NASA

National Aeronautics and
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December 4, 1996

NRA-96-HEDS-02

RESEARCH ANNOUNCEMENT

Microgravity Materials Science: Research and Flight Experiment Opportunities

Letters of Intent Due: January 24, 1997
Proposals Due: March 11, 1997

OMB Approval No. 2700-0042

MICROGRAVITY MATERIALS SCIENCE:
RESEARCH AND FLIGHT
EXPERIMENT OPPORTUNITIES

NASA Research Announcement
Soliciting Research Proposals
for the Period Ending
March 11, 1997

NRA-96-HEDS-02
Issued: DECEMBER 4, 1996

Office of Life and Microgravity Sciences and Applications
Human Exploration and Development of Space Enterprise
National Aeronautics and Space Administration
Washington, DC 20546-0001

NASA RESEARCH ANNOUNCEMENT
MICROGRAVITY MATERIALS SCIENCE:
RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

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NASA RESEARCH ANNOUNCEMENT

MICROGRAVITY MATERIALS SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

This NASA Research Announcement (NRA) solicits research proposals to conduct scientific investigations in the discipline of microgravity materials science. These investigations may involve space experiments using new or existing research instruments, ground-based experiments, or theoretical research intended to support the study of materials science using microgravity. Flight experiments may be proposed that require the development of new instruments or use other instruments described in this solicitation. Descriptions of the technical areas of interest under this research announcement appear in Appendix A, Section II.

Participation is open to U.S. industry, educational institutions, other nonprofit organizations, NASA centers, other U.S. Government agencies, and to international investigations. **In the case of international investigations, NASA only funds U.S. investigators involved in the investigation.** Proposals must be submitted before March 11, 1997. NASA reserves the right to consider proposals received after that date if such action is judged to be in the best interests of the Government. Proposals will be evaluated by scientific peer review and, if appropriate, engineering feasibility reviews; selections are planned to be announced by October 1997.

Appendices A and B provide technical and program information applicable only to this NRA. Appendix C contains general guidelines for responding to an NRA.

This Announcement will not comprise the only invitation to submit a proposal to NASA for research support or flight opportunities in microgravity research. This Announcement is part of a planned sequence of solicitations inviting proposals in the disciplines of the microgravity program.

NASA Research Announcement Identifier: NRA-96-HEDS-02

NRA Release Date:	**DECEMBER 4, 1996**
Letter of Intent Due:	**JANUARY 24, 1997**
Proposal Due:	**MARCH 11, 1997**

This NRA is available electronically via the Internet at:

http://microgravity.msad.hq.nasa.gov/96_materials_science_NRA

Letters of Intent may be submitted via the world wide web through the following address:

http://microgravity.msad.hq.nasa.gov/96_matsci_letter_of_intent

Alternatively, letters of Intent may also be submitted via electronic mail to the following address:

loi@hq.nasa.gov

If electronic means are not available, you may mail Letters of Intent to the address given below.

Submit Proposals to the following address:

Dr. Michael J. Wargo

NASA c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-02)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA cannot receive proposals on Saturdays, Sundays or Federal holidays.

Proposal Copies Required: 15

Non-U.S. Proposals. Special instructions apply to non-U.S. proposals. In addition to sending the original proposal (and copies) to NASA through Information Dynamics Inc. as directed above, one (1) additional copy along with the Letter of Endorsement (see page A-18, Section VI) must be forwarded to:

Ms. Ruth Rosario
ref: NRA-96-HEDS-02
Space Flight Division
Code IH
National Aeronautics and Space Administration
Washington, DC 20546-0001
USA

Proposers will receive a postcard confirming receipt of proposal within 10 working days of the due date.

Obtain Programmatic Information About This NRA From:

Dr. Michael J. Wargo
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Selecting Official: ....Director
Microgravity Science and Applications Division
Office of Life and Microgravity Sciences and Applications
NASA Headquarters

Your interest and cooperation in participating in this effort are appreciated.

Arnauld E. Nicogossian, M.D.
Associate Administrator for
Life and Microgravity Sciences and Applications (Acting)

APPENDIX A
NRA-96-HEDS-02

TECHNICAL DESCRIPTION

MICROGRAVITY MATERIALS SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

I. INTRODUCTION

A. BACKGROUND

NASA's Microgravity Science and Applications Division (MSAD) conducts a program of basic and applied research in microgravity to improve the understanding of fundamental physical, chemical, and biological processes. In this program, NASA sponsors investigations by university, industry, and Government researchers using both ground-based and space-flight facilities.

The materials science discipline has been an integral part of the microgravity science and applications program since its inception. The Division released a NASA Research Announcement (NRA) for materials science in 1994 and expects to release NRA's in materials science approximately every two years. Other MSAD supported disciplines with periodically released solicitations are biotechnology, combustion science, fluid physics, and fundamental physics. For additional information on research opportunities available through the Microgravity Science and Applications Division, contact:

Dr. Bradley M. Carpenter
Code UG
National Aeronautics and Space Administration
Washington, DC 20546-0001

Telephone: (202) 358-0813
Telefax: (202) 358-3091

The Space Processing and Commercialization Division of the Office of Life and Microgravity Sciences and Applications encourages proposers to address objectives in commercial research. Please see the attachment at the back of this NRA (Notice of Areas of Interest for Materials Applied Research for the Commercial Development of Space Program) for information on opportunities that exist for proposals which predominantly feature applied commercial research and must have an industrial, cost sharing partner. This attachment is for informational purposes and is not part of this NRA.

B. RESEARCH ANNOUNCEMENT OBJECTIVES

The materials science program seeks a coordinated research effort involving both space- and ground-based research. Ground-based research forms the foundation of the materials science program providing the necessary experimental and theoretical frameworks for rigorously assessing and, ultimately, quantitatively understanding the phenomena. This research may eventually mature to the point where it can become the focus of a well defined flight experiment. This NRA has the objective of broadening and enhancing the MSAD microgravity materials science program through the solicitation of:

1. Scientific experiments that, through the use of a long-duration microgravity environment, will lead to major advances in the understanding of fundamental aspects of materials science.

2. Scientific experimental and theoretical research that will a) advance research in materials science, b) expand both the scientific scope and the research community associated with the materials science program, c) broaden the understanding of microgravity experiment results, d) clarify objectives for future microgravity experiments, e) contribute to NASA's Human Exploration and Development of Space (HEDS) Enterprise, and f) advance materials research and contribute to the national economy by developing enabling technology valuable to the U.S. private sector.

In support of the HEDS Enterprise goal to "Enrich life on Earth through people living and working in Space," individuals participating in the MSAD Program are encouraged to help foster the development of a scientifically informed and aware public. The MSAD Program represents an opportunity for NASA to enhance and broaden the public's understanding and appreciation of the value of research in the microgravity environment of Space. Therefore, all participants in this NRA are strongly encouraged to promote general scientific literacy and public understanding of the Microgravity environment and Microgravity Materials Science through formal and/or informal education opportunities. Where appropriate, supported investigators will be required to produce, in collaboration with NASA, a plan for communicating to the public the value and importance of their work.

The flight opportunities projected for early use (1999-2001) of the International Space Station (ISS) can primarily accommodate small experiments that can take best advantage of capabilities provided by EXPRESS Racks (see p. B-9) and the Microgravity Science Glovebox (see p. B-9). Facility class hardware (e.g. the Space Station Furnace Facility) providing more power is not expected to be available to support flight experiments until ISS Assembly Complete in 2002.

Further programmatic objectives of this NRA include objectives broadly emphasized by the civil space program, including: the advancement of economically significant technologies; technology infusement into the private sector; and enhancement of the diversity of participation in the space program, and several objectives of specific importance to the microgravity science program. These latter objectives include the support of investigators in early stages of their careers, with the purpose of developing a community of established researchers for the International Space Station and other missions in the next 10-20 years, and the pursuit of microgravity research that shows promise of contributing to economically significant advances in technology.

II. MICROGRAVITY MATERIALS SCIENCE RESEARCH

A. INTRODUCTION

There is abundant practical motivation for advancing materials science; it plays a key role in virtually all aspects of important national economic areas. While the ability to process materials is clearly beneficial to humankind, many areas are still not well understood. Advances in materials science benefit a wide range of applications where materials are important and other areas of research which depend on advances in materials science as a basis for their continued progress. Long-duration microgravity is an important tool for establishing quantitative and predictive cause and effect relationships between the structure, processing, and properties of materials. Establishing, understanding and using these relationships are important elements in achieving increased international competitiveness.

The NASA microgravity materials science program currently supports research in a broad range of areas that can be categorized in two orthogonal ways. The program has previously been described in terms of class behavior. Using this approach, the materials systems being investigated include electronic and photonic materials, glasses and ceramics, metals and alloys, and polymers and nonlinear optical materials. The Materials Science Discipline Working Group (DWG), an advisory body to MSAD, has identified research areas, classified in terms of fundamental physical and chemical phenomena, that it believes would benefit from access to long duration, high quality microgravity conditions. Also included in the recommended research areas are those activities that the DWG believes are required to fully realize the potential of microgravity research (e.g. process modeling, materials characterization, etc.). The recommended research areas are described below. NASA is currently requesting proposals for research in these areas under this announcement. Innovative proposals in areas of materials science not specified in this announcement, that show a clear indication that they will benefit from access to long duration, high quality microgravity conditions and/or support the interpretation of microgravity research results are also invited. A few high-risk, high-payoff-if-successful ideas will be considered for funding at lower than average levels for up to two years if resources are available. Young investigators and investigators new to microgravity materials science research are encouraged to submit proposals.

B. MICROGRAVITY MATERIALS SCIENCE OBJECTIVES AND DESCRIPTION OF PARTICIPATION

Materials science deals with the relationships between the processing, structure, and properties of materials. The goal is to control the processing to yield materials with exceptional properties and enhanced performance. This is being accomplished today in limited cases by applying a fundamental understanding of materials at the atomic, molecular, and macroscopic levels.

The ability of processing to alter the properties of a material is rooted in the understanding that the properties of most materials are dictated by the microstructure of the material, i.e. the morphology, size, spatial distribution, and chemical composition of the material's constituent phases and defects. Thus, if the relationship between processing and microstructural development is well understood, then a first principles design of a material with desired properties can indeed be realized. Although many great strides have been made in understanding this crucial relationship, much more work needs to be done to reach this goal.

Many of the techniques used to process materials are strongly influenced by the presence of a gravitational field. For example, during the formation of a solid phase from a fluid, as is the case during crystal growth and solidification, gravitationally driven convection of the fluid is probable. This fluid flow can alter the spatial distribution of impurities in the liquid and resulting solid, induce structural defects in the crystal, and, due to the complexity of the flows which are possible, make the results of crystal growth and solidification experiments performed on earth difficult to interpret. The presence of a gravitational field also can lead to sedimentation when two phases have different densities and at least one phase is a fluid. This can lead to unwanted coagulation of the minority phase as is the case during phase separation in certain polymer blends and in the colloidal processing of ceramics.

A microgravity environment thus offers new opportunities to develop a deeper understanding of the relationships between many materials processing techniques and the resultant microstructures and materials properties. As the magnitude of the gravitationally induced body force is much lower, the convective flow of fluids can be greatly reduced, thus permitting a more precise control of the phase transformation. In addition, gravitationally induced sedimentation, hydrostatic pressure, and deformation can be greatly reduced. Non-contacting forces such as acoustic, electromagnetic, and electrostatic fields can be used to position specimens and thus reduce the contamination of reactive melts. Finally, experiments performed in a microgravity environment will allow phenomena which are usually masked by the presence of gravity to be rigorously studied.

The processing of materials is evolving from an empirical to a more predictive science. Nevertheless, a fully predictive model of the relationships between the microstructure of a material and the technique used to process the material remains an elusive goal. Microgravity studies offer a unique set of conditions which can be used to extend our present understanding in ways which are not possible in a terrestrial laboratory.

The technological applications of importance to this discipline are quite broad. They range from directional solidification and crystal growth to the production of ceramic powders. The key elements of the supporting scientific knowledge base underpinning these process technologies are listed below in descending priority as recommended by the Materials Science Discipline Working Group:

1. Thermodynamics and kinetics of phase transformations
2. Prediction and control of microstructure including morphological development and defect formation
3. Heat, mass, and momentum transport
4. Interfacial phenomena

Along with the knowledge base, a data base provided by the quantitative measurement of relevant thermophysical properties is of high priority. These data are of paramount importance for precise modeling and interpretation of experimental phenomena. Since a significant number of investigations were selected in the 1994 NRA in this area, only a limited number will be selected from this NRA. These will help to establish program balance and support flight and flight definition investigations.

The goals of the microgravity materials science research program are: 1) to advance the scientific understanding of materials processes affected by gravity, 2) to use low-gravity experiments for insight into the physics and chemistry of materials processes, 3) to provide the scientific knowledge needed to improve these processes, 4) to contribute to the understanding and performance of Earth-based systems that depend on materials science, and 5) to develop unique technologies specifically supporting low-gravity experiments and practical aspects of materials science.

To accomplish these goals, this research announcement is soliciting proposals for all areas of microgravity materials science research. These may be either:

1. Ground-based experimental and theoretical research proposals

   or

2. Flight proposals to conduct experimental research in a high quality, long-duration microgravity environment

C. AREAS OF RESEARCH RECOMMENDED BY THE MATERIALS SCIENCE DISCIPLINE WORKING GROUP

1. Nucleation and Metastable States

In order for a material to transform to a more ordered phase (vapor to liquid or solid, and liquid to solid), it is necessary to first form an aggregate or cluster of molecules above a critical size to initiate the process. Such an aggregate may form on a foreign surface, such as a container wall or a speck of dust (heterogeneous nucleation), or may form spontaneously from random internal fluctuations (homogeneous nucleation). Homogeneous nucleation can occur only if the melt is cooled well below its normal freezing temperature without solidifying. Heterogeneous nucleation will almost always occur first if there are any impurities that can act as nucleation sites. Understanding and being able to control nucleation is extremely important in materials processing.

For example, if it is desired to produce a fine grained casting, one would try to produce a very large number of nuclei and distribute them randomly throughout the melt. Gravity-driven convection plays an important role in this process as was demonstrated in a series of experiments conducted under reduced gravity conditions using sounding rockets. This is an example of how microgravity experiments may be used to elucidate the essential features of a process and to suggest better control strategies for use on earth, in this case by enhancing convection or artificially stirring the melt.

On the other hand, it is often desirable to suppress nucleation in order to be able to cool a melt to a temperature well below its normal freezing point. Solidification of deeply undercooled melts is usually initiated by a single nucleation site and is very rapid. Rapid solidification can produce an extremely fine microstructure with enhanced mechanical properties. If the solidification is rapid enough, the atoms simply do not have time to arrange themselves in their lower energy or equilibrium configuration and metastable crystalline or amorphous phases can be produced. A metastable phase can have a different crystalline structure which can greatly alter its physical properties. Perhaps the best known example of a metastable crystalline phase is diamond, which is the metastable phase of carbon. Graphite is the equilibrium phase.

An amorphous phase may be thought of as a liquid structure, which lacks long-range crystalline order, frozen in place. Glass is an example of an amorphous solid. Amorphous materials are highly resistant to chemical attack because there are no crystalline grain boundaries, sites which are particularly susceptible to chemical reactions. Similar amorphous structures can be achieved in some metallic alloys by rapid solidification. One example is “Metglas" which consists mainly of iron and boron. The absence of grain structure makes it extremely easy to magnetize and demagnetize with very little hysteresis loss, thus making it very useful in transformer cores where it is three times more efficient than the conventional iron-silicon core material. Contrast this with the new iron-boron-neodymium magnet material which is an extremely good permanent magnet because its fine grain structure tends to pin the magnetic domains and prevent demagnetization. These examples demonstrate how crucially the physical properties of a material depend on its microstructure.

The ability to melt and solidify specimens without a container removes a major source of impurities and heterogeneous nucleation sites, thus permitting very large undercooling to be achieved. On Earth, this can be accomplished for small samples by levitating and melting them electromagnetically, or by dropping small molten droplets through a long evacuated tube and allowing them to solidify during free-fall.

These techniques have been used extensively but have limitations. It is not possible to control the heating and levitating force independently in an electromagnetic levitator that also employs electromagnetic heating. Use of a quench gas to cool the sample seems to introduce surface nucleation. There is also some evidence that flows in the melt driven by the induced currents may induce nucleation and limit the amount of undercooling. These difficulties can be overcome in a drop tube, but it is not yet possible to observe the droplet as it cools in order to make accurate temperature measurements. Also, the sample size and the amount of undercooling are limited by the time available for the fall.

In reduced gravity, the sample may be positioned by a much lower induced current or may even be allowed to float freely. This decouples the heating from the levitation and reduces the amount of stirring in the melt. The temperature may be measured optically during the cooling and solidification process and thermophysical properties such as specific heat, heat of fusion, and thermal diffusivity can be inferred.

Initial microgravity experiments should focus on factors that limit the degree of undercooling, such as the degree of superheat required to dissolve or evaporate potential nucleation sites, the use of fluxing agents to remove impurities and prevent oxidation, and the effects of stirring on nucleation. Once techniques for obtaining maximum undercooling have been determined, the emphasis of experiments should be on forming metastable and amorphous phases and determining their properties. It may also be possible to perform critical tests to evaluate the various theories of nucleation which have never actually been experimentally verified completely and in fact have been a source of controversy.

Development of a suitable experimental facility for this type of work should be started as soon as possible. Crucial to this development is an accurate contactless technique for continuously measuring the sample temperature that does not require a prior knowledge of the emissivity. Also, methods for obtaining extremely low partial pressures of reactive gases such a oxygen must be developed since oxides and other reaction products will rapidly form on the molten samples and in some systems act as nucleation sites.

Nearly all commercial glass products are formed from high temperature melts (liquids), so it is important to possess both good scientific and technical knowledge for such melts in much the same way as similar knowledge is valuable for metallic melts. Most importantly, the ability to form a glass from a high melting point liquid is controlled by the ability to prevent or control crystal nucleation and growth during cooling. Microgravity offers unique opportunities to investigate the properties and processing of high temperature glass forming melts and their crystallization behavior, for which there is only limited knowledge at this time because of problems directly dependent on gravity. Better understanding of fundamental scientific phenomena such as nucleation/crystallization, mass transport (diffusion), separation of immiscible liquids, and surface tension/segregation forces is possible in microgravity. Microgravity eliminates problems caused by thermally driven convection occurring in fluid (viscosity < 1 Pa·s) melts in one-g that limit our ability to acquire precise and accurate data.

2. Prediction and Control of Microstructure (including pattern formation and morphological stability)

The microstructure developed during the solidification of an alloy plays a key role in determining the properties of a material. Since different microstructures can be developed in a given material by changing processing conditions, it is critical to understand the fundamental phenomena that dictate microstructure formation and how these phenomena are influenced by changes in processing conditions. This knowledge is required for the design of processing conditions to develop a specific microstructure that gives a desired set of properties to the material. A proper design of microstructure involves the selection of stable or metastable phases and the development of an appropriate morphology of the selected phase. For a single phase material, the interface morphology can be planar, cellular or dendritic; whereas for two-phase growth one can obtain either a lamellar/rod eutectic or a layered structure depending upon the growth conditions and the phase diagram. Understanding of the fundamental physics and chemistry that control the selection of phases as well as controls the selection of microstructures is critical to improving our ability to design appropriate microstructures with desired properties.

In some eutectic systems, directional solidification can produce a structure consisting of regularly spaced rods of one phase embedded in the other, or alternating lamellae of the two phases. A potentially important application for these materials, termed "in situ composites", is in turbine blades for high performance jet engines. The aligned structure increases the strength and creep resistance along the axis of the blade. A second potential application is eutectic manganese-bismuth magnets where the magnetic coercivity may be optimized by correlating the eutectic rod diameter to the size of a single elongated magnetic domain.

The processing variables are the growth rate at which the solidification takes place and the temperature profile in the region near the solid/melt interface. The best control of these variables is achieved by the process of directional solidification, in which the material is solidified in one direction under known conditions of growth rate and temperature gradient. Such a directional solidification process is present in many industrial processes such as directional freezing of cast turbine blades, laser welding of alloys, and Bridgman growth of electronic materials. Changes in growth rate and thermal gradient alter the relative importance of thermal/mass transport and interfacial energy effects, and the magnitude of this partitioning of available driving force dictates the formation of specific microstructures. The precise quantitative understanding of this partitioning effect is difficult to evaluate terrestrially since the thermal and mass transport in the liquid occurs by both the diffusive and convective modes of transport. Although there has been significant progress recently in modeling the development of microstructures during solidification, the role of convection is still poorly understood. To a large extent, this is due to the inability of theoretical models to account for convective effects whereas earth-based experiments cannot avoid them. Microgravity experiments provide a unique opportunity to quantitatively understand the fundamental interaction between diffusive transport phenomena and interface energy effects, and thus allow the precise correlation of these interactions with the development of different phases and different microstructures.

Three critical, unsolved theoretical problems in solidification processes are to understand the role of processing conditions in: (i) selecting stable or metastable phases, (ii) producing plane front, cellular, dendritic or eutectic growth; and (iii) developing the scaling laws which quantitatively relate the solidified structures' characteristic dimensions to the processing conditions. These characteristic dimensions, for a given phase and a given morphology, are generally related to the mechanical properties of the material. Although significant progress has been made on these problems, the theories generally cannot account for the effects of convection because of the complex phase boundary geometries involved. Convective flows are unavoidable in Earth's gravity because of the lateral density gradients that arise due to solute rejection making it impossible to test and refine the existing theoretical models and to quantify the importance of convective effects in ground-based solidification processing.

The solidification conditions in most welding and casting processes give rise to a cellular or dendritic interface which is characterized by a significant segregation of solute in the solidified material. This is due to the solute concentration in the cell or dendrite being much lower than the mean solute composition causing the intercellular or interdendritic region to become richer in solute. The region in which solid cells/dendrites coexist with the surrounding liquid is called the "mushy" zone. When the last liquid finally solidifies, a complex pattern of segregated solute remains. In addition, the solute concentration in the mushy zone can become large enough to form a nonequilibrium phase (for a given composition) which is often an intermetallic compound that can significantly alter the mechanical properties of the material. Through understanding the correlation between microstructure formation and processing conditions, it would be possible to obtain an optimum microstructure from a given processing technique.

When solid and liquid or gaseous phases coexist for some time, microstructural changes can occur such that larger particles will grow at the expense of smaller ones so as to lower the free energy of a system by reducing the total surface energy. This effect, known as Ostwald Ripening or microstructural coarsening, is important in the coarsening of microstructures with time under operating conditions, or in the sintering of fine particles. There is also a large class of industrially important dispersion-hardened alloys in which extremely small particles are either added to or caused to precipitate from the melt during solidification. Since the strengthening effect of the dispersed particles diminishes as their size increases, the coarsening process must be understood and controlled. The process of coarsening requires mass transport which can be influenced by gravitationally induced flow of liquid between particles, or settling of particles in the solid plus liquid or vapor phase. In extreme cases, liquid flow in the two-phase zone can lead to transport of solid fragments over large distances. Microgravity experiments provide a unique opportunity to understand the coarsening phenomenon through the suppression of convective and sedimentation effects.

Low-gravity experiments carried out in sounding rockets, in aircraft flying parabolic trajectories, or in orbital flights have illustrated the significance of suppressing convection during solidification processes. Experiments studying dendritic growth have shown evidence that both primary and secondary dendrite arm spacing change as the effects of gravity are reduced. Space experiments with growth of the manganese-bismuth eutectic revealed, surprisingly, that the rod diameter and spacing were considerably smaller than that predicted by the classical theory of eutectic spacing selection which assumes no convection. Growth in strong magnetic fields, which also suppress convective flows, produced results similar to the flight experiments. Paradoxically, control experiments carried out on the ground, in which convective flows were present, agreed very well with the classical theory. European experimenters on Spacelab 1 and the first German Spacelab, D-1, have found similar results with some systems, agreement with the classical theory in other systems, and larger spacings than predicted in still other systems. These disparate results indicate that there is still much to be learned about the role of convection during eutectic solidification.

Many industrial processes in polymer production rely on processing polymer particles or aggregates dispersed in a solvent matrix. Layering or stratification of polymer and solvent occurs on the ground because of gravitational effects. This leads to anisotropic properties in the final product. Conducting experiments on materials such as these in microgravity would eliminate stratification and should lead to a better understanding of fundamental processes involved without the masking effects of gravity. The comparison between the properties of materials processed in 1-g compared to those produced in microgravity would help to establish quantitative relationships between stratification effects and anisotropy.

Most high technology polycrystalline ceramics are sintered or densified assemblages of small single crystal particles. The densification occurs to minimize the high surface energy associated with the small particles. Surface energy is a weak force and both isolated particles and systems of particles tend to adopt configurations that minimize surface energy, e.g., coarse particle size and, in anisotropic systems, faceted particle shape. Both the nature of the minimum energy state and the pathway by which it is achieved are important topics for study. From a technology standpoint, both faceting and coarsening can be viewed as undesirable processes during sintering; that is, they can reduce the amount of energy stored in a powder without causing densification. In contrast, monitoring the evolution of particle size and shape offers the opportunity to gain direct information regarding the mechanism(s) responsible for their change and the relative importance of the different mass transport paths: vapor phase, surface, grain boundary, and volume diffusion.

The study of coarsening and faceting of dispersed or loosely agglomerated particles in microgravity offers the opportunity of obtaining a much better understanding of these two processes that are so central to the technological production of crystalline ceramics. While neither the transport mechanisms nor the driving force involve gravity directly, working in a one-g field can complicate the experimental investigation of such phenomena. In the case of single particles, particles are always in contact with a substrate. The technical issues that arise include chemical reactivity, frictional drag, and morphology of the contact point. In one-g, studying systems of particles effectively means working with powder compacts due to the need for mechanical stability. This restricts the range of variables that are accessible. For example, it may be desirable to work with low number densities of particles that are not fully connected in order to test deviations from mean field models. In addition, the contiguity and connectedness of the particles may strongly influence growth and faceting processes. Furthermore, morphologies produced at particle contacts by a balance of surface energy can obscure that which would otherwise be dominated by surface energy.

The flow of granular media is an important mechanism during handling and processing of ceramic and glass materials. Powders exhibit fluid-like macroscopic behavior in normal gravity, and hydrodynamic instabilities can be observed in ground-based experiments on powder. In microgravity environments, van der Waals and electrostatic forces would be expected to play a dominant role in the behavior of granular materials. Experiments and models which illuminate and quantify the cross-over in the behavior of granular materials are needed.

Ceramic processing science has progressed little beyond the needs of traditional ceramics. Yet the emergence of new and improved technologies hinge critically on rational improvements in wet (or suspension) processing of ceramic powders. Previous research has focused on model systems consisting of single phase, monosized ceramic particles. However, it is clear that relevant ceramic systems will either be single or multiphase with engineered particle size distributions (e.g. bimodal or trimodal). Hence, a fundamental understanding of these systems, referred to here as "complex ceramic suspensions", is required. The development of this science base would benefit significantly from research conducted in a microgravity environment since density-driven phase separation and/or particle size-induced segregation effects will be dramatically reduced relative to ambient conditions.

Microgravity conditions offer the possibility of producing composite structures which are not possible or easily obtainable on earth. Of particular interest are ceramic-metal or other composites consisting of phases of widely differing density, and composites which consist of discrete areas of a second phase contained within a major phase. In the first case, approaches to fabricating metal-ceramic composites on earth are restricted by density differences and thus segregation of phases during fabrication. For example, efforts to impregnate ceramic preforms or to mix ceramic and metal powders or other precursors are impeded by problems associated with ceramic preforms floating to the surface and metal phases being non-uniformly distributed. Processing approaches which allow uniform mixtures to be prepared on Earth and heat-treated under microgravity conditions should allow the formation of layered ceramic-metal structures, uniform interconnecting two-phase structures, or homogenous particulate-reinforced structures. The removal of gravity's effect on phase segregation will allow wetting interactions between the two or more phases to be more clearly understood.

In the second case, mixing of whiskers or other second phase particles with ceramic powders to produce composites is difficult and can result in non-uniform structures. Mixing powders and whiskers in an aqueous medium in space should allow the preparation of more uniform, novel, or controlled structures because settling due to gravitational forces can be avoided or controlled. For example, mixing can be achieved by the application of mechanical force only without the effects of convection. Although aggregation of particles will occur, these clusters will not settle as in Earth's gravity; thus, it should be possible to grow clusters of certain sizes and make layered structures by artificially applying a gravitational force of specified duration (in a centrifuge, for example) or by filtration. A uniform composite containing dispersed clusters or individual particles in a major phase could also be made by filter pressing.

Combustion synthesis of ceramic generates high temperatures at and ahead of the reaction front. These high temperatures generate liquids and possibly gases which are subject to gravity-driven flow. The removal of such gravitational effects is likely to provide increased control of the reaction front with a consequent improvement in control of the microstructure of the synthesized ceramic products. Experiments need to be developed to determine the role that gravity (and lack of gravitational forces) plays in the synthesis process.

3. Phase Separation and Interfacial Phenomena

Another class of polyphase materials of interest to microgravity materials science research is the monotectic systems, characterized by a region of liquid phase immiscibility. For a range of compositions, the melt of such systems will separate into two immiscible liquids as the temperature is lowered. The two liquids may form initially as a fine dispersion of one phase in the other, potentially a good starting point for a useful microstructure. However, when these materials are solidified, it is normally found that the liquids have formed much less desirable large agglomerates. If this agglomeration process could be understood and controlled, a range of useful materials might result.

Sedimentation is the most obvious effect causing agglomeration of the dispersed liquids. Since the two liquids of a monotectic system are always of different composition, they will invariably have different densities. In Earth's gravity, the two liquid phases will stratify before they can be frozen, resulting in a highly segregated solid. It was once believed that if this buoyancy-driven sedimentation could be avoided by solidifying such systems in microgravity, a fine dispersion of one phase in the other would be produced. However, attempts to accomplish this have been only partially successful, indicating that effects other than gravity also lead to segregation of the two liquid phases. An extensive series of ground-based experiments, using transparent organic systems that having similar monotectic phase diagrams and which can also be made neutrally buoyant, has revealed the effects which occur when gravitationally-induced segregation is relatively unimportant. These experiments uncovered a rich variety of phenomena driven by interfacial energy.

A clear example of the dominating influence of interfacial energy effects occurs in monotectic alloy systems as the temperature falls below the critical temperature at which liquid phase separation first occurs. Over a limited range of temperature below the critical value, one of the liquids exhibits "perfect wetting" behavior, encapsulating the other liquid and coating any container. If final freezing occurs within this temperature range, massive segregation is produced. Alternatively, if final solidification occurs via the monotectic reaction, below the perfect wetting temperature range, a well aligned two-phase structure with a uniform spacing between phases may be achieved in a directional growth process. Regularity of the structure requires that flows driven by the temperature and composition dependence of surface energy be suppressed. The minority liquid phase may form droplets which migrate in a gradient of temperature or composition. Because larger droplets move faster than smaller ones, the latter will be overtaken and engulfed. Eventually, all of the minority phase is therefore segregated into a few large droplets. In fact, depending on the alloy system, thermal gradients as small as one (1) Kelvin per centimeter in low gravity can have the same effect as Earth gravity in causing massive segregation.

The temperature and composition dependence of surface energy may also cause mixing in single phase liquids. Convective flows driven by surface energy forces can be similar to or greater than those induced by gravity. When temperature gradients are large, such as in welding, these flows can be very rapid, and their quantitative understanding is critical for modeling the shape of weld pools.

Surface tension is a function of both temperature and composition, so that a gradient in either will drive flows. Fluid flow driven by variations in the surface tension along a free surface is called Marangoni convection. Usually, Marangoni convection is obscured by density-driven convective flows. Limited experience during space experiments indicates that above a critical Marangoni number (ratio of surface tension force to viscous force), the flow becomes unsteady and temperature fluctuations in the melt are observed. In addition, a detailed series of ground and low-gravity experiments have demonstrated that striations due to Marangoni convection are produced in float-zone grown silicon.

Additional interfacial energy effects are the determining factors in other forms of microgravity materials processing. One example is the formation of potentially unique composite materials by the directional solidification of an alloy melt which initially contains a uniform dispersion of fine solid particles. In this case, the interplay between solidification velocity and particle/liquid interfacial energy is crucial in determining the distribution of the strengthening particles. Some combinations of these processing variables result in the particles being entrapped at the solidification front to give a uniform microstructure, while others result in particles being repelled from the solidification front, producing segregation and poor properties.

Interfacial energy effects are also critical in containerless processing, where the extent of wetting between the solid(s) forming from the liquid controls the degree of undercooling and thus, the resulting microstructure. Brazing, soldering, and welding operations are additional processes which are influenced by interfacial phenomena. Here, understanding of both wetting and surface energy driven flows can be primary factors in achieving success.

In addition to the phenomena which occur at interfaces between two fluids, processes occurring at solid-vapor interfaces can be influenced by gravitationally-induced convective flows. Compound semiconductors are materials whose unique properties are optimized when they are formed as single crystals by a process called physical vapor transport (PVT). Mercurous chloride, an acousto-optic material, mercuric iodide, a gamma ray detector, and silicon carbide, a wide gap semiconductor, represent several examples. In PVT, the material to be crystallized is evaporated from a heated source, transported as vapor, and finally deposited on a seed crystal held at a lower temperature. Crystal properties are influenced by atomic attachment kinetics at the crystal vapor interface, by the rate of arrival of species from the vapor (and hence influenced by convection phenomena), and by the formation of compositionally variant or impurity enriched boundary layers in the vapor near the crystal surface. Sharp, well defined facets are a characteristic feature of high quality PVT crystals grown under reduced gravity which minimizes convective flow in the vapor. These crystals exhibit greater crystallographic homogeneity than their Earth-grown counterparts, resulting in significantly improved resolution for radioactive detectors fabricated from these crystals. A quantitative explanation for these improvements is still lacking.

It is clear that a consideration of interfacial phenomena is common to numerous materials processing technologies. While limited studies of these interfacial effects are possible on Earth using density-matched immiscible systems, even in these systems, perfect density matching is possible only at a single temperature. Therefore, a microgravity environment provides a unique opportunity to study and quantify surface energy phenomena in order to promote more effective materials processing both on Earth and under microgravity conditions.

4. Transport Phenomena (including process modeling and thermophysical properties measurement)

All of the important phenomena that determine materials structure and properties during processing are controlled by heat, mass, and momentum transport. For each of these effects, the nature of the transport is determined by the relative importance of convective and diffusive transport. When diffusive effects are dominant, the system response is controlled by materials properties, whereas the system response is controlled by processing conditions when convective effects dominate. Microgravity provides a unique environment in which the relative importance of convective and diffusive transport can be controlled by the experimenter.

Convective flows originate in solidifying systems because the density varies with both composition and temperature. Any density differences interact with gravity to produce buoyancy forces which drive convection. It is often desirable to suppress this convection, producing materials under purely diffusive conditions. Examples include the control of segregation in crystal growth and the testing of theories of microstructure development. To accomplish this requires a comprehensive understanding of the transport processes.

This understanding can be significantly improved through process modeling. It may not be sufficient to simply reduce gravity, even by six orders of magnitude, to eliminate undesirable convection. Alternatively, it may be unnecessary to go to space at all. The goal of process modeling is to represent the experimental system as a set of mathematical equations, whose solution describes the system behavior. Varying system parameters in the model allows exploration of the system, enabling the design and interpretation of experiments, and comparison of theoretical predictions with experimental results. Realistic process models are therefore an invaluable adjunct to experimental investigations.

Most of the process models developed to date have considered only steady accelerations. Additional model development is needed to assess the importance of transient and oscillatory accelerations, known to be present on orbiting spacecraft (g-jitter). Recent developments in mathematical modeling have also made it possible to determine the sensitivity of a given experiment to perturbations or uncertainties in imposed boundary or initial conditions, geometry or thermophysical properties. Further development of these techniques would be of significant benefit to the MSAD program.

A serious deficiency in our ability to model materials processing is the paucity of accurate thermophysical property data for most materials in the molten state. This is a problem not only for scientists modeling microgravity experiments, but for many industrial researchers who are beginning to use process modeling for terrestrial processes. The lack of high temperature thermophysical data is partially due to the extreme difficulty of making accurate measurements on melts in unit gravity. European experiments on Spacelab 1 and the first German Spacelab, D-1, showed that diffusion coefficients for a variety of materials measured in space differ considerably from the accepted values obtained on earth either because of wall effects (such measurements are usually made in capillary tubes) or because of residual convection, which is virtually impossible to avoid. Also, the effect of thermodiffusion (Soret effect) was found in space experiments to be as much as an order of magnitude larger than previously estimated. No accurate measurements had been made of this effect on Earth, although it now appears to play a more important role in mass transport in many terrestrial processes than had been realized previously.

The relevant thermophysical properties needed for reliable materials processing models include:

- Electro-optical properties

Emissivity
Electrical conductivity
Optical properties

- Calorimetric properties
  Specific heat
  Heats of mixing, formation, transformations, etc.

- Transport Coefficients
  Thermal conductivity
  Viscosity
  Diffusion coefficients

- Density

- Thermodynamic Moduli
  Thermal expansion coefficients
  Compressibility, etc.

- Vapor pressures and activity coefficients

- Surface tension / interfacial energies

- Equations of state

The most time-consuming step in manufacturing common glasses on Earth is bubble removal, “fining." Information that leads to faster fining on Earth would have enormous economic value. Thermal convection on earth is a major complication in studying bubble motion and the diffusion of gasses from bubbles; convection destroys simple diffusion profiles. An improved understanding of fining of glass would be much more easily obtained without the effects of gravity in a microgravity environment.

Evaporation of volatile components from glasses such as PbO or Na_2O can alter the surface composition of glass melts that lead to convective flows, composition variations, and composition and property gradients. Convective flows make analysis of material loss and the resulting composition change difficult if not impossible. Separation of the material loss by convection in the absence of gravity offers the possibility to greatly simplify the process and improve the quality of a large number of commercial glasses.

A fundamental issue of ceramic-metal joining and the fabrication of interpenetrating 3-dimensional ceramic-metal and ceramic-ceramic composites is the wetting of the solid ceramic phase by the molten metal or molten ceramic. Most wetting experiments are carried out under 1g conditions which can influence the spreading and contact of the molten phase with the solid substrate. This gravity-induced contact can lead to increased reaction and spreading of the molten phase and misrepresentation of the real degree of wetting. Infiltration behavior of molten metals and ceramics into porous ceramics to produce composites is inconsistent with measured 1g wetting experiments. Wetting experiments need to be carried out under reduced-gravity conditions to determine the wettability of ceramics by molten metals and other ceramics.

5. <u>Crystal Growth, and Defect Generation and Control</u>

During directional solidification of semiconductors, generation of destabilizing temperature gradients in the melt is unavoidable, resulting in buoyancy-induced convective mixing of the liquid phase. On Earth, this convective mixing is intensive, and influences the segregation of melt constituents at the growth front. Nearly all Earth-grown crystals exhibit radial and axial compositional non-uniformities characteristic of growth from well- or nearly well-mixed melts. Although intentional mixing schemes such as the accelerated crucible rotation technique or the application of an oscillatory magnetic field can provide improvements in crystal quality, growing crystals in space provides the opportunity to reduce the convective flow intensity and, for some classes of systems and charge sizes, achieve diffusion-controlled mass transfer during growth. This also is expected to promote the growth of higher quality crystals and can yield information on important materials parameters including the mass-diffusion coefficient and the mass-segregation coefficient.

The early crystal growth experiments of the Apollo-Soyuz Test Project (ASTP) and Skylab have established the potential of microgravity processing to achieve diffusion controlled growth in small diameter charges. However, the reduced-gravity levels achieved during growth in space unmask or introduce phenomena that are not important or present during Earth-based growth. In some materials systems, for example, the normally occurring density variations in the melt provide a stabilizing effect during growth. These same density variations create complications related to the alignment of the residual gravity vector with respect to the growth direction during growth in reduced gravity. Transients in the direction and magnitude of the gravity vector (g-jitter) can introduce additional difficulties. Furthermore, the space experiments have shown that during growth the melt may separate from the non-wetting crucible permitting surface-tension driven convective mixing of the melt.

Development of a comprehensive theory of segregation during directional solidification has been aided recently by the advances in computational power permitting detailed numerical modeling of solidification processes. Because of improvements in growth hardware design providing for accurate quantification of thermal boundary conditions, and because the gravitational field on Earth is one-dimensional and steady, axisymmetric models of crystal growth can currently predict the experimental results well enough to be useful in guiding the selection of experiment parameters. The above complications associated with space processing, however, show that these models cannot be directly used for analysis of space experiments through a simple reduction of the gravity level in the simulations. Indeed, the three dimensional unsteady acceleration field and the possible Marangoni convection in space result in complex flow structures; numerical modeling has only recently begun to assess and quantify these effects. For example, in axisymmetric simulations, it has been shown that the alignment of the gravity vector parallel to the growth surface in space, as opposed to perpendicular to the growth surface, can result in a two order of magnitude increase in the convective intensity at the same gravity level. This phenomenon has been observed experimentally in growth experiments on the first United States Microgravity Laboratory (USML-1) and the first United States Microgravity Payload (USMP-2) missions in HgZnTe and HgCdTe, respectively. In a detailed analysis of the g-jitter effects, the compositional variations in the melt associated with the transients in residual acceleration have been shown to persist over time periods much longer than those characterizing the g-jitter. Thus, simulation of unsteady transport processes in space is required. These considerations, along with the implications of Marangoni convection if present, indicate that diffusion-controlled growth may be only marginally achievable in space. More importantly, if a crystal grown in space does not exhibit all characteristics of diffusion controlled growth, our ability to interpret the experimental results and identify controlling phenomena is limited.

Magnetic damping of convection in electrically conductive melts can be used to provide a higher degree of control of convection in the melt. In this approach, the motion of an electrically conductive melt in a magnetic field produces an opposing Lorentz force field that reduces the flow velocities in the melt. Modeling results indicate that the superimposed effect of moderate magnetic fields and the microgravity environment of low earth orbit can reduce convective flow intensities to an extent unreachable either by using magnets on Earth, or by microgravity processing alone. Magnetic damping also can potentially reduce the influence of Marangoni convection and high-frequency transients in the melt flow velocities associated with g-jitter. Magnetically stabilized Czochralski crystal growth experiments indicate that intensive turbulent flow perturbations can be suppressed at relatively low magnetic field strengths (of the order of 0.1-0.2 Tesla). This suggests that magnetic fields may significantly reduce the deleterious effects of convective perturbations associated with g-jitter. Fundamental considerations also suggest that magnetic damping may suppress Marangoni convection in microgravity.

The generation and propagation of defects during the fluid to solid phase change is generally understood on only an empirical basis. For example, it is known that defects are generated (or nucleated) at the tri-junction between the container wall, the solid, and the melt during directional solidification and that these defects tend to propagate along a direction perpendicular to the melt-solid interface. The degree of fluid motion is also known to have an influence on defect concentration and distribution as demonstrated by the striations observed in Czochralski-grown materials. The deconvolution of growth rate and fluid flow contributions to defect generation is still unresolved; the details of the generation and propagation of defects remains one of the least understood mechanisms related to the preparation of high quality single crystal materials from the melt or from the vapor. This is still true even though defects, whether they are impurity atoms or lattice defects, have a major impact on electronic and optical properties, the very reasons most single crystals are grown.

New characterization techniques, such as atomic force microscopy and synchrotron X-Ray topography, are giving a fresh approach to the study of defects in semiconductor crystals. Atomic force microscopy shows that the established technique of etch pit density determination, even when done accurately, does provide a complete representation of the defect structure at the semiconductor surface. Synchrotron X-Ray topographs reveal not only twins but a cellular structure of low angle grain boundaries, lines indicating slip planes initiating at the twin boundaries, and dislocations within the subgrains.

There is mounting evidence from flight experiments that fluid flows influence defect generation and propagation, and microgravity experiments should provide an excellent method for learning more about this important topic. For example, there are results from a TEXUS (sounding) rocket flight experiment which show many growth-induced striations in InSb in the Earth-grown portion, and no striations in the space-grown portion except for those induced for interface demarcation by electric current pulses. One important experiment that does show promise of providing useful information in this area is the Bridgman growth of $Cd_{0.96}Zn_{0.04}Te$. The defect generation observed in this material was markedly reduced in two ingots grown aboard the Shuttle during the USML-1 mission compared to ingots grown under otherwise identical conditions on Earth. A quantitative explanation for these results is still being investigated.

Polymer crystal growth is more complex than the growth of inorganic crystals because of the large molecular weights of the individual polymer molecules and their structural complexity that makes molecular attachment to a growing crystal stereochemically complicated. Equally important is that, in microgravity, it is possible to study the fundamentals of polymer crystal growth. Not only can the effects of temperature and compositional gradients on growth kinetics in the absence of gravity-induced convective effects be studied, but also the effect of the size of the individual polymer units and their interaction with the solvent molecules on the crystal growth be studied.

Many polymeric materials have potential as unique nonlinear optical materials. Thin films of polymers produced by vapor deposition contain high defect concentrations that limit their utility as nonlinear optical materials. Microgravity experiments on inorganic crystal growth by vapor deposition clearly show that materials with lower defect concentrations can be produced. A quantitative explanation for these results is still lacking.

It has been demonstrated that much larger, and defect-free protein crystals can be grown in microgravity compared to those grown on Earth. These results suggest that gravity can play a role on the kinetics of rearrangement of large molecules during crystal growth from solution. There are many other polymers, such as nonlinear optical materials, for which the availability of single crystals would be extremely useful for property studies and to determine the effects of crystal defects on properties. Microgravity provides the opportunity to investigate the growth of such crystals.

6. Extraterrestrial Processes and Technology Development

As one of NASA's five core Strategic Enterprises, the Human Exploration and Development of Space (HEDS) is a catalyst to open the space frontier by exploring, using, and enabling the development of Space and to expand the human experience into the far reaches of space. Specifically, understanding the fundamental role of gravity in the space, Lunar, and Martian environments in chemical and physical systems to achieve breakthroughs in science and enabling technology. Our goal is to develop the knowledge and experience that will ultimately be used to decide how best to proceed. The need for improved understanding of materials processing phenomena to enable future space technologies and operations should be recognized as one of the primary opportunities of the materials science discipline. The focus of the MSAD program in the HEDS strategic Enterprise is to foster fundamental understanding, building a foundation of knowledge that can be applied to both Earth- and space-based technologies. There are new technologies that can enable new rigor in microgravity materials science research. In particular, we seek technologies that permit in situ, real time, quantitative measurement (diagnostics) of materials processes and that can be incorporated in a straight forward manner in flight experiments. Examples include technologies that can quantitatively assess processes such as coarsening, solidification, defect generation, crystal growth from the vapor, solution, etc.

Gravity plays a dominant role in many of the systems, processes, and technologies that are needed to achieve the goals of the HEDS Enterprise. These include physical and chemical processes in the areas of welding and joining, radiation protection, energy transformation and power storage, and use of in situ resources in extraterrestrial environments. We are seeking to establish and support a limited number of research areas that will play a key role in our support of the HEDS Enterprise. It is expected that microgravity will contribute to the understanding of these scientific issues. In this period of program definition, emphasis will be placed on fundamental aspects of HEDS related activities. As a result, we can leverage the predictive nature of our basic understanding of structure, processing, property relationships to yield non-empirical approaches to development and design. Though a number of representative examples of potential HEDS involvement are given below, not all areas can be supported through this announcement.

The provision of shielding for a Mars mission or a Lunar base from the hazards of space radiations (solar flares, galactic cosmic radiation) is a critical technology since astronaut radiation safety depends on it and shielding safety factors to control risk uncertainty appear large. Thus, the development and evaluation of high performance radiation shield materials is a research area where materials science can play a pivotal role. Understanding the basics physics of the shielding process should allow the tailoring of materials performance through control of structure. Empirical evidence indicates that favorable characteristics include: high electron density per unit mass, minimum nuclear cross section per unit mass, and high hydrogen content. High performance shielding materials would be particularly useful for protecting crews during the protracted journey to Mars.

A recent workshop on Shielding Strategies for Human Space Exploration made several observations and recommendations. Many past lunar missions have identified the possible use of in situ resources such as regolith or regolith-derived compounds for space radiation shielding. Possible hybrid shielding concepts require greater investigation. New combinations of materials, each possessing favorable performance related characteristics (shielding, structural, etc.) may markedly improve synergistic possibilities for reduced launch mass. Some possible candidate materials include the layering of various materials, regolith/epoxy mixtures, borated composites, and novel dual use materials (e.g. magnesium hydride as a hydrogen storage medium).

There is a continuum of issues important to the HEDS Enterprise in the area of welding and joining. We continue to seek quantitative and predictive understanding of how the microstructure of welds, and thus their chemical and physical properties, is influenced by gravitational (buoyancy) effects and surface tension driven fluid flows. The magnitude and nature of these flows can influence weld pool shape.

These become important issues for our exploration activities as welds may be needed for servicing spacecraft on orbit and/or in transit to the Moon and Mars. Welding, brazing, and soldering joining techniques could be used for structures/facilities assembly and servicing while under extraterrestrial conditions of 1/6 (Lunar) or 1/3 (Martian) the acceleration of gravity at Earth's surface.

One process under consideration for in situ resource utilization on the Martian surface is the creation of ethylene and polyethylene based materials from the CO_2 in the atmosphere and the water thought to be available subsurface. The process of joining these materials together and to other structural materials must be understood before their use is approved.

Advanced sensor development is needed to image the Martian surface, analyze its atmosphere, and look for mineral resources and possible layers of water ice underground. It is also needed for the next generation of "smart" robotic explorers. These sensors will be coupled with improvements in machine vision, process management and control, and artificial intelligence algorithms to permit development safe and productive exploration with the communications latency caused by the remoteness of Mars.

In Situ Resource Utilization (ISRU) is a rapidly developing area relevant to exploration of other bodies in the solar system. Due to the cost constraints associated with transporting all of the necessary resources for a sustained visit and return trip from either the Moon or Mars, utilization of natural resources at the landing site is receiving strong consideration. Basic physical and chemical methods will be applied to process local resources into usable commodities. The focus of activities of the materials research community must be to develop an understanding of these processes in non-Earth environments. Proposals are encouraged on efforts to advance the current understanding of materials processing in a low gravity environment with the goal of improved process design and development. Examples of local resource utilization related physical and chemical processes include lunar derived oxygen and metals production from regolith (soil), creation of bricks from regolith for radiation protection and structures fabrication, and energy conversion and storage.

Lunar regolith contains significant amounts of oxygen, chemically bound in various minerals, which would require processing to manufacture oxygen for use in propulsion and for life support systems. A major challenge is to combine the processing of regolith to produce oxygen as well as metals present in the same minerals. Similarly, it is believed that Martian soil contains significant amounts of water which can be electrolyzed into oxygen and hydrogen again for propellants and life support. Using the Martian atmosphere for the production of oxygen, carbon monoxide and methane for propellants is also possible. In all of these scenarios, a fundamental understanding of the dynamics of solid/gas and liquid/solid phase transformations, and the performance of electrochemical systems are required for representative techniques expected to be used for regolith processing. Fundamental studies would yield a non-empirical approach to process development and design, thus generating support technologies independent of the process chosen for actual manufacturing to imbue flexibility and efficiency in the designs.

Energy conversion and storage is considered a basic aspect of "living off the land" in both Lunar and Martian environments. Examples can be as simple as the transformation of solar energy into thermal energy and stored in lunar regolith bricks for subsequent release during night time periods. More complex approaches include fabrication of solar cells from regolith derived materials and storing the resulting energy in advanced batteries, compounds (e.g. hydrogen and oxygen), high performance flywheels, etc.

III. EXPERIMENTAL APPARATUS AND FLIGHT OPPORTUNITIES

Several flight instruments have been developed by or through NASA in order to address the objectives of the materials science discipline described in the preceding section. Appendix B provides brief capability descriptions of the flight hardware and ground-based reduced-gravity testing facilities.

Flight opportunities available through this NRA will be on the appropriate space platform including the Space Shuttle and the International Space Station. Science protocols should consider the additional benefits that could accrue from skilled crew interaction with experiments available during many of these flight opportunities. Residual acceleration levels of the order of 10^{-4}g are available in a Space Shuttle orbiter. Space Shuttle flights are usually of 7-10 days duration, although some flights of 16 days and longer are possible. The acceleration environment aboard the Space Station should be substantially better during limited time periods. The Space Acceleration Measurement System (SAMS) is expected to be available for the measurement and recording of actual accelerations at or near the apparatus during experimentation. Downlink channels enable investigators to monitor their instrument status and science data streams in near real time. An uplink channel enables them to act on that information.

IV. UNDERGRADUATE STUDENT RESEARCH OPPORTUNITIES

Active research experience is one of the most effective techniques for attracting talented undergraduates to and retaining them in careers in mathematics, science, and engineering. The undergraduate years are critical in the educational sequence, as career-choice points and as the first real opportunities for in-depth study. MSAD is endeavoring to foster the development of undergraduate students by offering supplements of approximately $5,000/student for undergraduate student research projects. These projects should involve students in a meaningful way in ongoing research programs or in related sub-projects specifically designed for this purpose. This may include software development activities for programs that demonstrate principles of microgravity or microgravity research. Programs should be developed in such a way that they are not computer platform (hardware or operating system) specific, they adhere to open standards, and they can be easily incorporated into sites on the World Wide Web so that students, teachers and the general public may have access to them.

The proposals for the undergraduate student research projects should include: the nature of the student activities, presenting plans that will ensure the development of student-faculty and student-student interaction and communication; a concise description of the experience and record of the principal investigator and any potential advisors of students; and the criteria for evaluating the success of the project. The proposal should be a separate section (see information on proposal formatting in Section V, subsection B) of approximately two pages and will not to be counted against the maximum page limit. This effort should be shown as a separate line in the budget summary for each year.

The review criteria (in addition to those indicated in Appendix A, Section VIII, B) for the supplements will be:

1. The value of the educational experience for the student participants, particularly the appropriateness of the research projects(s) for and the nature of student participation in these activities;

2. The quality of plans for student preparation, student mentoring and follow through designed to promote continuation of student interest and involvement in research;

3. The proposed arrangements for managing the project and how the project will be evaluated.

If selected for involvement in this program, investigators are required to submit reports on these activities in conjunction with reporting on the primary grant. In particular, reports should include information on the activities of each student, the degree of interaction with their mentors, the future career plans of the student (if known) and an evaluation of the project’s progress.

V. PROPOSAL SUBMISSION INFORMATION

This section gives the requirements for submission of proposals in response to this announcement. The research associated with a typical proposal submitted under this announcement must be conducted by a Principal Investigator who is responsible for all research activities and may include one or more Co-Investigators. Proposers must address all the relevant selection criteria in their proposal as described in Section VI and must format their proposal as described in this section. Additional general information for submission of proposals in response to NASA Research Announcements may be found in Appendix C.

A. LETTER OF INTENT

Organizations planning to submit a proposal in response to this NRA should notify NASA of their intent to propose by electronically sending a Letter of Intent (LOI) via the World Wide Web to the following address:

http://microgravity.msad.hq.nasa.gov/96_matsci_letter_of_intent

Letters of Intent may be submitted via e-mail to the following address: loi@hq.nasa.gov
If electronic means are not available, you may mail Letters of Intent to the address given for proposal submission in the following section.

The Letter of Intent, which should not exceed two pages in length, must be typewritten in English and must include the following information:

- The potential Principal Investigator (PI), position, organization, address, telephone, fax, and e-mail address.
- A list of potential Co-Investigators (Co-I's), positions, and organizations.
- General scientific/technical objectives of the research.
- The equipment of interest listed in this NRA, if appropriate.

The Letter of Intent should be received at NASA Headquarters no later than January 24, 1997; facsimile transmission (FAX 202-358-3091) is acceptable. The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. Investigators may also request more detail on the capabilities of the specific equipment that might be utilized to accomplish their scientific objectives.

The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. Investigators may also request more detail on the capabilities of the specific equipment that might be utilized to accomplish their scientific objectives.

B. PROPOSAL

Proposals submitted in response to this Announcement must be typewritten in English and contain at least the following information in the format shown below:

- Title Page
- Table of Contents
- Executive Summary (replaces abstract) (1-2 pages)
- Research Project Description
  Statement of the hypothesis, objective, and value of this research
  Review of relevant research
  Justification for new or further microgravity research
  Description of Experimental or Analytical Method
  Data Analysis
  References
- Appendices
  Management Plan (appropriate for large or complex efforts)
  Undergraduate Student Research Opportunity Proposal (if applicable)
  Complete vitae for the PI and all Co-investigators
  Current and Pending Support

Facilities and Equipment (see Appendix C, Section 7-h)
Proposed Costs (see Appendix C, Section 7-i)
Signed Certifications (see below)

- 3.5 inch computer diskette containing an electronic copy of the principal investigator's name, address, complete project title, and executive summary.

The title page must clearly identify the research announcement to which the proposal is responding, title of the proposed research, principal investigator, institution, address and telephone number, total proposed cost, proposed duration, and must contain all signatories.

The executive summary should succinctly convey, in broad terms, what the proposer wants to do, how the proposer plans to do it, why it is important, and how it meets the requirements for microgravity relevance. The executive summary replaces the proposal abstract.

The management plan is necessary when the proposed research involves large or complex efforts among numerous individuals or other organizations to insure a coordinated effort.

The proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11 inch paper with a 10- or 12-point font. Extensive appendices and ring-bound proposals are discouraged. Reprints and preprints of relevant work will be forwarded to the reviewers if submitted as attachments to the proposal. Proposers should prepare cost estimates by year for a period not greater than four years in preparing budget plans in response to this Research Announcement.

The guidance in Appendix C, Section 8 regarding the content of renewal proposals is not applicable to this NRA. Renewal proposals should not rely on references to previous proposals for any information required for a complete proposal.

Each proposal requesting financial support should include signed Certifications Regarding Lobbying; Debarment, Suspension and other Responsibility Matters; and Drug-Free Workplace Requirements. Copies of these certifications may be found at the end of this document.

Fifteen copies of the proposal must be received at NASA Headquarters by March 11, 1997, to assure full consideration. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

Dr. Michael J. Wargo
NASA c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-02)
300 D Street, S.W., Suite 801
Washington, D.C. 20024

Telephone number for delivery services: (202) 479-2609

NASA cannot receive proposals on Saturdays, Sundays or Federal holidays.

Non-U.S. Proposals: See next section

Proposers will receive a postcard confirming receipt of proposal within 10 working days of the due date.

VI. ADDITIONAL GUIDELINES FOR INTERNATIONAL PARTICIPATION

Non-U.S. proposals and U.S. proposals which include non-U.S. participation, must be endorsed by the appropriate government agency in the country from which the non-U.S. participant is proposing. The letter of endorsement from the sponsoring agency should indicate that 1) the proposal merits careful consideration by NASA, and 2) sufficient funds will be made available to undertake the activity as proposed if the proposal is selected. **NASA will not transfer funds to non-U.S. participants.**

Proposals from non-U.S. entities should not include a cost plan. All proposals must be typewritten in English and must follow all other guidelines and requirements described in the NRA. Non-U.S. proposals will undergo the same evaluation and selection process as those originating in the U.S.

Special instructions apply to non-U.S. proposals. In addition to sending the original proposal (and copies) to NASA through Information Dynamics Inc. as directed above, one (1) additional copy along with the Letter of Endorsement must be forwarded to NASA, in time to arrive before the deadline established for this NRA:

Ms. Ruth Rosario
ref: NRA-96-HEDS-02
Space Flight Division
Code IH
National Aeronautics and Space Administration
Washington, DC 20546-0001
USA

All proposals must be received before the established closing date; those received after the closing date will be treated in accordance with NASA's provisions for late proposals. Sponsoring government agencies may, in exceptional situations, forward a proposal directly to the above address if review and endorsement is not possible before the announced closing date. In such cases, NASA should be advised when a decision on endorsement can be expected. **A letter of endorsement from the sponsoring government agency must be received by NASA before May 1, 1997; if the letter of endorsement is not received prior to this date, the proposal will be deemed non-responsive and will not be reviewed by NASA**.

Successful and unsuccessful proposers will be contacted directly by the NASA Program Office (Microgravity Science and Applications Division) coordinating the NRA. Copies of these letters will be sent to the sponsoring government agency. Should a non-U.S. proposal or a U.S. proposal with non-U.S. participation be selected, NASA's Office of External Relations will arrange with the sponsoring agency for the proposed participation on a no-exchange-of-funds basis, in which NASA and the sponsoring agency will each bear the cost of discharging its respective responsibilities. Depending on the nature and extent of the proposed cooperation, these arrangements may entail a letter of notification by NASA, an exchange of letters between NASA and the sponsoring agency, and an agreement or memorandum of understanding between NASA and the sponsoring government agency.

VII. EVALUATION AND SELECTION

The following section replaces Section 13 of Appendix C.

A. EVALUATION FACTORS AND PEER REVIEW PROCESS

The principal elements considered in the evaluation of proposals solicited by this NRA are: 1) overall scientific and technical merit of the proposal, 2) relevance to the NASA microgravity program as determined by the investigation's articulated need for a microgravity environment, or articulated support of a microgravity research program (including scientific and technology aspects of the Human Exploration and Development of Space Enterprise), and 3) realism and reasonableness of the proposed cost. Articulation of the need for a microgravity environment in rigorous, quantitative terms will be deemed to have greater microgravity relevance. Qualitative articulation of the need for a microgravity environment will be deemed to have lower microgravity relevance. Intrinsic merit has the greatest weight, followed by relevance to NASA's objectives, which has slightly lesser weight. Both of these elements have greater weight than cost.

The programmatic objectives of this NRA, as discussed in the introduction to this Appendix, will be applied by NASA to enhance program breadth, balance, and diversity.

Evaluation of the intrinsic merit of the proposal includes consideration of the following factors, in descending order of importance:

1. Overall scientific or technical merit, including evidence of unique or innovative methods, approaches, or concepts, and the potential for new discoveries or understanding, or delivery of new technologies/products and associated schedules

2. Qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel who are critical in achieving the proposal objectives

3. Institutional resources and experience that are critical in achieving the proposal objectives

4. Overall standing among similar proposals available for evaluation and/or evaluation against the known state-of-the-art.

Evaluation by NASA of the cost of a proposed effort includes comparison against historical experience with efforts of similar scope and scale, and the relationship of the proposed cost to available funds. Cost is a significant evaluation factor, and NASA may select proposals with an offer of funding below the requested budget.

The evaluation process for this NRA will be based on a peer review of the proposal's intrinsic scientific and technical merit, articulated relevance to the microgravity program, and cost of the research plan. The reviewers will be scientific and technical experts from government, academia, and industry. Each proposal will be reviewed independently by members of the review panel and discussed at a review panel meeting to determine a consensus evaluation for the proposal. All proposals will be evaluated on a merit scale of 1 (worst rating) to 9 (best rating). A rating below 5 is not generally considered for funding. An engineering review of potential flight hardware requirements will be conducted by NASA for proposals that include flight experiments. The external peer review and internal engineering review will be coordinated by the Enterprise Scientist for Materials Science.

The MSAD Director will make the final selection based on science panel and programmatic recommendations. Upon completion of all deliberations, a selection statement will be released notifying each proposer of proposal selection or rejection. Offerers whose proposals are declined will have the opportunity of a verbal debriefing regarding the reasons for this decision. Additional information on the evaluation and selection process is given in Appendix C.

B. SELECTION CATEGORIES, PERIOD OF SUPPORT, AND FLIGHT PROGRAM PROCESS

Proposals selected for support through this NRA will be selected as either ground-based- or flight-definition investigations. Investigators offered support in the ground-based program normally will be required to submit a new proposal for competitive renewal after at most four years of support. Investigators offered flight definition status are expected, in addition to their research work, to begin preparing detailed flight experiment requirements and concepts for flight development shortly after selection in cooperation with the assigned Project Scientist from a NASA Center.

A flight experiment represents a considerable investment of resources, both human and financial. The Principal Investigator for a flight investigation in definition phase has the responsibility to continue the pursuit of basic knowledge which will make a flight experiment fully meaningful, and, in addition, will be responsible for major contributions to the large effort needed to define and build the flight experiment. In the first six months following selection, the Principal Investigator will meet with NASA representatives to discuss any technical feasibility issues related to the proposed flight experiment. These discussions will also include identification of resources needed to establish feasibility, produce a draft Science Requirements Document (SRD), conduct a Science Concept Review (SCR) of the flight experiment, and conduct the Requirements Definition Review (RDR) roughly one year after the SCR. Successful completion of these reviews will be required before the investigation will be approved for flight. It may be decided as a result of these discussions that the project should revert to ground-based status. This will not in any way preclude the PI's opportunities to propose for renewal of the research effort as a ground-based investigation, or to propose a flight experiment at a later date. The period of performance will be unchanged; the duration of support for the project will be as indicated at selection.

NASA may not have a specific opportunity to conduct a given flight experiment in it's planning manifest at the time of selection from this NRA. However, if during the period of support, an opportunity arises to take this research to flight, this type of project would be directed to prepare a Science Requirements Document. This will place the project on the path of flight experiment development, entailing further peer review as well as project reviews. Should such an opportunity not arise within the first three years after selection, continued support for the project would be contingent upon submittal of a new proposal to the Microgravity Materials Science NASA Research Announcement to be released in the Fall of 2000.

The primary purpose of the SRD is to define a flight experiment to a level of specificity adequate to guide the development of a fully satisfactory experimental apparatus, as well as to justify the requirement for flight (as opposed to other low gravity platforms) in reference to specific individual experiments. The requirement for flight of specific experiments is a key determination of the SCR and RDR. Through the course progress to flight, the SRD will be a point of reference for decisions involving the scope of the flight experiment and allocation of resources. The SRD should clearly state and effectively justify a focused program of flight research, identifying what is considered to be minimal and optimal experiment outlines. Some limited evolution of the experiment definition over the following several years is expected, as continuing ground-based research refines objectives, but the document should be in final form by the time of the RDR. The SRD is used to guide the design, engineering, and integration effort for the instrument. The SRD describes specific experiment parameters, conditions, background, and justification for flight. Ground-based, normal, and reduced-gravity experimentation, as well as any necessary modeling efforts, may also be required to prepare an adequate Science Requirements Document. The amount of support (technical, scientific, and budgetary) provided to investigators by NASA will be determined by the Enterprise Discipline Scientist for Materials Science in collaboration with the Discipline Manager for Materials Science (at Marshall Space Flight Center) based upon specific investigator needs and the availability of resources to NASA and MSAD.

These activities are in preparation for a Science Concept Review (SCR) to be held within approximately two years of the beginning of Investigator funding. Investigations not selected for flight because of scientific, technological, or programmatic considerations at the SCR will be placed in the ground-based program and funding will continue until the end of the original four-year period. This Review will be conducted before a scientific peer panel that will be asked to assess:

- The significance of the problem being investigated including the benefits that the experimental and theoretical results would provide to the materials science research community and industry.
- The maturity of the overall scientific investigation.
- The scientific objectives of the proposed flight experiments.

- The need for a microgravity environment to achieve the proposed scientific objectives.

- The priorities of these scientific objectives.

- The rigor with which the proposed flight experiment has been conducted terrestrially (e.g. influence of gravity, reproducibility and quantification of experimental conditions and results, materials characterization, modeling, application/verification of current and/or developing theoretical framework etc.).

- The scientific specifications for the proposed flight experiments as expressed in the preliminary draft of the Science Requirements Document.

- The conceptual design for the apparatus and whether this design could be expected to deliver a level of performance that allows the scientific objectives to be achieved.

- Technology issues that would prevent a timely, successful achievement of the scientific objectives.

The selected investigations will be required to comply with MSAD policies, including the return of all appropriate information for inclusion in the MSAD archives during the performance of and at the completion of the contract or grant.

Commitment by NASA to proceed from flight definition to the execution of a flight experiment will be made only after several additional engineering and scientific reviews and project milestones have established the feasibility and merit of the proposed experiment. Investigations not selected for flight at these reviews will be funded for a limited period (approximately one year) to allow an orderly termination of the project.

VIII. NRA FUNDING

The total amount of funding for this program is subject to the annual NASA budget cycle. The Government's obligation to make awards is contingent upon the availability of appropriated funds from which payment for awards can be made, and the receipt of proposals which the Government determines are acceptable for an award under this NRA.

For the purposes of budget planning, it is assumed that the Microgravity Science and Applications Division will fund as many as 20 to 30 research proposals, at varying levels of funding depending on the objectives of the research. While some proposals may be significantly higher, most are expected to be lower than the anticipated average of $100,000 per year per proposal for ground-based research and $175,000 per year per proposal for flight definition, with correction for inflation. Resources permitting, a few high-risk, high-payoff-if-successful ideas will be considered for funding at an average level of $50,000 per year for up to two years.

Proposed budgets will normally include a portion of the researchers' salaries, travel for the investigators and students to about three science and NASA meetings per year, other expenses (publication costs, computing or workstation costs etc.), burdens, and overhead.

APPENDIX B
NRA–96–HEDS–02

HARDWARE AND FACILITY DESCRIPTIONS

The Microgravity Science and Applications Division (MSAD) is conducting a program to acquire and fly scientific instrumentation flight hardware to successfully complete investigations selected through this and associated NRA's. After successful completion of the Science Concept Review (SCR), the Principal Investigator (PI) will work with National Aeronautics and Space Administration (NASA) personnel to determine which existing scientific instrument can be used to conduct the flight experiments, or what type of new apparatus must be developed. The discipline of microgravity materials science has an advantage compared to other microgravity research areas in that a large number of high temperature apparatus of various capabilities have been developed by NASA and its international partners, and are available for use by U.S. investigators. NASA's Marshall Space Flight Center (MSFC), as the lead center for microgravity materials science research, maintains the management and engineering expertise to develop new flight hardware to meet an investigation's specific performance requirements, or can provide guidance to a PI who proposes to develop flight hardware as part of the investigation. In addition, NASA is currently planning the transition of most research flight operations from the Space Shuttle to the International Space Station (ISS) at the end of this decade. MSAD has initiated development of the common support equipment for a Space Station Furnace Facility (SSFF) to be used for high temperature materials science investigations early in the ISS era. This broad, evolutionary program is expected to meet the science requirements of increasingly sophisticated microgravity investigations and to permit the development of experiment equipment for research throughout the life of the ISS.

I. CURRENT FLIGHT HARDWARE

The experiment apparatus described in this section are existing or under development for flight on a Space Shuttle mission or the ISS (as noted). NASA anticipates flight opportunities for investigations capable of using Shuttle hardware through 2001 and ISS hardware beginning as early as 1999. Minor modifications of the current hardware may be possible to make it more versatile and to accommodate users and experiments other than those for which it was originally designed. Several potential enhancements are highlighted in the descriptions for the current hardware. This listing is not all inclusive of available flight apparatus, and investigators are free to identify or propose against alternate existing apparatus to that mentioned in this section. Availability of the instruments described here, with or without modification, is contingent upon the availability and allocation of resources, and cannot be guaranteed at this time.

More detailed descriptions of the current flight hardware may be requested in the Letter of Intent described in Appendix A, Section V.

A. SPACE STATION FURNACE FACILITY (SSFF) CORE SYSTEM

In November 1993, MSAD authorized full scale development of the SSFF Core System. Defined by a series of science workshops and formal reviews from 1987 to 1992, the SSFF Core System is an array of common or "core" hardware systems which provide support functions for separately developed experiment-unique modules. The rationale is to greatly shorten the experiment implementation time by judiciously providing for all major non-experiment-unique long-lead-time hardware development, and reducing cost by eliminating repeated hardware and software development for items such as thermal control systems, power conversion and conditioning systems, etc. This approach also reduces the mass required to be launched and returned for each materials science experiment to be performed on the Space Station. The Experiment Modules themselves remain in the definition phase at the time of this Announcement. Several Experiment Modules are projected to be based on the existing U.S. and International Hardware described in this section. Several others, described in Section II.A of this Appendix, are Experiment Modules to be developed in response to successful proposers to this announcement.

SSFF Baseline Capabilities. SSFF can simultaneously operate two of any four Experiment Modules located in the SSFF Instrument Racks. Up to 7 kW of electrical power and corresponding active cooling is provided to the Experiment Modules. Experiment Module data is recorded during times of no communication with Earth. The SSFF provides an Astronaut Crew interface (laptop type computer) on the Space Station and Earth-based User Operations Facility for command and monitoring of the SSFF Experiment Modules by the science teams.

SSFF Enhanced Capabilities. Planned enhancements of the SSFF Core include the addition of a video processing subsystem to allow compression, storage, and transmission to the ground of video images provided by Experiment Modules. Other enhancements will be considered on a case-by-case basis. Normally, capabilities required by only one or a small number of Experiment Modules will be provided in that Experiment Module and not by the SSFF Core System.

B. ADVANCED AUTOMATED DIRECTIONAL SOLIDIFICATION FURNACE (AADSF)

Developed for flight in the cargo bay of the Space Shuttle, the AADSF is a modified Bridgman-Stockbarger type directional solidification furnace. The AADSF gradient zone region is modified between missions to be optimized for the needs of a particular cadre of investigators. The AADSF was successfully operated on the Second United Stated Microgravity Payload Mission (USMP–2) in March 1994 and the Third United States Microgravity Payload Mission (USMP–3) in February 1996. The AADSF with a sample exchange mechanism (SEM) is scheduled for flight on the Fourth United States Microgravity Payload Mission (USMP–4) in October 1997.

AADSF Baseline Capabilities. The AADSF Furnace Module is a five heater zone furnace, comprising a hot zone with end guard heater, a booster heater between the gradient zone and hot zone, an unpowered gradient zone, a cold zone and a cold zone guard heater. The hot zone bore is approximately 2.5 cm diameter and 26 cm long. The cold zone bore is approximately 2.5 cm diameter and 12.5 cm long. The length and bore of the temperature gradient region is based on the thermal profiles required by the Principal Investigator. The gradient zone can be outfitted with a metal heat extraction plate and two ceramic insulating plates to modify the gradient temperature profile. The hot zone has been operated in ground test up to 1150°C; and the cold zone operated to 850°C. Up to six thermocouples of mixed type can be accommodated in the cartridge containing the sample ampoule.

The AADSF can be operated from the ground during the mission to change furnace set points and translation rates and current pulsing programs. Sample ampoule thermocouple data and furnace control and housekeeping data are downlinked in near-real-time during mission operations. The orbiter crew has the ability to boot up the computer from the orbiter in the event of a computer malfunction.

An AADSF-like furnace is a potential candidate Experiment Module for the Space Station Furnace Facility.

AADSF Enhanced Capabilities. A sample exchange mechanism (SEM) has been added to one of the AADSF flight units for the USMP–4 mission. This enhancement accommodates a maximum of three muffle tubes. Each muffle tube has typically contained one sample enclosed in an ampoule which, then, allows for up to three samples to be processed during a single mission. Muffle tubes have been configured with more than one sample. The samples will be loaded and retrieved on the ground. Current pulse interface demarcation, up to a current level of 20 amperes, has also been added to this unit.

C. CRYSTAL GROWTH FURNACE (CGF).

The CGF is a modified Bridgman-Stockbarger type directional solidification furnace capable of hot zone temperatures to 1600°C, and the exchange of experiment samples by the astronaut flight crew. The CGF system occupies two full Spacelab racks and comprises four avionics boxes and an Integrated Furnace Experiment Assembly (IFEA). The IFEA contains the Experiment Apparatus Container, which houses a Reconfigurable Furnace Module.

The CGF was successfully operated on the First United States Microgravity Laboratory Mission (USML–1) in June–July 1992, and performed flawlessly in processing all eight samples planned during the Second United States Microgravity Laboratory (USML–2) mission in October–November 1995. The CGF underwent significant modifications and upgrades for the reflight including the addition of current pulse interface demarcation capability.

CGF Baseline Capabilities. The CGF Reconfigurable Furnace Module comprises three zones with a total of seven heater elements. The heated zones consist of a hot zone with redundant heater elements, a guard heater, a booster heater between the hot zone and gradient zone, an unpowered gradient zone, and a cold zone with redundant heater elements and a cold zone guard heater. The bore of the furnace is approximately 3 cm in diameter; the hot zone length is approximately 25 cm, and the cold zone length is approximately 16 cm. The length of the gradient zone is selectable pre-mission from 1.0 to 7.0 cm, based on the thermal profiles developed by the PI during ground based characterization testing. A Ground Control Experiment Laboratory or ground prototype of the CGF System is available to support pre-flight PI ground-based science testing activities. The gradient zone can be outfitted with a metallic heat extraction plate to assist in radial heat dissipation. The hot zone has been operated in ground test up to 1350°C; and the cold zone operated to 1225°C in support of previous flight investigations. Up to six thermocouples and up to four failure sensors can be located in the cartridge containing the sample ampoule. The furnace can be translated for directional solidification between 0.002 mm/min. and 8.3 mm/min. during processing; a rapid translation capability of up to 1200 mm/min. is also available. Sample ampoules/cartridges can be up to 2 cm in diameter and up to 20 cm in length. The current pulse interface demarcation system can deliver a coded string of current pulses of up to 40 amperes to the sample .

The CGF can be operated from the ground during the mission to change furnace set points, translation rates, and interface demarcation settings. Sample ampoule thermocouple data and failure sensor information, in addition to furnace control and housekeeping data, are downlinked in real-time and delayed near-real-time modes during mission operations, which provides a high degree of flexibility and interactive capability with the experiment operations for the PI and science team.

D. MATERIAL POUR L'ETUDE DES PHENOMENES INTERESSANT LA SOLIDIFICATION SUR TERRE ET EN ORBITE (MEPHISTO).

MEPHISTO is a joint U.S./French flight research program to study the physics of solidification. Research themes include micro- and macro-segregation in binary alloys or doped semiconductors, morphological stability of solid/liquid interfaces, transition from planar to cellular to dendritic interface morphologies, and mass transport effects on interface undercooling. MEPHISTO refers to both this joint research program and the unique flight and laboratory apparatus provided by the French to NASA for use by U.S. PIs under the terms of the international agreement. French PIs are assigned by the French Government, and U.S. PIs are assigned by NASA. MEPHISTO has successfully completed flights in the First United States Microgravity Payload (USMP–1) Mission in October 1992, the USMP–2 mission in March 1994, and the USMP-3 mission in February 1996.

MEPHISTO Baseline Capabilities. The MEPHISTO flight apparatus is carried in the cargo bay of the Space Shuttle for orbital operations. MEPHISTO processes three identical samples simultaneously to acquire information from a variety of in situ, real-time measurements. One sample is instrumented to measure interface temperature by use of the Seebeck effect. A second sample is instrumented to determine position and velocity of the solid/liquid interface through sample resistance measurement. Thermocouples can be located within this sample and/or ampoule. The third sample is configured to allow interface marking through current induced interface demarcation, using current pulses of up to 50 amperes, for post flight examination of the sample. Thermocouples can also be located within this sample. Thermocouple, Seebeck, and resistance measurements are provided in near-real-time to the PI on Earth, and MEPHISTO can be commanded from the ground to adjust experiment parameters, repeat measurements and solidification process cycles. MEPHISTO crucibles accommodate samples 6 mm diameter and 800 mm long. The sample length is dictated by the need to provide a stationary interface for thermoelectric power signal as a reference for Seebeck measurements at the solidification interface of the same sample. The MEPHISTO apparatus has demonstrated axial temperature gradients between 10°C/cm and 250°C/cm for one of the initial material systems studied (tin) and is capable of hot zone temperatures of up to 1000°C. Furnace translation rates of $5x10^{-5}$ cm/sec to $5x10^{-2}$ cm/sec are provided. Because use of the Seebeck effect to measure interface temperature requires detailed knowledge of the thermoelectric physical properties of the specific material system to be studied, NASA strongly advises proposers specifically interested in the MEPHISTO to establish this information early in their research program.

MEPHISTO Enhanced Capabilities. The French Space Agency has previously identified an increase in the hot zone maximum temperature to approximately 1500°C as a possible enhancement for future flights of MEPHISTO. Additional modification would be considered on a case-by-case basis.

E. ADVANCED GRADIENT HEATING FURNACE (AGHF)

The AGHF is a multi-user tubular furnace for high temperature directional solidification research developed by the European Space Agency (ESA). It is currently configured for operations inside a Spacelab module on board the Space Shuttle. The AGHF was successfully flown aboard the Life and Microgravity Science (LMS) mission in June-July 1996. Several experiments were processed using shared operational time. AGHF or an AGHF-like apparatus is a candidate as an Experiment Module of the Space Station Furnace Facility.

AGHF Baseline Capabilities. The AGHF is a Bridgman type gradient furnace consisting of a heated section with two individually controlled heaters acting on a common thermal diffuser, separated from a cooled heat extraction zone. The furnace is displaced relative to the sample. The AGHF is currently optimized for sample diameters of up to 20 mm, current pulse interface demarcation up to 30 amperes, and a high degree of thermal stability. Sample cartridges up to 32 cm long containing up to 28 thermocouples can be translated up to 14 cm in the furnace, from 0.6 mm/hr to 600 mm/hr. The AGHF can be commanded/monitored on Earth in a similar manner as CGF.

F. MILLIKELVIN THERMOSTAT (MITH).

MITH Baseline Capabilities. This is a microgravity materials science and fluid physics apparatus capable of both autonomous operation and remote control operation through uplink and downlink communication. In its current configuration, this apparatus permits study of the solidification behavior of transparent organic materials, such as succinonitrile (SCN) or pivalic acid (PVA) in dendrite growth experiments.

A single sample can be repeatedly melted and supercooled with solidification observed at the center of a 4 to 6 cm diameter spherical test volume. Spontaneous initiation of solidification is minimized by using highly purified test materials, isothermal control during each solidification test cycle, and compatible stainless steel and glass test chamber construction.

The thermostat can measure and control the test chamber with high precision and accuracy by using an isothermal bath around the chamber. The test chamber allows orthogonal photography and digital imaging of the chamber test volume. The digital imaging system is a charge coupled device (CCD) camera which, in conjunction with three onboard computers, has three principal capabilities. First, the CCD cameras identify the first appearance of solidification at the center of the target sample volume and then activate the high resolution photographic system. Second, the CCD cameras store adjustable field-of-view images. Finally, CCD images are available for transmission to ground control and can be used to determine appropriate remote adjustments of some of the experiment parameters such as: photographic frame rate, undercooling temperature, etc. For postflight analysis, still-frame Schlieren photography provides up to 500 alphanumerically annotated, high resolution photographs from two 35 mm cameras. These photographs show orthogonal views of the test volume for accurate determination of random solidification growth direction.

The MITH is currently designed for location in the open shuttle bay on the USMP carrier. It is thermally isolated in a conditioned N_2 atmosphere and is isolated from astronaut physical access during flight.

MITH Enhanced Capabilities. Possible enhancements to the MITH include variable photographic magnification and field of view, greater video field of view, and increased frame rate. Video enhancements may allow study of transient phenomena during flight. Other possible enhancements include a new sample chamber with multiple moveable, independent dendrite initiation sites. In addition, a possible volumetric measuring device to calculate the percent solidification, may be possible.

The MITH could be further enhanced to provide physical access during flight to accommodate in-flight experiment changeout. Substitution of different test chambers would allow performance of other than dendrite growth experiments. The following capabilities could also be made available: fluid changeout;

still-frame and video film changeout; camera and TV "point of focus," variable focus, and increased magnification using high resolution TV technology.

G. MIDDECK GLOVEBOX (MGBX).

The Middeck Glovebox is a multi-user and multidiscipline facility that provides an enclosed working space for experiment manipulation and observation. The MGBX occupies two standard lockers in the Space Shuttle middeck. The Middeck Glovebox door opening to insert or retrieve investigation hardware is 20.3 cm by 19.4 cm, with a working volume of 35 liters. The Glovebox working volume is approximately 39.0 cm wide, 25.0 cm deep, and 23.0 cm high. Forced air cooling can withdraw a maximum of 60 W of investigation generated heat. Up to 60 W of 24, ±12, and 5 VDC power is available for experimenter apparatus.

The MGBX can be used in various modes of pressure and air circulation. The working area can serve as a sealed environment that is isolated from the crew cabin atmosphere, as a constantly recirculating atmosphere that is maintained at a pressure slightly lower than the middeck ambient, or as a working area open to the middeck. Multipurpose filters exist to remove particles, liquids, and reaction gasses from the recirculated air.

Due to limitations of the Space Shuttle middeck, there is no standard data or video downlink. There is the possibility of some near-real-time video downlink (from the Shuttle Camcorder), but this will be decided on a mission-by-mission basis. Three video recorders provide data storage, with digital data stored in the audio channels; an additional connector records 10 channels of data (five analog and five digital) to the interface frame data recorder. An adjustable light switch, video port plugs, a backlight panel, and cutout window covers provide illumination.

The overall philosophy of the Glovebox program is to provide the ability to conduct less complex science investigations or technology demonstrations in a microgravity environment in a faster, better, and cheaper manner. The hardware development cycle is approximately 2 to 3 years. Currently ten glovebox investigations in the disciplines of materials science, fluid physics, biotechnology and combustion science are under development for flight, and additional Glovebox flight opportunities for new investigations are planned on a frequent basis from 1996 through 1999.

H. GLOVEBOX LASER LIGHT SCATTERING HARDWARE

A compact instrument has been designed that is capable of both static and dynamic light scattering measurements. This instrument was designed to operate in the Space Shuttle glovebox facility and occupies the volume of an 8” cube. It accepts cylindrical test cells with an outer diameter of 10 mm. A translation motor enables interrogation of a 2 cm length of a test cell with a translation velocity of either 24 µm/sec or 0.6 mm/sec. It is equipped with a pigtailed laser diode which delivers approximately 6-8 mW of power at 780 nm to the test section. A fiber optic pickup at 90 degrees delivers scattered light to an avalanche photodiode detector. A glovebox facility camera can be positioned to record static light scattering data incident on a semi-cylindrical diffuse screen (approx. 30 degrees – 160 degrees). Test samples can be oscillated about the cell axis with a fixed 2 degree amplitude. The instrument is capable of inducing single impulses or sinusoidal oscillations with variable frequency (15–70 Hz). The instrument is controlled via software resident in a laptop computer which also contains a digital correlator card to compute the temporal autocorrelation function from the avalanche photodiode output. The instrument should be able to interface with the ISS Microgravity Science Glovebox facility with minor modifications.

I. SUPPRESSION OF TRANSIENT ACCELERATION BY LEVITATION (STABLE)

STABLE is an actively controlled vibration isolation system which has been baselined to control 50% of the U.S. allocation of payloads to be flown on ISS. Designed to operate on the component level rather than the rack level, it has been successfully proven on USML–2 in late 1995 with a small simple system to study materials processes in microgravity that are applicable to crystal growth mechanics. The STABLE system operates by the application of dual axis wide-gap electromagnetic actuators with feedback from accelerometers.

II. FUTURE DIRECTIONS

The evolving focus of the MSAD emphasizes the development of modular payloads that can be configured (or easily reconfigured) to accommodate specific investigations and their experiment-unique equipment. In addition, NASA has developed descriptions of candidate SSFF Experiment Modules perceived as suitable for a subset of the research described in Appendix A. These general hardware capabilities descriptions are included as a point of departure for researchers to consider the type of capabilities that might meet their science requirements; researchers should not, however, feel limited by these capabilities. The descriptions are concepts for guidance only, as some of the NASA systems given have not been committed for development. The proposals received in response to this NRA will be used to more accurately determine the capabilities needed in future flight hardware. These Experiment Modules, now in the early concept definition stage, could, if developed, be available for flights in 2002 and beyond.

In addition, for smaller materials science experiments, which do not require the high temperature support equipment of the SSFF Core System, NASA is developing general purpose payload integration and support equipment for experiment-unique apparatus on the ISS. This will allow the continued development of small experiment apparatus for use in either the Space Shuttle or ISS during the early years of the transition of research operations from Shuttle to Station.

A. SPACE STATION FURNACE FACILITY EXPERIMENT MODULES.

In addition to the SSFF Core System and existing materials science apparatus described in Appendix B Part I of this NRA, NASA is conducting studies of potential SSFF Experiment Modules based on the preliminary performance specification of PIs selected from the Microgravity Materials Science NRAs in 1991 and 1994. The materials science Experiment Modules described here are in the conceptual design/brassboard stage and have not yet been approved for development. In addition, coordination of plans for microgravity materials science apparatus development is underway with our international partners to insure that identical research capabilities are not inadvertently duplicated on the ISS. The final selection of initial SSFF Experiment Modules will be based on the needs of the individual research projects which successfully complete a SCR; a mix of investigation-unique and multi-user Experiment Modules is probable. Additional SSFF Experiment Modules are anticipated, and will be based on the results of future Microgravity Materials Science NRAs.

1. High Gradient Furnace with Quench (HGFQ).

The HGFQ is expected to be a Bridgman type furnace for conducting metals and alloys solidification experiments on the ISS, using the capabilities of the SSFF. It is intended to be a long duration payload that will operate on the ISS for four consecutive “increments” of one year duration each.

HGFQ Baseline Capabilities: The furnace hot zone will have three heated zones, an actively cooled chill block (cold zone), and a quench block with vacuum ring designed to quench a 5 mm segment of the sample material. The furnace will operate in a gas environment. The length of the gradient zone is reconfigurable from 1 to 3 cm and is selected before delivery to the ISS. The first mission is designated as having a 3 cm length. The first mission can accommodate a cartridge diameter of 16 mm and sample length of 20 cm. Sample instrumentation with 2 to 12 thermocouples can be located in the cartridge containing the sample material. The furnace bore can accommodate cartridge diameters up to 25 mm. The furnace will be capable of establishing a thermal gradient of greater than 100°C/cm with a maximum hot zone temperature of 1400°C. A rapid translation capability will be provided, with capability of moving the sample in position for quench within 1 second. The quench system shall provide a rate sufficient to reduce the temperature by 300°C over a quench duration of 1 second from beginning of quenching.

The HGFQ may be operated from the ground during the mission to change furnace set points, translation rates, and interface demarcation settings. Sample ampoule thermocouple data, as well as furnace control and housekeeping data, will be downlinked in near-real-time during mission operations. A sample exchange mechanism permits 10-12 cartridges to be loaded at one time.

2. Low Gradient Furnace (LGF)

The LGF is a multi-discipline multi-user device for high temperature materials research and is currently being developed by ESA. The LGF is planned to be one of the first Experiment Modules to be placed on the ISS. It will be housed in a dual vertical configuration in one-half of a standard space station rack along with another Experiment Module which will be developed by the United States. The SSFF Core System will provide support functions for each of the modules in the dual configuration Instrument Rack. The planned capabilities of the furnace system will be determined to a large degree by the LGF module furnace insert that is designed to support the selected crystal growth investigations.

LGF Baseline Capabilities. The LGF is a low temperature Bridgman-Stockbarger furnace primarily intended for crystal growth experiments. The furnace design will accommodate on-orbit replaceable heater module inserts which can interface with the furnace structure and can satisfy a wide range of planned flight experiments. The primary thermal control sensors used for the heater module elements are planned to be fiber optic type optical sensors. Up to 10 sample thermocouples which are selectable for each experiment can be supported by the furnace apparatus. Two of these modular inserts for the LGF are defined below.

1) The LGF low gradient module insert will have a bore diameter of the furnace insert of 3.0 cm and can support a 2.5 cm diameter cartridge of up to approximately 24 cm in length. Sample ampoules/crucibles of up to approximately 2.0 cm in diameter and 14 cm in length can be accommodated in the furnace. The length of the hot zone is approximately 16 cm with a 10 cm isothermal region. The cold zone length is 12 cm and the passive adiabatic zone is fixed at lengths from 2.0 to 5.0 cm. The hot zone will be comprised of a guard heater, main or plateau heater, and a booster heater. The cold zone will have similar heater elements in addition to a cooling ring to radially dissipate the heat. The LGF low gradient module insert will be capable of achieving temperatures up to 1600°C. Current pulsing will be available to mark the solid/liquid interface during processing.

2) One of the future modular inserts expected to be developed for the LGF will satisfy the requirements of the previously planned Thermophysical Properties Furnace. This Bridgman-Stockbarger thermophysical properties furnace module insert will provide directional solidification capability with a thermal gradient region and also meet stringent isothermality requirements of up to approximately ±0.1°C over the full sample length, utilizing heat pipe technology. Processing temperatures up to 2000°C with thermal gradients from 10 to 100°C/cm will be attainable, along with high speed cartridge quench capability. Variable furnace translation rates will be available for sample processing scenarios to satisfy a wide range of experiment requirements in addition to a rapid quench capability. The cartridge which will house the sample ampoule/crucible will have an outside diameter up to 3.0 cm.

Current pulse amplitudes of between 5 and 60 amps, depending on the sample resistance, will be available in the LGF module inserts at pulse durations up to 4,000 msec. In addition, control capability will be provided for a motor drive system to provide precise control for shear cell experiments. Additional sample diagnostics and in situ measurements, including sample resistivity measurements and solid/liquid interface detection, are planned to be available within the furnace design. The furnace can be translated at processing rates during directional solidification between 10^{-4} mm/sec and 0.2 mm/sec and from 1 mm/sec to 50 mm/sec for rapid translation.

Module inserts as well as science samples housed in suitable cartridges can be manually replaced during on-orbit operations by the crew. Telescience capabilities are provided, including sample thermocouple and resistivity data, in addition to failure sensor data downlinked in real time to the PI team on the ground as well as being displayed on-board.

B. ISS MICROGRAVITY SCIENCE GLOVEBOX (MSG).

Planning for a larger version of the Glovebox for ISS has begun. Utilities similar to the Middeck and Mir Gloveboxes are envisioned, with a larger work area, more power, and increased data handling capability for glovebox investigations to be performed within the Glovebox. The MSG will be developed by ESA and available for use in the U.S. Laboratory Module of the ISS in late 1999.

C. EXPEDITE THE PROCESSING OF EXPERIMENTS TO SPACE STATION (EXPRESS) RACK.

The ISS Program Office has developed an extension of the Space Station accommodations for small and modular-type subrack payloads. Known as the EXPRESS Rack, it provides simple and standard interfaces for the integration of payloads, and will allow for the operation of subrack, experiment-unique materials science equipment in the ISS.

The EXPRESS Rack provides the interfaces to accommodate middeck locker payloads and Standard Interface Rack (SIR) drawer payloads. Two configurations of the EXPRESS Rack are provided: one accommodates fifteen four-panel-unit SIR drawers or multiples thereof, the other accommodates eight middeck lockers and two SIR drawers. Because of the modular accommodations, multiple payload disciplines can be accommodated and operated simultaneously in each EXPRESS Rack. Resources that may be provided to the payloads are 28V electrical power, air and liquid cooling, RS422, Ethernet, analog and discrete data interfaces, video, vacuum, and nitrogen.

The physical integration needs of payloads are reduced due to the standard and simple interfaces. In addition, a streamlined analytical integration process is under development by the ISS Operations and Utilization Office for the EXPRESS Rack users to manifest and integrate standard payloads in eleven months or less before launch.

D. ELECTROSTATIC LEVITATION FURNACE (ELF).

An Electrostatic Levitation Furnace is being developed for the Japanese Experiment Module (JEM) in the ISS, which will be operational after the year 2000. The National Space Development Agency of Japan (NASDA) has been developing the JEM and a variety of experiment facilities for the ISS. The ELF is one of the facilities for materials science research in the JEM's microgravity environment.

Containerless processing is a key technology in material science research for investigating the formation of metastable phases and nucleation phenomena and for measuring thermophysical materials properties such as heat capacity, surface tension, thermal conductivity, and viscosity of molten samples. The ELF is an experimental system required for scientific investigations in such fields under microgravity. The facility enables containerless sample processing by means of electrostatic levitation. The ELF also has heating capability, gas environment control capability, non-contact temperature measurement capability, and automated sample exchange capability.

The levitation section consists of two sample position detectors, an ultraviolet lamp, upper and lower electrodes and a position control unit. The sample in the chamber is charged by the UV lamp, and position is achieved by adjusting the balance between the sample inertia and coulomb forces generated by two electrodes. The heating section consists of a chamber, four heating lasers and their power control unit. According to the current design, four laser diodes with 0.80 µm to 0.81 µm wavelengths are employed, and a total power of 1,000 W will be applied. The four lasers are controlled independently, creating the capability for heterogeneous sample heating as well as homogeneous heating.

The ELF has a pyrometer, a thermal imaging system and a video camera to monitor the sample condition. The pyrometer will be used to measure the temperature center of the sample surface, while the thermal imaging system is for measurement of the temperature distribution of the sample. In the thermal imaging system, the thermal image of the sample is divided into pixels, and the average temperature of the pixel will be sent to the ground. A video camera will be used to observe the sample. From this image, we can understand the status of the sample, status of levitation and positioning, and status of the experiment.

The ELF for ISS is in a fundamental design phase; key technology development and overall configuration design are in progress. Concerning levitation and heating, a breadboard model has been manufactured and ground based tests have been conducted. During these tests, a YAG laser with 100 W power has been employed as a heating device. Thus far, samples of pure aluminum and zirconium, with 2 mm in diameter have been successfully levitated and melted in vacuum conditions. Functional tests in a reduced gravity have also been performed by using parabolic flights and will be conducted on a TR–1A sounding rocket.

E. SpaceDRUMS

The Canadian Space Agency is developing an acoustic levitator known as SpaceDRUMS (Dynamically Responding Ultrasonic Matrix Sonar). The facility uses 20 narrow beam transducers operating at 64kHz positioned at corners of a dodecahedron to position the sample. PID control via cameras has demonstrated the ability of the system to react to some extreme g-jitter during DC 9 flights and to levitate in a stationary position a 4 cm sample. The force necessary is of the order of mN. Static field control is also possible. Various configurations of heating are now being studied, including laser heating, a spherical furnace and mirror furnaces.

F. LOW TEMPERATURE FURNACE WITH QUENCH

A small low power furnace for temporal and spatial isothermal holding (±0.1°C typical) has been equipped for water quenching. The cartridge is constructed of aluminum with integral heaters for ease of control, good heat transfer, and rapid quenching. The Lewis Research Center (LeRC) developed furnace and controller/recorder fit into the middeck glovebox facility and are consistent with glovebox provided utilities. It could be mounted in a rack or Get Away Special (GAS) environment. Specimen volume is about 9 cc, maximum temperature is 200°C, and quench rate is approximately 30 degrees per second.

G. SURFACE LIGHT SCATTERING HARDWARE

NASA's Advanced Technology Development (ATD) program is sponsoring the development of surface light scattering hardware. This instrument is designed to non-invasively measure the surface response function of liquids over a wide rage of operating conditions while automatically compensating for gross surface movement. The surface response function can be used to compute surface tension, properties of monolayers present, viscosity, surface tension gradient, and surface temperature and its gradient. The instrument uses optical and electronic building blocks developed for the laser light scattering program at NASA LeRC along with several unique surface light scattering components and new algorithms.

H. LASER LIGHT SCATTERING HARDWARE

A versatile, miniature, modular light scattering instrument has been developed at NASA LeRC for the use in microgravity. An enhanced multi-angle Laser Light Scattering (LLS) facility is in the process of being developed. LLS can be used to measure microscopic particles in the size range of 30 angstroms to above three microns. It is a non-invasive technique which can determine particle structure, weight-average molecular weight, and particle-particle interactions. A Space Shuttle glovebox version of this instrument has been used on orbit to measure PMMA hard spheres concentrations in an index matched solution to determine the order-disorder phase boundary. This technique is also appropriate for studying protein crystal growth, spinodal decomposition, aggregation, diffusive transport, critical phenomena. etc. Design and development of flight hardware for accommodation in the EXPRESS rack on Spacelab have already been started. The hardware will be capable of making static and dynamic light scattering measurements. Specific capabilities include: Bragg diffraction and photon counting from 10 degrees to 170 degrees with 0.25 degrees resolution; small angle scattering from 0.10 degrees to 10 degrees with 0.25 degrees resolution; Bragg scattering from 10 degrees to 60 degrees; and ability for sample rotation and oscillation. Flight hardware for use on the ISS is in the planning phase.

III. GROUND-BASED FACILITIES

Investigators often need to conduct reduced gravity experiments in ground-based facilities during the experiment definition and technology development phases. The NASA ground-based reduced-gravity research facilities that support the MSAD materials science program include an array of specialized laboratory apparatus, such as laboratory equipment (i.e. furnace systems, special diagnostic tools and equipment, etc.), an evacuated drop tube at MSFC, a drop tower at LeRC, and parabolic flight research aircraft. A variety of specialized test apparatus have been constructed and used to conduct a wide range of materials science research. In general, these apparatus have been developed to accommodate specific individual investigator's requirements. In addition, other hardware and facilities have been developed which have the potential for use by investigators. Investigators should denote any additional facilities needed for their research, and such facilities, if available, can be made accessible on a limited basis.

A. 105 METER DROP TUBE.

A 105 meter long by 25 centimeter diameter drop tube located at the Marshall Space Flight Center provides 4.6 seconds of low gravity process time. The facility, primarily intended for containerless processing applications, can maintain a vacuum level of 10^{-6} torr or can be backfilled with various gases to increase cooling rates. Two heating methods are currently available: an electron-beam furnace and an electromagnetic levitator. Other heating methods are possible. Samples are viewed through ports located at eight meter intervals in the tube. The drop tube has been used for the study of undercooling, nucleation, and solidification phenomena in molten metal samples. However, the facility could also accommodate studies of semiconductor, ceramic, or glass materials.

B. 5.18 SECOND ZERO GRAVITY FACILITY.

The 5.18 second Zero-Gravity Facility has a 132 meter free fall distance in a drop chamber which is evacuated by a series of pumpdown procedures to a final pressure of 1 Pa. Experiments with hardware weighing up to 450 kilograms are mounted in a one meter diameter by 3.4 meter high drop bus. Residual acceleration of less than 10^{-5} g is obtained. At the end of the drop, the bus is decelerated in a 6.1 meter deep container filled with small pellets of expanded polystyrene. The deceleration rate is typically 60 g (for 20 milliseconds). Visual data is acquired through the use of high-speed motion picture cameras. Also, other data such as pressures, temperatures, and accelerations are either recorded on board with various data acquisition systems or are transmitted to a control room by a telemetry system capable of transmitting 18 channels of continuous data. Due to the complexity of drop chamber operations and time required for pump-down of the drop chamber, typically only one test is performed per day

C. PARABOLIC FLIGHT RESEARCH AIRCRAFT.

The aircraft can provide up to 40 periods of low gravity for 22 second intervals each during one flight. The aircraft accommodates a variety of experiments and is often used to refine spaceflight experiment equipment and techniques and to train crew members in experiment procedures, thus giving investigators and crew members valuable experience working in a low gravity environment. Qualified observers or operators may fly with their experiment packages. The aircraft obtains a low-gravity environment by flying a parabolic trajectory. Forces twice those of normal gravity occur during the initial and final portions of the trajectory, while the brief pushover at the top of the parabola produces less than one percent of Earth's gravity (10^{-2} g). The interior of the aircraft bay dimensions are approximately three meters wide and two meters high by 16 meters long. Several experiments, including a combination of attached and free-floated hardware (which can provide effective gravity levels of nominally 10^{-3} g for periods up to 10 seconds) can be integrated in a single flight. The aircraft can supply a total of 80 amps of 28 volt dc, 90 amps of 115 volt ac 60 Hz and 30 amps open each phase of 3 phase 115 volt ac 400 Hz. These are maximum powers available to all users. Instrumentation and data collection capabilities must be contained in the experiment packages.

D. LOW GRAVITY AIRCRAFT MATERIALS SCIENCE APPARATUS.

1. Automated Directional Solidification Furnace (ADSF).

This furnace is based on a prototype of the Grumman ADSF that flew sounding rocket and Space Shuttle experiments with Mn–MnBi alloys. The furnace is located in the MSFC aircraft furnace laboratory and uses a basic Bridgman furnace configuration. This apparatus has been optimized for use in parabolic flight aircraft and has been fitted with a water spray interfacial quench device. The furnace has been employed extensively for KC–135 solidification experiments on metals and semiconductors over a 10 year period. It is compatible with the DC–9 platform. Representative materials that have been investigated using this apparatus include metal alloys, plastics, superconductors, and metal matrix composites. From one to four samples, 0.5 cm in diameter and 6–15 cm in length, are processed per flight. Containment is typically alumina or quartz ampoules. Maximum operating temperature is 1500°C; temperature gradients of approximately 100°C/cm are achievable in metal alloy systems. The furnace can be translated at 0.1 to 100 cm/min. over a distance of 8 cm. The quench rate is typically 100°C/sec. Instrumentation supports acquisition of two sample temperatures, furnace temperature, cold end temperature, accelerations on three axes (mounted to furnace), and furnace position.

2. Isothermal Casting Furnace (ICF).

The ICF is designed for multidimensional solidification (bulk casting) during a single aircraft parabolic maneuver. The furnace is located in the MSFC aircraft furnace laboratory. The sample thermally soaks at a predetermined temperature for a specific length of time and is then quenched by a stream of helium gas during the low gravity period of the parabola. The furnace has been used for aircraft experiments for 10 years. Typical experiments include the testing of crucible wetting characteristics for immiscible alloys or semiconductors during solidification under low gravity conditions. Previously processed materials include iron-carbon alloys, immiscible metal alloys (e.g., aluminum-indium), and cadmium telluride. Sample dimensions are typically 0.9–1 cm in diameter by approximately 2 cm in length. The furnace operates over a range of temperatures from 100 to 1350°C. Quench rates range from 1°C/sec to 50°C/sec. Up to three sample temperatures can be recorded along with acceleration along three axes.

3. Quench Furnace With X-Ray.

The Quench Furnace with X-Ray is also available for ground-based low-gravity research at LeRC. This three zone, end chill, directional solidification furnace with a water quench can reach a maximum temperature of 700°C. It was developed to study the solidification of metal samples during low-gravity testing in research aircraft. The liquid-gas and solid-liquid interfaces are recorded using x-ray scanning and high resolution CCD camera.

E. COMPUTATIONAL CAPABILITIES.

NASA has the capability to provide the research community numerical modeling analysis (such as SINDA, HEATRAN, COSMOS, FIDAP) of material/fluid flows as influenced by thermal gradients, concentration gradients, surface tension, magnetic fields, gravitational acceleration, g-jitter and other driving forces. The emphasis is on physically based models giving quantitative flow descriptions. The facilities have commercial and specialized software operating in a workstation environment with access to mainframes.

F. LORAL ELECTROSTATIC LEVITATOR (ESL).

A new containerless electrostatic levitator research facility for materials and fluids is being established at MSFC, derived from technology developed at the Jet Propulsion Laboratory (JPL). The facility uses electrostatic forces to levitate specimens in a vacuum chamber, then a high power infrared laser heats and melts these specimens. By isolating a material from all but its radiation environment, the disturbing influences of container walls and impurities are removed. The electrostatic forces will levitate a wide variety of materials: conductors, semiconductors, and insulators.

The specimen's position is controlled using a sophisticated three-dimensional digital feedback system manipulated through an intuitive and convenient computer interface. All of the controls over the specimen's motion and heating can be handled by a single user sitting at the control terminal.

Once a specimen is levitated and melted, the ESL can apply a range of measurement techniques to measure the material's thermophysical properties, such as specific heat capacity, density, surface tension, viscosity, and optical emissivity—all as functions of temperature. At a given temperature, density is measured through analysis of a digitized silhouette image, and viscosity and surface tension are obtained from the frequency and rate of decay of shape oscillations.

G. HIGH MAGNETIC FIELD SOLIDIFICATION FACILITY

Built at MSFC, the High Magnetic Field Solidification Facility includes two 5 Tesla superconducting magnets each with a vertical, 25 cm diameter room temperature bore. The use of a strong magnetic field can suppress fluid motion, thus simulating some of the effects of low gravity. By this means some important parameters can be determined which enable better use of the valuable and limited processing time in space. Resistance heated tubular furnaces capable of temperatures to 1200°C with bore diameters up to 2.5 cm are available and include thermal control and translation mechanisms. With appropriate inserts, the thermal environment of flight furnaces such as CGF and AADSF can be closely approximated. During FY96, ground based studies for two flight experiments, plus 2 other funded ground based studies have used the furnace. Prospective PI-specific modules would be considered for adaptation for this facility.

H. MAGNETIC DAMPING FURNACE.

A prototype ground-based Magnetic Damping Furnace is expected to be a directional solidification Bridgman-Stockbarger furnace with or without magnetic damping. The major design characteristics of this device will include the application of a 0–0.2 Tesla magnetic field over the melt/solidification process if desired. The three zone furnace will operate at temperatures from 200 to 1175°C in the hot zone, 200–1200°C in the booster zone, and 150–950°C in the cold zone. A variable gradient zone of 0.5–5 cm length with a thermal gradient of up to 70°C/cm and an isothermality of ±0.1% is planned. The translating furnace will be capable of processing a sample from 12 to 20 cm in length with a diameter of up to 1.5 cm.

I. STEREO IMAGING VELOCIMETRY (SIV).

A system of hardware and software has been designed to allow acquisition of three-dimensional vectors describing flow simultaneously throughout an experimental volume. Used for ground-based and flight experiments, the quantitative results may be compared directly with numerical or analytical predictions of flow velocities. The system requires a transparent fluid seeded with particles large enough to be viewed as a full pixel on a video screen. Two synchronized orthogonal views provide the raw data. While generally used with light, the algorithms for velocity vectors could also be used with x-ray images of suspended particles. The SIV system has worked for sample volumes between eight cc's and two cubic meters. For experiments planned for the ISS, the Fluids and Combustion Facility will contain orthogonal video cameras which can record the data required for three-dimensional velocity analysis.

J. X-RAY MICROSCOPE

This instrument is designed to view in situ solidification of thin, light samples with high resolution. The technique uses direct x-ray projection from a point source. The divergent beam passes through the sample. With a furnace permitting solidification to within a few mm of the x-ray source, in situ interfaces can be visualized at a resolution of 30 µm.

K. SPREADING RESISTANCE MEASUREMENT

A Solid State Measurements model 150 spreading resistance apparatus is available at MSFC. To use this instrument an investigator is expected to provide his/her own set of measurement probes.

L. CONTRACTED FACILITIES

Other facilities available include the use of the National Synchrotron Light Source (NSLS) Synchrotron facility at Brookhaven National Labs and the use of the triple axis x-ray diffractometer at the University of Wisconsin – Madison. These two facilities are under contract to support NASA PIs through FY1999. For projects requiring such services beyond this date, PIs should include separate line items to cover the availability of these facilities.

1. NSLS Source

The use of the X–19C beam line at Brookhaven is available through a grant to Prof. Michael Dudley of University of New York at Stony Brook to examine NASA samples. This facility uses white beam radiation and can provide x-ray topographies in both reflection and transmission.

2. Triple Axis Diffractometry

Under the same grant, Prof. Richard Matyi of the University of Wisconsin – Madison is contracted to examine NASA single crystal material. This work is done in close conjunction with the white beam x-ray topography and has proven to be a unique combination of facilities for quantifying the perfection of crystals.

ACRONYM LISTING

AADSF ADVANCED AUTOMATED DIRECTIONAL SOLIDIFICATION FURNACE
ADSF AUTOMATED DIRECTIONAL SOLIDIFICATION FURNACE
AGHF ADVANCED GRADIENT HEATING FURNACE
ATD ADVANCED TECHNOLOGY DEVELOPMENT
CCD CHARGE COUPLED DEVICE
CGF CRYSTAL GROWTH FURNACE
ELF ELECTROSTATIC LEVITATION FURNACE
ESA EUROPEAN SPACE AGENCY
ESL ELECTROSTATIC LEVITATOR
EXPRESS EXPEDITE THE PROCESSING OF EXPERIMENTS TO SPACE STATION (Rack)
HGFQ HIGH GRADIENT FURNACE WITH QUENCH
ICF ISOTHERMAL CASTING FURNACE
IFEA INTEGRATED FURNACE EXPERIMENT ASSEMBLY
ISS INTERNATIONAL SPACE STATION
JEM JAPANESE EXPERIMENT MODULE
JPL JET PROPULSION LABORATORY
LeRC LEWIS RESEARCH CENTER
LLS LASER LIGHT SCATTERING
LMS LIFE AND MICROGRAVITY SCIENCE (Spacelab Mission)
MEPHISTO MATERIAL POUR L'ETUDE DES PHENOMENES INTERESSANT LA SOLIDIFICATION SUR TERRE ET EN ORBITE
MGBX MIDDECK GLOVEBOX
MirGBX MIR GLOVEBOX
MITH MILLIKELVIN THERMOSTAT
MSAD MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION
MSFC MARSHALL SPACE FLIGHT CENTER
MSG MICROGRAVITY SCIENCE GLOVEBOX
NASA NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NASDA NATIONAL SPACE DEVELOPMENT AGENCY (of Japan)
NRA NASA RESEARCH ANNOUNCEMENT
NSLS NATIONAL SYNCHROTRON LIGHT SOURCE
PI PRINCIPAL INVESTIGATOR
PVA PIVALIC ACID
SCN SUCCINONITRILE
SCR SCIENCE CERTIFICATION REVIEW
SIR STANDARD INTERFACE RACK
SIV STEREO IMAGING VELOCIMETRY
SSFF SPACE STATION FURNACE FACILITY
STABLE SUPPRESSION OF TRANSIENT ACCELERATION BY LEVITATION
USML UNITED STATES MICROGRAVITY LABORATORY
USMP UNITED STATES MICROGRAVITY PAYLOAD

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS FOR SOLICITED RESEARCH PROPOSALS

(August 1988)

1. FOREWORD

a. NASA depends upon industry, educational institutions, and other nonprofit organizations for most of its research efforts. While a number of mechanisms have been developed over the years to inform the research community of those areas in which NASA has special research interests, these instructions apply only to "NASA Research Announcements," a form of "broad agency announcement" described in 6.102(d)(2) and 35.016 of the Federal Acquisition Regulation (FAR). The "NASA Research Announcement (NRA)" permits competitive selection of research projects in accordance with statute while at the same time preserving the traditional concepts and understandings associated with NASA sponsorship of research.

b. These instructions are Appendix I to 18-70.203 of the NASA Federal Acquisition Regulation Supplement.

2. POLICY

a. NASA fosters and encourages the submission of research proposals relevant to agency mission requirements by solicitations, "NASA Research Announcements," which describe research areas of interest to NASA. Proposals received in response to an NRA will be used only for evaluation purposes.

b. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published for individual proposals.

c. A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act.

3. PURPOSE

These instructions are intended to supplement documents identified as "NASA Research Announcements." The NRA's contain programmatic information and certain "NRA-specific" requirements that apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRA's.

4. RELATIONSHIP TO AWARD

a. A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded on the basis of a proposal submitted in response to an NRA. NASA does not have separate "grant proposal" and "contract proposal" categories, so all proposals may be prepared in a similar fashion. NASA will determine the appropriate instrument.

b. Grants are generally used to fund basic research in educational and nonprofit institutions, while research in other private sector organizations is accomplished under contract. Additional information peculiar to the contractual process (certifications, cost and pricing data, facilities information, etc.) will be requested, as necessary, as the procurement progresses. Contracts resulting from NRA's are subject to the Federal Acquisition Regulation and the NASA FAR Supplement (NHB 5100.4). Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NHB 5800. 1).

5. CONFORMANCE TO GUIDANCE

a. NASA does not have any mandatory forms or formats for preparation of responses to NRA's; however, it is requested that proposals conform to the procedural and submission guidelines covered in these instructions. In particular, NASA may accept proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

b. In order to be considered responsive to the solicitation, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation. NASA reserves the right to reject any or all proposals received in response to an NRA when such action is considered in the best interest of the Government.

6. NRA-SPECIFIC ITEMS

a. Several proposal submission items will appear in the NRA itself. These include: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information.

b. Items included in these instructions may be supplemented by the NRA, as circumstances warrant. Examples are: technical points for special emphasis; additional evaluation factors; and proposal length.

7. PROPOSAL CONTENTS

a. The following general information is needed in all proposals in order to permit consideration in an objective manner. NRA's will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

b. Transmittal Letter or Prefatory Material

(1) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(2) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(3) Type of organization e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(4) Name and telephone number of the principal investigator and business personnel who may be contacted during evaluation or negotiation;

(5) Identification of any other organizations that are currently evaluating a proposal for the same efforts;

(6) Identification of the specific NRA, by number and title, to which the proposal is responding;

(7) Dollar amount requested of NASA, desired starting date, and duration of project;

(8) Date of submission; and

9) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

c. **Restriction on Use and Disclosure of Proposal Information**

It is NASA policy to use information contained in proposals for evaluation purposes only. While this policy does not require that the proposal bear a restrictive notice, offerers or quoters should, in order to maximize protection of trade secrets or other information that is commercial or financial and confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting appropriate identification, such as page numbers, in the notice. In any event, information (data) 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 offerer, 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.

d. **Abstract**

Include a concise (200-300 word, if not otherwise specified in the NRA) abstract describing the objective of the proposed effort and the method of approach.

e. **Project Description**

(1) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge in the field; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the general plan of work, including the broad design of experiments to be undertaken and an adequate description of experimental methods and procedures. The project description should be prepared in a manner that addresses the evaluation factors in these instructions and any additional specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Note, however, that subcontracting significant portions of a research project is discouraged.

(2) When it is expected that the effort will require more than one year for completion, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should, of course, 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.

f. **Management Approach**

For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and any necessary arrangements for ensuring a coordinated effort should be described. Aspects of any required intensive working relations with NASA field centers that are not logical inclusions elsewhere in the proposal should be described in this section.

g. **Personnel**

The principal investigator is responsible for direct supervision of the work and participates in the conduct of the research regardless of whether or not compensation is received under the award. A short biographical sketch of the principal investigator, a list of principal publications and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities 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.

h. **Facilities and Equipment**

(1) 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 on the project.

(2) 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 to purchase. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for both research and non-research purposes should be explained.

i. **Proposed Costs**

(1) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., principal investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all manpower data in terms of man-months or fractions of full-time.

(2) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self-evident. List estimated expenses as yearly requirements by major work phases. (Standard Form 1411 may be used).

(3) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 18-31 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).

j. **Security**

Proposals should not contain security classified material. However, if the proposed research requires access to or may generate security classified information, the submitter will be required to comply with applicable Government security regulations.

For other current projects being conducted by the principal investigator, provide title of project, sponsoring agency, and ending date.

k. **Special Matters**

(1) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

(2) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

8. RENEWAL PROPOSALS

a. Renewal proposals for existing awards will be considered in the same manner as proposals for new endeavors. It is not necessary that a renewal proposal repeat all of the information that was in the original proposal upon which the current support was based. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the proposal are expected to be covered during the period for which extended support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

b. NASA reserves the right to renew an effort either through amendment of an existing contract or by a new award.

9. LENGTH

Unless otherwise specified in the NRA, every effort should be made to keep proposals as brief as possible, concentrating on substantive material essential for a complete understanding of the project. Experience shows that few proposals need exceed 15-20 pages. Any necessary detailed information, such as reprints, should be included as attachments rather than in the main body of the proposal. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of "one-of-a-kind" attachments: their availability may be mentioned in the proposal.

10. JOINT PROPOSALS

a. Some projects involve joint efforts among individuals in different organizations or mutual efforts of more than one organization. Where multiple organizations are involved, the proposal may be submitted by only one of them. In this event, 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 would be made.

b. Where a project of a cooperative nature with NASA is contemplated, the proposal should describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. However, the proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which purport to specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

11. LATE PROPOSALS

A proposal or modification thereto received after the date or dates specified in an NRA may still be considered if the selecting official deems it to offer NASA a significant technical advantage or cost reduction.

12. WITHDRAWAL

Proposals may be withdrawn by the proposer at any time. Offerers are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

13. EVALUATION FACTORS

a. Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's objectives, intrinsic merit, and cost.
b. Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

c. Evaluation of its intrinsic merit includes the consideration of the following factors, none of which is more important than any other:

(1) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(2) The offerers capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(3) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel who are critical in achieving the proposal objectives.

(4) Overall standing among similar proposals available for evaluation and/or evaluation against the known state-of-the-art.

d. Evaluation of the cost of a proposed effort includes the consideration of the realism and reasonableness of the proposed cost and the relationship of the proposed cost to available funds.

14. EVALUATION TECHNIQUES

Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases, however, proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house where NASA has particular competence; others are evaluated by a combination of in-house people and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of-interest and protection of proposal information), such as by mail or through assembled panels. Regardless of the technique, the final decisions are always made by a designated NASA selecting official. A proposal which is scientifically and programmatically meritorious, but which is not selected for award during its initial review under the NRA may be included in subsequent reviews unless the proposer requests otherwise.

15.SELECTION FOR AWARD

a. When a proposal is not selected for award, and the proposer has indicated that the proposal is not to be held over for subsequent reviews, the proposer will be notified that the proposal was not selected for award. NASA will notify the proposer and explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a debriefing.

b. When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation with the submitter. Formal RFP’s are not used to obtain additional information on a proposal selected under the NRA process.

However, the contracting officer may request certain business data and may forward a model contract and other information which will be of use during the contract negotiation.

16. CANCELLATION OF NRA

NASA reserves the right to make no awards under this NRA and, in the absence of program funding or for any other reason, to cancel this NRA by having a notice published in the Commerce Business Daily. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation. Cancellation may be followed by issuance and synopsis of a revised NRA, since amendment of an NRA is normally not permitted.

NASA RESEARCH ANNOUNCEMENT (NRA) SCHEDULE

MICROGRAVITY MATERIALS SCIENCE: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

All proposals submitted in response to this Announcement are due on the date and at the address given below by the close of business (4:30 PM EST). NASA reserves the right to consider proposals received after this deadline if such action is judged to be in the interest of the U.S. Government. A complete schedule of the review of the proposals is given below:

NRA Release Date: ....DECEMBER 4, 1996

Letter of Intent Due: ....JANUARY 24, 1997

Proposal Due: .... MARCH 11, 1997

Submit Proposal to:

Dr. Michael J. Wargo
NASA c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-02)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA cannot receive proposals on Saturdays, Sundays or Federal holidays.

Final Selections: .... October 1997

Funding commences: .... November 1997
(dependent upon procurement process)

ATTACHMENT

This attachment is not part of the preceding NASA Research Announcement (NRA). It is a notification that opportunities exist for proposals which predominantly feature applied commercial research and must have an industrial cost sharing partner.

Office of Life and Microgravity Sciences and Applications
Space Processing and Commercialization Division

Notice of Areas of Interest for
Materials Applied Research for the Commercial Development of Space Program

In July of 1994, the NASA Administrator signed the Agenda for Change which challenges NASA to change the way it conducts business and emphasizes the importance of the Commercial Technology Mission. As a result, the Space Processing and Commercialization Division of the **Office of Life and Microgravity Sciences and Applications** (OLMSA) encourages proposers to address objectives in commercial research. NASA seeks and encourages, to the maximum extent possible, the fullest commercial use of space. The OLMSA Space Processing program focuses on the use of space for developing commercial processes, products and / or services by industry with the goals of (1) Fostering the development of new processes, products and services using the attributes of space and space technology, (2) Increasing U.S. business participation in space enterprise, (3) Providing the opportunity for students to engage with industry in space program activities, and (4) Facilitating mutually beneficial international partnerships with industry to expand commercial use of space.

Submission and Scope of Proposal

Proposals selected in response to this announcement benefit from; (a) the expertise and support of the NASA Centers for Space Commercialization (CSC), and of NASA, (b) the fact that NASA, to foster these developmental, high risk activities, does not charge for transportation to space unless a profit is expected, and (c) the participants may retain certain proprietary rights.

The space processing program uses industry requirements as the basis for commercial technology development, prototyping, and demonstration. Proposals must be submitted to an appropriate Center for Space Commercialization. Proposals submitted for unspecified hardware or general support facilities should apply to the CSC with the appropriate area of expertise as identified in the following list. **Please note that hardware and facility availability is subject to negotiation through the CSC.**

Space Vacuum Epitaxy Center

Areas: Advanced thin film materials and devices for commercial application through vacuum growth technologies using terrestrial and space vacuum environments

Space Vacuum Epitaxy Center
University of Houston
Houston, TX 77204-5507
Director: Dr. Alex Ignatiev
(713) 743-3621
(713) 747-7724 (FAX)

Center for Commercial Development of Space Power and Advanced Electronics
Areas: Casting and solidification technologies, Thermal Physical Properties measurements in microgravity environments

Center for Commercial Development of Space Power and Advanced Electronics
Auburn University
Space Power Institute
231 Leach Center
Auburn, AL 36849-5320
Point of Contact: Dr. Ruel A. Overfelt
(344) 844-5940
(344) 844-5900 (FAX)

Space Product Development Office (FA21)
Areas: Use of NASA sponsored furnaces and equipment in space research for commercial applications. Two specific uses include: (1) samples to run in the Extreme Temperature Translation Furnace under vacuum in microgravity up to temperatures to 1600°C (2) superconducting materials samples for determining Tc and Jc values over time in a space environment. Other NASA sponsored equipment includes Physical Vapor Transport and Float Zone single crystal growth apparatus for use in microgravity.

Space Product Development Office (FA21)
Marshall Space Flight Center
Huntsville, AL 35812
Point of Contact: J.R. Watkins
(205) 544-0645
(205) 544-5892 (FAX)

Consortium for Materials Development in Space
Areas: Metal Sintering, Metal Electrodeposition, Non-Linear Optical Materials, Polymer Foams, Atomic Oxygen, Space Experiment Furnace, Accelerometers, Implant Technology Electrodeposition, Materials Dispersions, Organic Separations, superconductivity

Consortium for Materials Development in Space
University of Alabama - Huntsville
Research Institute Building / M-65
301 Sparkman Drive
Huntsville, AL 35899
Director: Dr. Charles Lundquist
(205) 895-6620
(205) 895-6791 (FAX)

Proposals should be submitted to one of the four Centers for Space Commercialization (CSC) listed above. Proposal submission is limited to only one CSC. The CSC's were established in 1985 and are consortia of government, academia, and industry conducting space-related research with commercial potential. NASA provides access to space and contributes to the organizational costs of each CSC. The CSC's secure additional funding through partnerships with industrial affiliates. The CSC's can also assist the private sector with insights as to the benefits of applying space-based knowledge or capabilities to the solution of problems, the acquisition of new data and techniques, the development of new capabilities, and the means of accomplishing spaceflight activities. These are all aimed towards exploiting the characteristics of space flight for the development of new commercially viable products, processes, industries, and markets.

These proposals must include the envisioned product developed using the research results, the projected market for the product research, and the private sector resources committed for the research effort. Areas of focus are those areas in the field of Materials Science which correspond to the areas of expertise of individual CSC's. Flight hardware capability should be used by researchers for consideration for part of proposal generation. However, proposers may also submit hardware they have developed as part of the proposal. General questions regarding proposals should be addressed to the appropriate CSC.

Selection Criterion

Evaluation will be conducted by and selections made by CSC's. Since the goal of the Space Processing Program is to foster the use of space for commercial products and services, support for research activity depends upon the envisioned product and its commercial potential and impact. In order to be selected through the appropriate CSC, each product must meet the following five criteria:

First Criterion: Technical assessment
- The need for space flight is clearly defined and justified
- The technical approach is feasible and supports development of the product

Second Criterion: Business plan
- A non-U.S. Government market is defined and of sufficient size
- There is evidence that the proposed process or product better meets the target market
- There is a commercial affiliate(s) to provide evidence of necessary resources, capability, planning, and experience to bring the product to market
- The proposed space activity is essential to product development and is consistent with business planning
- A roadmap exists that includes the essential activities to bring the product to market beyond the space development activities
- Significant private resources (financial and in-kind) are at risk

Third Criterion: Space Access
- The required flight opportunities exist and can accommodate stated research
- The space research requirements are consistent with potential product benefits

Fourth Criterion: Funding Adequacy
- Funding requirements are identified and justified
- The commercial affiliate provides evidence of funding commitment for the research program
- Government funding is available and consistent with required commitment

Fifth Criterion: International Collaborators
- An agreement exists which clearly demonstrates the benefit of the activity to the U.S. taxpayer

Proposal Outline

To facilitate coordination and review, the following is the suggested outline for proposal submission. It is requested that the proposals contain this information and in the format shown below:

- Title Page
- Table of Contents
- One Page White Paper Overview including:
  - Concept
  - Objectives
  - Approach (including space flight requirements)
  - Hardware (development or usage)
- Executive Summary
- Commercial Product Description
- Justification (see criteria)
  - Technical Assessment
  - Business Plan
  - Space Access
  - Funding Adequacy

The proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11 inch paper with a 10- or 12-point font.

Five copies of the proposal must be received by the appropriate CSC by March 3, 1997, to assure full consideration. Proposal submission is limited to only one CSC per proposal.

Proposal Evaluation

The initial proposal assessment is based on technical assessment / business plan merit, compliance with the selection criteria, fit with ongoing programs, potential availability of hardware, funds, and flight opportunities. This assessment will provide the basis for any future discussions or negotiations between the proposer and the CSC. Please note that, after discussion with the proposer, a CSC may reject the proposal or take other actions including suggesting referral to another CSC.

It should be noted that industrial participants are cost sharing partners and support all phases of the process from developing initial requirements to implementation of final results. It should further be noted that increased funding will not necessarily be available for the CSC as a result of a collaboration associated with this NASA Notice. However, the degree and amount of proposed investment, in addition to the suitability of the content of the proposal, could generate interest in the revaluation of programs and priorities. It is to be understood that all selected proposals are to be negotiated directly between the proposers and CSC.

FORM A

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF LIFE & MICROGRAVITY SCIENCES & APPLICATIONS
MICROGRAVITY SCIENCES AND APPLICATIONS DIVISION

SOLICITED PROPOSAL APPLICATION
PLEASE FOLLOW INSTRUCTIONS CAREFULLY

LEAVE BLANK
NUMBER
REVIEW GROUP
DATE RECEIVED

1. COMPLETE TITLE OF PROJECT

2. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR *(First, middle, and last name; degrees; position title)*

3. COMPLETE MAILING ADDRESS
Internal Mail Code or Location
Office or Organization Division
Agency/Center, Company, or Institution
Street or P.O. Box
City, State, Zip Code

4. TELEPHONE NUMBER *(area code, number, extension)*
FAX NUMBER
E-MAIL ADDRESS

5. CONGRESSIONAL DISTRICT

6. SOCIAL SECURITY #

7. IS THIS PROPOSAL ☐ NEW ☐ RENEWAL ☐ REVISED

8. HAS THIS PROPOSAL (OR SIMILAR REQUEST) BEEN SUBMITTED TO NASA OR ANY OTHER AGENCY?
☐ No ☐ Yes IF YES, SPECIFY AGENCY AND YEAR SUBMITTED:

9. CO-INVESTIGATORS *(First, middle, and last name; degrees)*

10. CO-INVESTIGATOR'S ORGANIZATION

11. DATES OF ENTIRE PROPOSED PROJECT PERIOD
From:
Through:

12. COSTS REQUESTED FOR FIRST 12-MONTH BUDGET PERIOD
12a. Direct Costs $
12b. Total Costs $

13. COSTS REQUESTED FOR ENTIRE PROPOSED PROJECT PERIOD
13a. Direct Costs $
13b. Total Costs $

14. APPLICANT ORGANIZATION *(Organization Name)*

15. TYPE OF ORGANIZATION
☐ Non Profit ☐ For Profit *(General)* ☐ For Profit *(Small Business)* ☐ Public, Specify: ☐ Federal ☐ State ☐ Local

16. ORGANIZATION OFFICIAL TO BE NOTIFIED IF AN AWARD IS MADE *(Name, title, address and telephone number)*

17. OFFICIAL SIGNING FOR APPLICANTORGANIZATION *(Name, title, and telephone number)*

18. PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR ASSURANCE: I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if a grant is awarded as a result of this application. Willful provision of false information is a criminal offense (U.S. Code, Title 18, Section 1001).

SIGNATURE OF PERSON NAMED IN 2
(In ink "Per" signature not acceptable.)

DATE

19. CERTIFICATION AND ACCEPTANCE: I certify that the statements herein are true and complete to the best of my knowledge, and accept the obligation to comply with NASA terms and conditions if a grant is awarded as the result of this application. A willfully false certification is a criminal offense (U.S. Code, Title 18, Section 1001).

SIGNATURE OF PERSON NAMED IN 17
(In ink "Per" signature not acceptable.)

DATE

FORM B

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR: ______________________

DETAILED BUDGET FOR 12-MONTH BUDGET PERIOD DIRECT COSTS ONLY		FROM		THROUGH	
Duplicate this form for each year of grant support requested		DOLLAR AMOUNT REQUESTS *(Omit cents)*			
PERSONNEL *(Applicant Organization Only)*					
NAME	**ROLE IN PROJECT**	**EFFORT ON PROJECT**	**SALARY**	**FRINGE BENEFITS**	**TOTALS**
	Principal Investigator				
	SUBTOTALS →				

CONSULTANT COSTS		
EQUIPMENT *(Itemize, use additional sheet if needed)*		
SUPPLIES *(Itemize by category, use additional sheet if needed)*		
TRAVEL	DOMESTIC	
	FOREIGN	
OTHER EXPENSES *(Itemize by category, use additional sheet if needed)*		

TOTAL DIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD*(Item 12a, Form A)*	**$**
INDIRECT COSTS FOR FIRST 12-MONTH BUDGET PERIOD	**$**
TOTAL COSTS FOR FIRST 12-MONTH BUDGET PERIOD*(Item 12b, Form A)*	**$**

FORM C

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR: ____________________

BUDGET FOR ENTIRE PROJECT PERIOD DIRECT COSTS ONLY

BUDGET CATEGORY TOTALS		1st BUDGET PERIOD	ADDITIONAL YEARS OF SUPPORT REQUESTED		
			2nd	3rd	4th
PERSONNEL(Salary and Fringe Benefits) (Applicant organization only)					
CONSULTANT COSTS					
EQUIPMENT					
SUPPLIES					
TRAVEL	DOMESTIC				
	FOREIGN				
OTHER EXPENSES					
TOTAL DIRECT COSTS FOR EACH BUDGET PERIOD		**$**	**$**	**$**	**$**
TOTAL INDIRECT COSTS FOR EACH BUDGET PERIOD		**$**	**$**	**$**	**$**
TOTAL DIRECT + INDIRECT COSTS FOR EACH PERIOD		**$**	**$**	**$**	**$**
TOTAL DIRECT + INDIRECT COSTS FOR ENTIRE PROJECT					**$**

JUSTIFICATION FOR UNUSUAL EXPENSES (Detail Justification in Cost Section of Proposal)

FORM D

CERTIFICATION REGARDING DRUG-FREE WORKPLACE REQUIREMENTS

This certification is required by the regulations implementing the Drug-Free Workplace Act of 1988, 34 CFR Part 85, Subpart F. The regulations, published in the January 31, 1989 Federal Register, require certification by grantees, prior to award, that they will maintain a drug-free workplace. The certification set out below is a material representation of fact upon which reliance will be placed when the agency determines to award the grant. False certification or violation of the certification shall be grounds for suspension of payments, suspension or termination of grants, or government-wide suspension or debarment (see 34 CFR Part 85, Sections 85.615 and 85.620).

I. GRANTEES OTHER THAN INDIVIDUALS

A. The grantee certifies that it will provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing a drug-free awareness program to inform employees about --

(1)The dangers of drug abuse in the workplace;

(2)The grantees policy of maintaining a drug-free workplace;

(3)Any available drug counseling, rehabilitation, and employee assistance programs; and

(4)The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace;

(c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);

(d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will --

(1)Abide by the terms of the statement; and

(2)Notify the employer of any criminal drug statute conviction for a violation occurring in the workplace no later than five days after such conviction;

(e) Notifying the agency within ten days after receiving notice under subparagraph (d) (2) from an employee or otherwise receiving actual notice of such conviction;

(f) Taking one of the following actions, within 30 days of receiving notice under subparagraph (d) (2), with respect to any employee who is so convicted --

(1)Taking appropriate personnel action against such an employee, up to and including termination; or

(2)Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or Local health, Law enforcement, or other appropriate agency;

(g)Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraphs (a), (b), (c), (d), (e), and (f).

B. The grantee shall insert in the space provided below the site(s) for the performance or work done in connection with the specific grant: Place of Performance (Street address, city, county, state, zip code)

____

____

Check ____ if there are workplaces on file that are not identified here.

II. GRANTEES WHO ARE INDIVIDUALS

The grantee certifies that, as a condition of the grant, he or she will not engage in the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance in conducting any activity with the grant.

____

Organization Name AO or NRA Number and Title

____

Printed Name and Title of Authorized Representative

____

Signature Date

____

Printed Principal Investigator Name Proposal Title

FORM E

CERTIFICATION REGARDING
DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS
PRIMARY COVERED TRANSACTIONS

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participants' responsibilities. The regulations were published as Part VII of the May 28, 1988 Federal Register (pages 19160-19211). Copies of the regulations may be obtained by contacting the U.S. Department of Education, Grants and Contracts Service, 400 Maryland Avenue, S.W. (Room 3633 GSA Regional Office Building No. 3), Washington, D.C. 20202-4725, telephone (202) 732-2505.

A. The applicant certifies that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;
(b) Have not within a three-year period preceding this application been convicted or had a civil judgement rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or Local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;
(c) Are not presently indicted for or otherwise criminally or civilly charged by a government entity (Federal, State, or Local) with commission of any of the offenses enumerated in paragraph A.(b) of this certification; and
(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or Local) terminated for cause or default; and

B. Where the applicant is unable to certify to any of the statements in this certification, he or she shall attach an explanation to this application.

C. Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lowered Tier Covered Transactions (Subgrants or Subcontracts)

(a) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principles is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department of agency.
(b) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

____
Organization Name AO or NRA Number and Title

____
Printed Name and Title of Authorized Representative

____
Signature Date

____
Printed Principal Investigator Name Proposal Title

FORM F

CERTIFICATION REGARDING LOBBYING

As required by S 1352 Title 31 of the U.S. Code for persons entering into a grant or cooperative agreement over $100,000, the applicant certifies that:

(a) No Federal appropriated funds have been paid or will be paid by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, in connection with making of any Federal grant, the entering into of any cooperative, and the extension, continuation, renewal, amendment, or modification of any Federal grant or cooperative agreement;

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting an officer or employee of any agency, Member of Congress, an or an employee of a Member of Congress in connection with this Federal grant or cooperative agreement, the undersigned shall complete Standard Form - LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subgrants, contracts under grants and cooperative agreements, and subcontracts), and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by S1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

____
Organization Name AO or NRA Number and name

____
Printed Name and Title of Authorized Representative

____
Signature Date

____
Printed Principal Investigator Name Proposal Title

NASA Research Announcement (NRA) Mailing List Update

This is the form to update information for the NASA Office of Life & Microgravity Sciences & Applications (OLMSA) NRA mailing list. Please fill out ***CONTACT INFORMATION*** *<u>completely</u>. Check <u>only</u> those that apply in* ***INSTITUTION TYPE*** *and* ***PROGRAM AREAS/DISCIPLINES****.* ***Fold the form, secure with tape (do not staple), and mail it back to the address on the reverse side. Proper postage must be applied.***

[illegible] electronically via E-Mail or World Wide Web to the following addresses:

Check one:

- ☐ 1. Please **add** my name to the mailing list.
- ☐ 2. Please **remove** my name from the mailing list (please attach mailing label).
- ☐ 3. Please **change** my current listing (please attach mailing label).
- ☐ 4. Please leave my current listing **unchanged** (please attach mailing label).

Contact Information

If your address has changed or your mailing label is incorrect, please provide COMPLETE contact information.

Prefix: (Mr., Mrs., Ms., Dr., Prof., etc.) ______ **Suffix: (M.D., Ph.D., Jr., III, etc.)** ______

Name, First: ______ **Last:** ______

Position Title: ______

Mail Code, Loc: ______

Office, Dept, Div: ______

______

Univ/Agency/Ctr, ______

______

Street or PO Box: ______

City: ______ **State:** ______

Zip Code: ______ **Country:** ______

Telephone No: ______ **Fax No:** ______

Internet/E-Mail: ______

Institution Type

(check all that apply)

- ☐ 1. College or University
- ☐ 2. Minority College or University
- ☐ 3. Minority Business
- ☐ 4. NASA Center
- ☐ 5. Other Government Agency
- ☐ 6. Nonprofit Corporation
- ☐ 7. Small Business
- ☐ 8. Private Industry
- ☐ 9. Foreign Addressee

Program Areas/Disciplines

(check main area of interest)

- ☐ **1. Life Sciences**
  - ☐ A. Advanced Life Support
  - ☐ B. Advanced Technology Development
  - ☐ C. Data Analysis
  - ☐ D. Environmental Health
  - ☐ E. Space Biology
  - ☐ F. Space Human Factors
  - ☐ G. Space Physiology & Countermeasures
  - ☐ H. Space Radiation Health
- ☐ **2. Microgravity Sciences**
  - ☐ A. Biotechnology
  - ☐ B. Combustion Science
  - ☐ C. Fluid Physics
  - ☐ D. Fundamental Physics
  - ☐ E. Materials Science

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