interest include, but are not limited to:

- Inflatable component concepts that create rigid structures from smaller packages.
- Kinematic and/or unfolding structures.
- Very thin membranes for antennas or reflectors. This includes the special tools or handling techniques to maintain membrane integrity.
- Extruded beam fabrication and other forms of manufactured structural component

2.4.3. Autonomous Rendezvous and Capture/Self-Assembling Systems

The range of mission and operations options in human exploration and commercial development of space will grow dramatically over time. Potential missions such as an unmanned re-supply vehicle or a deep space observatory must be capable of autonomously maneuvering to the location of other space systems and possibly assembling themselves. Innovative technologies and approaches to autonomous rendezvous and capture, and self-assembling systems are needed. For example, technology is needed for highly robust docking and capture systems that enable servicing, manipulation, and/or docking with space hardware. Of specific interest are scalable magnetic docking approaches that minimize the complexity of mechanical interfaces. This would include magnetic "pull-in" from small separation distances, self-correcting axial and rotational alignment of interfaces, and reliable mating of power, data, and fluid connections.

Advances in technologies are needed that provide autonomous utility (i.e., power communication, fluids, etc.) interface mating between elements. Advances in video guidance sensors that provide Six-Degrees-of Freedom (6-DOF) data for the final maneuvering and docking are needed. Specifically, needed improvements are lower mass, reduced power usage, and increased tracking rate performance. Range transponders that allow one spacecraft to rendezvous with another need increased data quality and extended range. Improved CPUs and other onboard elements in on-board computer and collision avoidance computers used to process rendezvous information are needed.

2.4.4. Inspection and Diagnostics in Space

The ability to inspect and diagnose problems involving large systems in space will be vitally important to many future human/robotic exploration mission systems. Such capabilities may also be one key to future commercial space servicing and large, commercially serviced space spacecraft. Areas include external inspection, autonomous identification of device failure, and detection of structural failures (such as crack/fraction and/or leak detection).

Human activities in space will increasingly rely upon complex systems made up of thousands of components. Although designed for high reliability, these systems will still need to be inspected for operational readiness or compliance, and when a system fails, a diagnosis must be done that identifies the faulty component for servicing. Approaches towards inspection and diagnosis that reduce or eliminate direct human involvement are appropriate. Inspection approaches that eliminate the need for human EVA activities are of particular benefit. Examples include:

- Advanced, compact, and highly versatile inspection and diagnostic capabilities for monitoring and evaluating the condition of vehicle structures and systems as well as enabling isolation of system failures to the component level
- Very small, free-flying, autonomous devices capable of long term external inspection activities
- Methods for self-diagnosis capabilities built into components that identify failed elements and ‘warn’ higher-level system functions of potential or actual problems
- Non-invasive tools or approaches that identify structural cracks, fatigue, excessive stress, etc.
- Tools for leak detection, particularly in remote or hard to reach locations
- Intelligent system management functions capable of reconfiguring components as the result of a fault detection and isolation process.

2.4.5. Servicing, Maintenance and Repair of Systems in Space

Future long-duration human exploration missions will require advanced, self-sufficient capabilities for servicing, maintenance, and repair to reduce the mass and volume of spare components and to enhance mission robustness. Concepts and technologies that address human-implemented, semi-autonomous, and autonomous servicing, maintenance and repair capabilities are appropriate under this program element. Also, concepts that might be applied in future high-payoff commercial applications are of particular interest. Examples include, but are not limited to:

- New concepts for orbital replacement units / line replacement units (ORU/LRUs) and components such as non-disposable filters, and common multi-application system elements that can be reprogrammed, reorganized, reconfigured, or otherwise modified to serve in multiple roles throughout a mission either as part of nominal operations or on a contingency basis
- Capabilities for calibration of scientific instruments, metrology instruments and systems equipment during a mission
- Capabilities for component level repair of avionics and mechanical systems and approaches to increase levels of component commonality
- Technologies such as cutting and joining that will be required for major structural repairs
- Capabilities such as machining, cleaning, heat treating, and metrology to support the production of structural and mechanical spares from bulk stock materials in the form of bar, rod, sheet, plate, etc.

2.4.6. Other Areas of Potential Interest

Other, lower priority, topics of potential interest in this area include autonomous rendezvous and capture / self-assembling systems, intelligent operations, and others.

2.5. Exploration and Expeditions (ExE)

Once explorers arrive at their destination, their tools will become the measure of their scientific productivity. Detailed exploration of the atmosphere, surface and interior of a planet will be enabled by flying, roving and subsurface systems. Sensors, instruments and laboratory systems will provide the capability for detailed *in situ* measurements. Highly capable communications networks will enable IVA crew, Earth-based scientists, and the public to participate in the expedition. The Exploration and Expeditions Theme includes surface systems, virtual exploration and sub-surface knowledge and access, with particular emphasis on developing breadboards and/or prototypes for experimental validation in test beds. The ExE theme offers unique commercial possibilities, and unlimited opportunities for industry, academic and NASA partnering.

HTCI is seeking proposals that would in the nearer-term mature and validate innovative ExE technologies at the breadboard or higher level, consistent with longer-term goals and strategic THREADS road maps. Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

2.5.1 Surface Systems

Considerable progress has been made in the past decade in a wide range of mechanical systems that incorporate mobility, manipulation and increasingly powerful onboard computing. Future HEDS missions will require a diverse range of surface systems that share common features with ongoing robotic missions and which are distinct. For example, future human exploration missions will certainly require one or more systems designed to convey humans safety over rough, unstructured terrain over periods of time ranging from hours to months.

The NASA Office of Space Science (including the Mars Program) will have substantial responsibility for technology relating to small-scale robotic surface systems (including approaches to rough terrain mobility). The emphasis under HTCI funding will be on systems that provide assurance of crew safety for substantially larger systems over periods ranging up to several years, rather than the smaller scale and shorter duration missions typical of robotic missions. One possibility is to establish one or more evolutionary, modular technology test beds – focused on HEDS functional requirements – for the validation of new mechanisms and software emerging from various programs.

Proposals for the development of concepts, test beds, and systems that address each of these needs are appropriate under this program element. Teaming between the PI and NASA engineers is encouraged to help focus and promote technology that can be practically integrated and tested with existing advanced hardware designs. Concepts that can be applied to high-payoff commercial applications are of particular interest. Specific examples of topic areas of interest include but are not limited to:

<u>Unpressurized Crew Mobility Vehicle Test Bed</u>

The unpressurized crew mobility vehicle test bed would serve as a platform for development, test, and evaluation of new concepts for planetary vehicle systems and subsystems. This test bed would be equipped with all systems necessary to make it a mobile vehicle but would be designed to enable retrofitting of alternative systems, subsystems, and crew interfaces for test and evaluation. The core vehicle may include design innovations such as advanced materials to minimize mass while providing appropriate structural characteristics. The test bed vehicle would operate in a 1-g terrestrial environment and be capable of traversing terrain analogous to that of the Moon and Mars. The payload for such a test bed vehicle would include two crewmembers wearing spacesuits with a combined mass of up to 330-350 kg plus a cargo of instruments, tools, and samples with a combined mass of up to 250 kg. Total driving range capability should be not less than 100 km per sortie and total operational duration capability should be not less than 12 hours per sortie.

<u>Prototype Robotic Assistants</u>

Prototype robotic assistants would serve as a platform for testing system concepts and designs that may be incorporated in future robotic assistant systems. Robotic assistants will be used to support EVA crewmembers by carrying tools, equipment, and samples and performing limited tasks at crewmember direction. These assistants will operate semi-autonomously by following crewmembers during EVA operations and by responding to movement commands and task instructions from the crewmembers. Innovative concepts are sought for self-mobile systems including novel mobility approaches to enable traversing of rugged terrain, natural interfaces with humans, autonomous path selection, and navigation capabilities. These assistants may include dexterous manipulator systems.

<u>Teleoperations</u>

Surface systems may require the ability to be operated remotely, with the amount of supervision ranging from direct control from operators on Earth or crewmember inside a surface habitat, to autonomous “leader-follower” control architectures. Innovative concepts for remote operations are sought, for mobile surface systems such as robotic astronaut assistants, unpressurized local rovers, and large, long-range crew/cargo transports. Functions that are the potential subject of teleoperated control include both surface movement, performance of tasks by manipulators mounted upon, mobile systems, and operation of drills.

Long-Range Crew/Cargo Transport Vehicles

Extended exploration of planetary surfaces will require pressurized vehicles capable of traverses of hundreds of kilometers lasting days or weeks. Design concepts are solicited for vehicles that provide extended range mobility, provide for all human needs over periods of days or weeks, and serve as a staging point for local human EVA operations.

2.5.2. Virtual Exploration (VE)

Sharing the experience of exploration is a key strategic goal of NASA’s HEDS Enterprise. One objective of this theme is to integrate and validate the technologies needed to revolutionize public engagement in future HEDS missions through “virtual exploration”. The technologies for higher rate communications, while critical to VE, are not a part of the purpose of this element. Rather, the focus is rapid exploitation of emerging commercial-off-the-shelf technologies to create new systems-level approaches, such as innovative human machine interfaces or virtual reality simulations using exploration data sets. Concepts that can be applied to high-payoff commercial applications are of particular interest.

2.5.3. Subsurface Knowledge and Access

The exploration of the lunar or planetary subsurface is of high priority to both scientists and planners of human missions. Technologies to explore the subsurface will evolve in a logical manner beginning with global surveys employing remote sensing technologies. These global surveys will be augmented, perhaps in the same opportunities, with regional and local surface-based surveys to map the subsurface in three dimensions, and to locate the most promising areas for subsequent drilling. Technologies for producing probabilistic survey maps will be needed to identify the most promising drilling sites. Drilling equipment will be required to function reliably in harsh planetary environments, while providing down-hole scientific samples. If subsurface aquifers are located, systems will also be required to bring water to the surface and store it. To address these challenges, proposals in the following technologies are of interest: drilling/coring/sample acquisition systems, and subsurface sounding (drilling site characterization). Concepts that can be applied to high-payoff commercial applications are of particular interest.

2.5.4. Other Areas of Potential Interest

Other, lower priority, topics of potential interest in this area include surface laboratory systems for human exploration missions. These systems would draw heavily on developments underway to extend surface science for robotic missions, but would exploit safely and effectively the unique capabilities offered by human explorers. Some examples of other R&T areas of interest include, but are not limited to: surface environmental effects, space communications and networks, surface laboratory systems.

2.6. Space Transportation (STR)

STR and related infrastructures are absolutely enabling for human/robotic exploration and development of space systems, and for a wide range of other applications. NASA's Office of Aerospace Technology (OAT) has principal responsibility for the development of vehicle-unique technology for future space transportation systems – particularly space propulsion technology. Technical objectives under the HTCI are confined to (1) systems studies to define HEDS-focused requirements for space transportation, (2) specific HEDS-enabling technology areas that are not presently addressed adequately by current programs, (3) highly innovative new HEDS-supporting R&T areas that are not addressed adequately at present by current programs.

Studies are needed that address the areas of Earth-to-orbit (ETO) transportation and infrastructure (including particular emphasis on studies in the areas of innovative ETO transportation and infrastructures for HEDS) and studies and research in relevant in-space transportation and infrastructure areas. Several critical component or subsystem-level technologies need development. One area of particular importance are the technologies associated with very low-cost in-space transportation, and in particular, electric propulsion.

HTCI is seeking proposals that would in the nearer-term mature and validate a hand full of specific, innovative STR technologies at the breadboard or higher level, consistent with longer-term goals and strategic THREADS road maps. Preliminary planning indicates that the following topics are of particular importance for HTCI funding in the near term.

2.6.1. In-Space Propulsion: High Power Electric Propulsion for Human Missions

Innovations in high power electric propulsion technologies are sought that will enable dramatic reductions in overall mission costs, enable rapid and affordable launch and space transportation systems, and lead to ambitious human exploration of the solar system. Proposals that seek to investigate and resolve the fundamental lifetime and performance limiting mechanisms of high power electric and electromagnetic thrusters are of particular interest. Concepts of interest include, but are not limited to, Hall thrusters, ion thrusters, magnetoplasmadynamic, pulsed inductive thrusters and Variable Specific Impulse Magnetic Rockets (VASIMRs). Proposals should include a description of the configuration, key design parameters, system level design parameters and system level requirements, sensitivities of the design parameters to requirements, mass distribution, system performance characteristics including justification of these characteristics, design issues, technology development needs and a cost estimate for the design, development, test, and system verification. Concepts that can be applied to high-payoff commercial applications are of particular interest.

Key supporting tools and component technology advances are also of interest, including innovations such as lightweight, high-temperature superconducting magnetic systems for electromagnetic thrusters, and trajectory design software tools to simulate missions using advanced electric propulsion concepts (such as those in which thrust and specific impulse can be varied at constant power).

2.6.2. Aero-entry and Descent Technologies

Innovations in atmospheric flight technologies are sought that will enable dramatic reductions in overall mission costs, enable rapid and affordable launch and space transportation systems, and lead to ambitious human exploration of the solar system and beyond. Technologies that offer significant improvements in mission performance, operational costs, reliability, operability, and safety are sought. Human planetary exploration also requires transportation of humans and large masses and volumes from a low energy orbit to a pre-selected landing sites in the presence of surface hazards and obstacles. One of the important challenges in accomplishing this is the safe, efficient, and cost effective dissipation of the energy of these large masses and volumes through the flight regime from entry into the Mars atmosphere to a safe, soft landing on the Mars surface.

Areas of interest include, but are not limited to, aerocapture, aeroassist, deceleration systems for target body entry and landing, and precision landing. Concepts must provide sufficient maneuverability to compensate for aerodynamic, atmospheric, navigation, and transportation system deviations and uncertainties. Proposals should include a description of the configuration, key design parameters, system level design parameters and system level requirements, sensitivities of the design parameters to requirements, mass distribution, system performance characteristics including justification of these characteristics, design issues, technology development needs and a cost estimate for the design, development, test, and system verification.

Concepts that can be applied to high-payoff commercial applications are of particular interest.

2.6.3. Other Areas of Potential Interest

Other topics of potential interest in this area include advanced chemical propulsion concepts and nuclear propulsion concepts, although these areas are of lower priority for HTCI funding in FY 2001. In general, only studies and/or architecture-enabling concepts (including other new innovative propulsion concepts) that are not otherwise funded will be considered for funding through this CAN.

3. Technology Flight Demonstrations (TFDs)

In order to accomplish in its goals, the HTCI must draw successfully upon research and technology development results from diverse programs across NASA and from outside the Agency. This knowledge and these technologies must be integrated into test beds and ground demonstrations (such as those indicated in the paragraphs above). In addition, wherever appropriate, new technologies will be validated in space through TFDs.

This proposal category includes initial demonstrations of viability for key HEDS concepts/elements in space using potentially nearer-term technologies, with an emphasis on enabling multi-purpose (space or terrestrial) applications of HTCI and related systems/technologies. These proposals might address two or more of the individual HTCI technology themes cited in Section 2 of this appendix. In this category, individual proposals requiring government funding of up to $400K in FY 2001 will be considered; there is no lower limit. Projects of this type should be proposed to be implemented in 24 months or less. Total government funding of up to $1,500K over 24 months (including FY2001) will be considered; there is no lower limit. The anticipated number of awards is up to approximately 8. The average award is anticipated to be approximately $750K over 2 years.

Activities supported under HTCI could include either (a) preliminary definition studies (e.g., “pre-Phase A” studies) of potential small-to-large scale technology flight experiments and demonstrations to be conducted in the future, or (b) implementation of small-scale initial TFDs (consistent with HTCI funding availability).

Any proposed TFD definition studies must include identification and documentation of potential TFD costs. It is recognized that detailed cost analyses are a likely product of TFD definition studies. However, for purposes of definition studies, offerors should indicate that likely cost of the potential future TFD to be defined using the following categories: (1) “small-scale”: approximately $0.5M to $2M (total cost, excluding launch), (2) “moderate-scale”: approximately $5 to $15M (total cost, excluding launch), or (3) “large-scale”: approximately from $25M to $350M in cost (total cost, excluding launch).

In general, the emphasis should be on efforts that integrate technologies from a number of areas within a theme (as described above), or across themes. Technology flight demonstration activities may involve the following HTCI R&T themes:

- Space Resources Development
- Space Utilities and Power
- Habitation and Bioastronautics
- Space Assembly, Inspection and Maintenance
- Exploration and Expeditions
- Space Transportation

Offerors should indicate clearly what technology experiments (involving which technologies) would be conducted as aspects of any TFD.

Technology flight demonstrations that validate technology applicable to initial missions beyond LEO to destinations in the Earth’s neighborhood (including Earth-Moon and Sun-Earth Libration Points, and the Moon) are of particular interest. Demonstrations that involve the use of the Space Shuttle and the International Space Station are of interest, although various launch vehicles may be considered as well as venues for experiments/demonstrations ranging from LEO to Earth-Moon space, to lunar or planetary surfaces.

In all cases, proposers should indicate how these demonstrations might be important to early science, commercial space or human space flight mission applications of HTCI (or other NASA) technologies. Concepts that can be applied to high-payoff commercial applications are of particular interest.

GLOSSARY OF ACRONYMS

6-DOF..............................Six Degrees of Freedom
AHS ....Advanced Habitation Systems
AHST...............................Advanced Human Support Technology
ALARA............................“as low as reasonably achievable”
AO ....Atomic Oxygen
CAN................................Cooperative Agreement Notice
CFR.................................Code of Federal Regulations
Co-I.................................Co-Investigator
CPU ....Central Processing Unit
DC...................................Direct Current
EMC................................Electromagnetic Compatibility
E/PO................................Education/Public Outreach
ETO ....Earth to Orbit
EVA ....Extravehicular Activity
ExE ....Exploration and Expeditions
FY ....Fiscal Year
g ....Gravity
G&A ....General and Administrative
GCR................................Galactic Cosmic Ray
GEO ....Geostationary Earth Orbit
HAB................................Habitation and Bioastronautics
HEDS..............................Human Exploration and Development of Space
HTCI...............................HEDS Technology / Commercialization Initiative
ISS...................................International Space Station
IVA ....Intravehicular Activity
kg ....kilogram
km...................................kilometer
kV ....kilovolt
kW ....kilowatt
LEO.................................Low Earth Orbit
LRV ....Line Replacement Unit
MAS................................Mission Architecture Studies
MOU...............................Memorandum of Understanding
MPD................................Magnetoplasmadynamic
MW.................................megawatt
NASA ....National Aeronautics and Space Administration
NEP.................................Nuclear Electric Propulsion
NIAC...............................NASA Institute of Aerospace Concepts
NOI ....Notice of Intent
NPRS ....NASA Peer Review Services
NRA................................NASA Research Announcement

OAT ....(NASA) Office of Aerospace Technology
OBPR...............................(NASA) Office of Biological and Physical Research
ORU................................Orbital Replacement Unit
OSF.................................(NASA) Office of Space Flight
OSS.................................(NASA) Office of Space Science
PEBB ....Power Electronic Building Block
PI.....................................Principal Investigator
PIT ....Pulsed Inductive Thrusters
PLSS ....Portable Life Support System
PMAD..............................Power Management and Distribution
POC ....Point of Contact
PV ....Photovoltaics
R&D................................Research and Development
R&T ....Research and Technology
RF ....Radio Frequency
RFI ....Radio Frequency Interference
SD ....Solar Dynamic
SAM................................Space Assembly, Inspection and Maintenance
SCMC ....Structural Concepts, Materials and Controls
SIM ....System Integration, Advanced Concepts, Analysis, Modeling
SNPG...............................Space Nuclear Power Generation
SPE ....Solar Particle Event
SPG.................................Solar Power generation
SRD ....Space Resources Development
STC.................................Strategic Technical Challenge
STR.................................Space Transportation
SUP.................................Space Utilities and Power
TFD.................................Technology Flight Demonstration
THREADS.......................Technology for Human/Robotic Exploration and Development of Space
TIM ....Technical Interchange Meeting
TSA.................................Technology-Systems Analysis
UV ....Ultraviolet
VASIMR..........................Variable Specific Impulse Magnetic Rocket
VE...................................Virtual Exploration
VEO ....Virtual Education Outpost
VRC ....Virtual Resource Center
W ....Watt
WPT................................Wireless Power transmission
WWW.............................World Wide Web