NASA
National Aeronautics and
Space Administration

December 3, 1996

NRA-96-HEDS-01

RESEARCH ANNOUNCEMENT

Microgravity Fluid Physics: Research and Flight Experiment Opportunities

Letters of Intent Due: ... February 18, 1997

Proposals Due: .... March 18, 1997

OMB Approval No. 2700-0042

MICROGRAVITY FLUID PHYSICS: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

NASA Research Announcement
Soliciting Research Proposals
for the Period Ending
March 18, 1997

NRA-96-HEDS-01
Issued: December 3, 1996

Office of Life and Microgravity Sciences and Applications
Human Exploration and Development of Space (HEDS) Enterprise
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

NASA RESEARCH ANNOUNCEMENT
MICROGRAVITY FLUID PHYSICS:
RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

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NASA RESEARCH ANNOUNCEMENT

MICROGRAVITY FLUID PHYSICS: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

This NASA Research Announcement (NRA) solicits proposals for flight experiments and for ground-based experimental and theoretical microgravity research in fluid physics. The fluid physics discipline represents a broad range of research areas ranging from heat and mass transfer to condensed matter physics. Descriptions of fluid physics research activities and interests are given in Appendix A.

Investigations selected for flight experiment definition must successfully complete a number of subsequent development steps, including NASA and peer reviews of the proposed flight experiment, in order to be considered for a flight assignment. NASA does not guarantee that any investigation selected for definition will advance to flight experiment status. Proposals are sought for a number of upcoming flight opportunities. Investigations selected for support as ground-based research under the Microgravity Science and Applications Division (MSAD) Research and Analysis (R&A) Program generally must propose again to a future solicitation in order to be selected for a flight opportunity.

Participation is open to U.S. and non-U.S. investigators and to all categories of organizations: industry, educational institutions, other nonprofit organizations, NASA centers, and other U.S. Government agencies. **Though NASA welcomes proposals from non-U.S. investigators, NASA does not fund Principal Investigators at non-U.S. institutions.** Proposals may be submitted at any time during the period ending March 18, 1997. Proposals will be evaluated by science peer reviews and engineering feasibility reviews. Late proposals will be considered if it is in the best interest of the Government. 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 the preparation of proposals solicited by an NRA.

This announcement will not comprise the only invitation to submit a proposal to NASA for access to the reduced-gravity environment and is part of a planned sequence of solicitations inviting proposals in the disciplines of the microgravity program.

NASA Research Announcement Identifier: NRA-96-HEDS-01
Letters of Intent Due: February 18, 1997, Proposals Due: March 18, 1997

This NRA is available electronically and Letters of Intent can be submitted electronically via the Microgravity Science and Applications Division Web Page at:

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

Alternatively, 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 below.

Submit Proposals to the following address:

Alexander D. Pline
c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-01)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA can not receive deliveries 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 orginal 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-13, Section VII) must be forwarded to:

Ms. Ruth Rosario
ref: NRA-96-HEDS-01
Space Flight Division
Code IH
National Aeronautics and Space Administration
Washington, DC 20546-0001
USA

Proposers will be mailed a postcard confirming receipt of proposal approximately 10 working days after the proposal due date.

Obtain programmatic information about this NRA from:

Alexander D. Pline
Enterprise Scientist for Fluid Physics
Code UG
National Aeronautics and Space Administration
Washington DC 20546-0001
(202) 358-0820
apline@hq.nasa.gov

Obtain additional reference information at the following address:

Dr. Nancy J. Shaw
MS 500-102
Microgravity Science Division
Lewis Research Center
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(216) 433-3285

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-01

TECHNICAL DESCRIPTION

MICROGRAVITY FLUID PHYSICS: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

I. INTRODUCTION

A. BACKGROUND

The Human Exploration and Development of Space (HEDS) Enterprise, one of five National Aeronautics and Space Administration (NASA) strategic enterprises, conducts a program of basic and applied research using the reduced-gravity environment to improve the understanding of fundamental physical, chemical, and biological processes. The scope of the program, sponsored by the Microgravity Science and Applications Division (MSAD), ranges from applied research into the effects of low gravity on the processing of various materials, to basic research that uses low gravity to create test conditions to probe the fundamental behavior of matter. This announcement is part of an ongoing effort to develop research in a specific scientific discipline, Microgravity Fluid Physics. The Division last released a NASA Research Announcement (NRA) for Microgravity Fluid Physics in 1994 and expects to continue to release NRA's in Microgravity Fluid Physics approximately every two years.

NASA has supported research in Microgravity Fluid Physics for over three decades. An extensive research program supports theoretical and experimental investigations in ground-based laboratories. Also, many investigations are conducted using fluid physics research apparatus built to take advantage of the limited low gravity test times available in ground-based facilities such as the drop-towers at the NASA Lewis Research Center, or NASA's Parabolic Low Gravity Flight research aircraft. These ground-based experiments, along with theoretical modeling, form the basis for most of our current understanding of the effects of gravity on fluid processes and phenomena.

In the MSAD program, ground-based research has been used to gain a preliminary understanding of phenomena, and to define experiments to be conducted in the extended low gravity test times available in spacecraft in low-Earth orbit. MSAD is developing several instruments to conduct fluid physics research that offer improved control and diagnostic capabilities over early experiments. These instruments are configured to investigate phenomena such as nucleate pool boiling, surface tension-driven flows, order-disorder transitions, granular media, and transport phenomena in critical systems. MSAD also anticipates limited near-term flight opportunities for investigations capable of making use of existing hardware where no or minor modifications would be required.

MSAD is also preparing for flight opportunities using International Space Station research instruments. MSAD is currently studying the development of modular research instruments that can be configured (or reconfigured) to accommodate multiple experiments and multiple users. This is envisioned as an evolutionary program with the objectives of providing experimental data in response to increasingly sophisticated science requirements and of permitting the evolution of experimental approaches and technologies as needed for scientific investigations throughout the era of the International Space Station. This announcement is being released as part of a coordinated series of discipline-directed solicitations intended to span the range of the MSAD program. Other MSAD-supported solicitations planned, as is this one, for periodic release over the next several years include:

Biotechnology
Combustion Science
Fundamental Physics
Materials Science.

B. RESEARCH ANNOUNCEMENT OBJECTIVES

This NRA has the objective of broadening and enhancing the MSAD microgravity fluid physics program, the goals of which are described in Section II, through the solicitation of:

1. Experiment concepts which will define and utilize new instruments for space-based experiments in fluid physics with an emphasis on research concepts that can be accommodated by small, simple instruments;

2. Experimental studies which require the space environment to test clearly posed hypotheses, using existing or slightly modified instruments in space-based experiments to increase the understanding of fluid physics; and

3. Ground-based theoretical and experimental studies which will lead to the definition or enhance the understanding of existing or potential flight experiments in fluid physics with an emphasis on research that will provide a scientific foundation for technologies required by future human space missions.

Further programmatic objectives of this NRA include objectives broadly emphasized by the civil space program, including: the advancement of economically significant technologies; technology infusion into the private sector; enhancement of the diversity of participation in the space program, public education and outreach and several objectives of specific importance to the microgravity science and applications 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.

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 Fluid Physics 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.

C. DESCRIPTION OF THE ANNOUNCEMENT

With this NRA, NASA is soliciting proposals to conduct research in microgravity fluid physics, with an emphasis on experimental efforts that are sufficiently mature to justify near-term flight development and are of a scale that provides sufficient flexibility to be accommodated on various research platforms. The goals of the discipline along with some identified research areas of interest are described in Section II. Proposals describing innovative low gravity fluid physics research beyond that described herein are also sought.

NASA is currently developing several types of flight instruments for microgravity fluid physics research. Brief descriptions of the current and planned capabilities are given in Appendix B, Section I. NASA anticipates several near-term flight opportunities for investigations with requirements which can be met by existing apparatus with only minor modifications. Successful proposals for use of the existing apparatus will be funded for advanced definition studies which will produce a detailed Science Requirements Document (SRD). Authorization to proceed into flight development is contingent upon successful peer review of the experiment and SRD by both science and engineering panels. NASA does not guarantee that any experiment selected for definition which plans to use existing hardware will advance to flight experiment status.

NASA also encourages submission of experiment proposals for which none of the existing flight instruments is appropriate. NASA anticipates the development of new fluid physics research experiment apparatus for the International Space Station. The hardware descriptions included in Appendix B, Section I should be viewed as examples to allow researchers to consider capabilities that might meet their science requirements. However, researchers should not feel limited by these capabilities. Selected proposals requiring development of new capabilities will be funded for definition studies to determine flight experiment parameters and conditions and the appropriate flight hardware. The length of the definition phase will be based on the experiment requirements, but will normally range from 6 to 24 months and will culminate in the preparation of an SRD.

Authorization to proceed into flight development is contingent upon successful peer review of the SRD by both science and engineering panels. NASA does not guarantee that any experiment selected for definition which requires new instrument development will advance to flight experiment status. Investigations that do not proceed into flight development will normally be asked to submit a proposal for continuation of support at the conclusion of a typical four-year period of funding. Promising proposals which are not mature enough to allow development of a flight concept within two years of definition may be selected for support in the MSAD Research and Analysis (R&A) Program. Investigations selected into the R&A program must generally propose again to a future announcement in order to be selected for a flight opportunity.

II. MICROGRAVITY FLUID PHYSICS RESEARCH

The microgravity fluid physics program encompasses a wide range of research in physics and engineering science, including studies of heat and mass transfer processes, fluid dynamics, and the physics of complex fluids.

Fluid physics is the study of the properties and motions of liquids and gases. Such studies arise from nature (e.g. in meteorology, oceanography, and living plants or animals) and technology (e.g. in biological, chemical and material processing, and fluid systems). Fluid phenomena span scales that range from nanometers to light years and constitute by their ubiquity one of the fundamental areas of science and engineering. The need for better understanding of fluid phenomena has created a vigorous, multi-disciplinary research community in fluid physics whose continuing growth has been marked by the steady emergence of new fields of relevance in both basic and applied science. Areas of technological and ecological importance like global atmospheric change, groundwater pollution, oil production, and advanced materials manufacturing often rely for their progress on advances in fluid physics. Scientists studying basic problems from chaotic systems to the dynamics of stars also turn to fluid physics for their models. Through the history of fluid physics, theory and experiment have maintained a synergetic relationship in building scientific knowledge. In recent years, research in fluid physics has been at the forefront in applying large-scale computational techniques to physical problems. The continuing advance of high-performance computing will drive new theoretical insights, which will spur a new generation of experimental fluid physics.

Microgravity research encompasses the phenomena related to gravitational fields (or equivalent accelerations with respect to inertial frames) whose magnitudes are but a small fraction of Earth's gravity. Gravity strongly affects many phenomena of fluid physics by creating forces in fluid systems that drive motions, shape boundaries, and compress fluids. Further, the presence of gravitational forces can mask effects that are ever present but comparatively small.

Fluid physics has a unique role in the NASA microgravity science program. Gravitational physics deals directly with the existence of gravity. Other scientific disciplines are interested in developing the potential of the microgravity environment as a research tool, and hope to create controlled conditions of fluid flow and heat and mass transport in specialized circumstances, e.g the growth of protein crystals, the solidification of a molten semiconductor, or the burning of liquid fuels. The goal of much of fluid physics research is simply to comprehend fundamental physical phenomena. In doing this, fluid physics contributes to seemingly distant fields of research by providing a fundamental framework of principles and basic understanding for flow and transport that specialists in other disciplines can apply to their problems. Fluid physics also has a crucial role in the space program in support of the effort to develop new technologies, or to adapt existing technologies (e.g. power generation, materials handling and processing, gas adsorption, and life support systems) for space operations or other extraterrestrial environments. A much sharper understanding of the detailed physics of these processes must be in hand before engineers can confidently design systems for use in non-Earth environments.

MSAD aims to support fundamental research and enabling technologies associated with space studies. It recognizes the need of supporting a vigorous theoretical and experimental ground-based program which supports space research and from which new ideas for space research can grow.

Studies of fluid phenomena and opportunities for research in space can be approximately classified according to their motivation, the known role of gravity, and the anticipated consequences of greatly diminished gravitational effects. Much research in microgravity fluid physics can be discussed within this conceptual structure: (1) how gravity, when eliminated or greatly reduced, results in putting to the fore effects otherwise masked, (2) the role of gravity, and how it produces fluid motions and compressions, and (3) how fluid-engineering systems perform in extraterrestrial environments.

A. UNMASKED PHENOMENA

When the influence of gravity on fluid behavior is diminished or removed, other forces can assume paramount roles. These forces can include capillary, thermocapillary, van der Waals, and electrochemical/electrokinetic forces, Soret and Dufour effects, and contact line dynamics.

1. Capillary Phenomena. Surface tension on fluid-fluid interfaces can control the shapes of liquid bodies of even large scale. Small disturbances can shift dramatically the position of a liquid from one portion of the container volume to another, leading to configurational changes that can be important in the drainage of fuel tanks and generally in the area of fluid handling. Capillary instabilities can lead to the breakage of a liquid body into several pieces. Contact line characteristics can significantly affect configurations.

2. Solid-Liquid Interactions. Contact-line dynamics of fluid-fluid-solid trijunctions can control the coating of solid surfaces, the cooling of hot surfaces, and the behavior of vapor bubbles in nucleate boiling. Macroscopic contact angles depend on contact-line speeds and, hence, normally on flows driven by gravity. Liquid films less than 100 nm in thickness can rupture due to van der Waals attractions, creating new contact lines. Both fluid and thermal management in spacecraft are dependent on the behaviors of thin films and contact lines.

3. Thermocapillary and Solutocapillary Phenomena. When a fluid-fluid interface is subjected to a tangential gradient of temperature and/or species concentration, shear stresses are created in the interface which drive bulk motions. Such surface effects can control the migration of droplets in bulk or along solid surfaces. They can enhance transport (compared to pure conduction) in large volume or in menisci. Steady motions can become unstable and lead to time-oscillatory behavior in containerless systems of materials processing. When a temperature gradient is imposed normal to an interface, the

pure conduction state persists until a critical value of the gradient is exceeded, leading to Marangoni convection.

4. Coalescence and Aggregation Phenomena. Numerous phase-separation processes rely on coalescence or aggregation of dispersed phases to form continuous phases. Boiling, condensation, foam drainage and coarsening formation, and (Ostwald) "ripening" of solid precipitates are familiar examples. In droplet condensation and foam coarsening, relative motions caused by gravity, thermocapillary migration and van der Waals forces all contribute to foam drainage and film rupture. In precipitate ripening, large clusters grow at the expense of smaller ones.

5. Bubble or Droplet Migration. Momentum imparted to the liquid by the vapor bubble during growth can tend to draw the vapor bubble away from the surface. Thermocapillary forces, arising from the variation of the liquid-vapor surface tension with temperature, tend to move the vapor bubble toward the region of higher temperature. Bubble motion will be governed by which of these two effects prevails. The growth and dynamics of vapor bubbles that nucleate at a heater surface are determined by the mechanics of detachment at contact lines in the presence of heat transfer.

6. Crystal Growth. The growth of crystals from melt, vapor, or solution can be quite different in microgravity conditions than on Earth, because of reduced convection. This may result in a solid product with more uniform composition and structure. Moreover, the virtual absence of buoyancy-driven convection can result in a process controlled by molecular diffusion and, therefore, usually more predictable and amenable to modeling. The fundamental mechanisms governing crystal growth, particularly those that pertain to crystal-fluid-interface morphology (dendrites, cells, and the structure of in situ eutectic composites), are not well understood and often are masked by buoyancy-driven convection that is often unavoidable on Earth. Carefully designed experiments conducted in microgravity might guide choices among alternative theories.

7. Electrokinetics and Electrochemistry. Electrokinetics concerns transport phenomena involving charged fluid interfaces and their associated diffuse layer of space charge. The motion resulting from such processes is usually in response to an imposed electric field, which, in turn, offers a means of manipulating multiphase systems. External fields are also used in separation processes such as electrophoresis, isotachophoresis, and isoelectric focusing. Due to the presence of intrinsic charge on interfaces, electrical effects also play pre-eminent roles in the behavior of a myriad of colloidal systems, including many of biological origin. Electrochemistry deals with phenomena associated with the transfer of electrons at electrodes, resulting in chemical reactions. Although electrolysis reactions are the most familiar examples, there are a host of electrochemical synthesis processes where fluid motion effects transport processes. Electrochemistry and electrokinetics overlap whenever electrical double-layers are involved. Microgravity can have a role in issues where hydrodynamic considerations are involved in the electrochemical processes. Density differences may arise from Joule heating or from concentration changes as a consequence of electrochemical reactions. On the other hand, without natural convection, rates of electrochemical processes are typically diffusion-limited and, hence, low. In the electrochemical engineering practice, significant electrolyte circulation is often achieved through buoyancy effects due to the presence of gas bubbles in parts of the electrolyte. Limitations on earth-based experiments in electrokinetics and electrochemistry arise due to density differences in the fluids; these differences lead to buoyancy-driven bulk motion or sedimentation of particles.

8. Measurement of the Equilibrium and Transport Properties of Fluids. If all forms of convection are absent, other mechanisms such as diffusion become important. For example, a temperature gradient gives rise to mass transport, the Soret effect, and a concentration gradient gives rise to a temperature gradient, the Dufour effect. Theoretical understanding of these diffusive effects in anything but very idealized model systems is hampered by the lack of experimental data for transport coefficients. These effects can be even more important in multicomponent systems in the Earth's gravitational field, but are very difficult to isolate from mass transfer. Some material properties of fluids could be measured more

accurately, in principle, in the absence of gravity. This is particularly true of the equilibrium and transport properties of critical fluids, which experience diverging compressibilities at the critical point and consequently are greatly effected by hydrostatic pressure on Earth.

9. Dynamics of Fluid-Solid Interfaces. A key problem in materials preparation is the morphological instability of a front separating a liquid that is freezing into a crystalline solid. In the simplest case, there is thermodynamic equilibrium at the interface, and the dynamics is limited by diffusion of heat and solute. Then the local thermal and solutal gradient at the interface and the interfacial energy determines whether the interface remains planar (with a homogeneous solid being produced) or the interface becomes unstable to cellular or dendritic morphologies (with solute segregation in the solid). The absence of convection would allow careful test of the theory. Further, if buoyancy is absent, otherwise small effects such as interface kinetics and strong anisotropies of kinetics and surface energy (typically experienced in crystallization from vapor or solution) can have large effects.

10. Micromechanics of Cohesionless Granular Media. Fluid-like behavior is exhibited in nature by granular solids. The mechanics of such materials is governed largely by frictional-elastic contact forces, inertia, and gravity. There are a number of scientifically and technologically important phenomena, such as size segregation in rapid flow, unstable plastic deformation in slow flow, and seismic "liquefaction", whose origins are poorly understood. Experimentation in a reduced-gravity environment could allow one to isolate and understand the forces of non-gravitational origin and to eliminate density-gradients associated with gravity.

11. Multiphase Flow. Stratified gas-liquid flows that are maintained on Earth may not exist in a microgravity environment, leading to changes in the characteristics of pressure drop and heat transfer. Bubbly flow in pipes channels is strongly affected by gravity. Under microgravity conditions, the phase distributions should change substantially. Forced-convection nucleate boiling depends crucially on bubble dynamics which are strongly affected by gravity. All of the above require new criteria.

B. GRAVITY-DRIVEN PHENOMENA

The force of gravity has two direct effects. On one hand, it acts on fluid bodies to drive motions due to the relative buoyancy of phases of unequal density. It also acts on single phase fluids subjected to non-uniform thermal and solutal fields. On the other hand, it produces hydrostatic pressures that act on compressible materials. These two effects give rise to a number of important consequences for Earth-based fluid physics research. Studying the effects of gravity on processes can allow one to sort out gravity-driven from other phenomena such as those discussed above.

1. Convective Phenomena. On Earth, differences in density, resulting from inhomogeneity in temperature and/or composition, can cause an otherwise quiescent fluid to convect, thus giving rise to the transfer of momentum, heat, and mass. In experiments on the earth's surface, buoyancy-driven convective motion is typically orders of magnitude more rapid than the slow migration caused by molecular diffusion. Differences in surface tension on interfaces that arise because of temperature or concentration gradients along a fluid surface lead to thermocapillary or Marangoni convection. Studies of coupled systems with gravity can lead to means of understanding how one could extract the background behavior from the whole. Coupled buoyancy-driven and Marangoni convection is one case. Another is the effect of buoyancy-driven convection on the evolution of morphological instability in crystal growth. Most experiments on convective phenomena use transparent liquids, and provide limited information on the behavior of low Prandtl number liquids like metals and semiconductors. New means are needed to observe non-intrusively flow fields in optically opaque materials.

2. Compressional Effects. Complex materials, composed of materials with differing densities, are subject on Earth to hydrostatic gradients that compress or separate the constituents. Granular media exhibit pattern changes under stress. Colloidal and protein crystals are subject to sedimentation. Thin

films in foams drain. Fundamental studies on Earth of complex materials determining the effects of gravity will indicate how successfully one can extract underlying phenomena from gravity-coupled behavior. Such understanding can lead to defining a role for microgravity experiments in a number of areas dealing with complex fluids.

C. EXTRATERRESTRIAL PROCESSES

As one of NASA's five core Strategic Enterprises, the Human Exploration and Development of Space (HEDS) Enterprise 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 of the fundamental role of gravity in the space environment in chemical and physical systems is needed to achieve breakthroughs in science and enabling technology. The need for improved understanding of fluid phenomena to enable future space technologies and operations should be recognized as one of the primary opportunities of the 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.

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 spacecraft systems, life support systems, bio-fluids, use of in situ resources and power generation in extraterrestrial environments. Many of the fluid physics principles involved in these systems are relevant to several technology areas simultaneously.

For example, under terrestrial conditions, gravity usually dominates the behavior of spacecraft thermal management systems, determining such important parameters as the heat transfer coefficient, pressure drop, residence time distribution, interfacial area, stability, and vibrational character of the flow. Design of heat transfer equipment, phase separators, chemical processing and separation devices, transfer lines, and pumps all depends on having sound physical models or empirical correlations. Because gravity produces dominant forces on Earth, existing models for the flow developed at normal gravity are expected to be inadequate for microgravity conditions. Of particular importance is the ability to predict the nature of boiling in the absence of buoyancy (which usually controls nucleate boiling) and of condensation, where gravity is usually employed to drain the condensate from the surface to maintain high transfer rates. Both of these processes depend critically on the flow patterns and distribution of shear in the fluid. Many of the most important, and yet least understood, problems in two-phase flow and heat transfer involve multidimensional phenomena. Thus, the development of mechanistic three-dimensional models of two-phase flow and heat transfer is essential for many applications of multiphase technology. Instabilities of thin liquid films may lead to temporal or spatial growth of surface waves, resulting eventually in rupture of the film. This can result in rapid dryout and overheating of the equipment. Knowledge of the mechanics of contact line motions under these circumstances, both on earth for a vertical wall, and in a microgravity environment would allow better understanding of these complex effects.

An area in which fluid dynamics can make a contribution is in support of human space flight in its technological and biomedical requirements. Life support systems, particularly in the nearly closed designs required for long-duration missions, rely on gravity-dependent processes for atmosphere revitalization, water reclamation, and waste management. As with spacecraft systems, these systems incorporate two phase flow designs where a better fundamental understanding of the parametric dependence of multiphase systems on gravity and improvements in models would allow more confident engineering design.

Fluid dynamics research may help understand and eventually control some of the physiological consequences of the space environment as well. Efforts to yield a fundamental understanding of bio-fluid dynamics, such as transport phenomena in blood and ionic diffusion through membranes and porous media to apply towards counteracting the effects of weightlessness are encouraged.

A rapidly developing area relevant to exploration of other bodies in the solar system is In Situ Resource Utilization (ISRU). Due to the cost constraints associated with carrying all 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 research community must be to develop an understanding of operation of these processes in non-Earth environment. Proposals are encouraged on efforts to advance the current understanding of unit operations 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 transport and processing of granular materials, chemical reaction engineering, product separation, liquefaction, and storage.

Lunar regolith (soil) 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. 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. Utilizing 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 granular media, solid/gas and solid/liquid phase separation, and transport phenomena in electrochemical systems are required for representative techniques such as regolith handling, fluidized beds, electrolysis, pyrolysis, sorption pumps and sabatier reactors. The dynamics of granular materials impact numerous technologies related to the utilization of regolith. For example, bulk solid flow processes, such as storage, handling, processing and management of coarse grained materials and powders and the design of silos and conveyors. The useful products resulting from many of these processes require the ability to handle cryogenics in extraterrestrial environments. The ISRU products will need to be liquefied or even frozen to be stored efficiently requiring a fundamental understanding of the cryogenic fluid dynamics. This understanding is also extremely important with respect to the handling of propellants aboard the spacecraft. Fundamental studies would yield a non-empirical approach to development and design, thus generating support technologies independent of the process chosen for actual manufacturing to imbue flexibility and efficiency in the designs.

In addition, other physical and chemical processes may benefit from further studies in low gravity environment. Examples include dust management, production of construction material, such as cement via steam hydration, mining of ^{3}He on the Moon for reactors and energy production/storage techniques such as batteries. Again, studies that contribute directly to the understanding of the underlying fluid physics in these processes would be of interest.

III. EXPERIMENT APPARATUS AND FLIGHT OPPORTUNITIES

A. EXPERIMENTAL APPARATUS

In order to address aspects of the research described in Section II, a number of pieces of flight hardware are being developed by NASA and its international partners. These are described in Appendix B, Section I. Section II of Appendix B lists the ground-based facilities that are available to support definition studies.

Limited early flight opportunities under this NRA will be on the Space Shuttle or the International Space Station (ISS). For the Shuttle opportunities, the experimental apparatus are located in the Spacelab, middeck or Spacehab, allowing astronaut interaction, or in the cargo bay. Residual acceleration levels on the order of 10^{-4} g are available in the Shuttle for limited periods of time. Flights range from 7 to 16 days in duration. The Space Acceleration Measurement System (SAMS) is expected to be available to measure and record actual accelerations at or near the apparatus for both Shuttle and ISS experiments. Considerable additional information on the Shuttle accommodations and capabilities can be found in the STS Investigators' Guide (see Bibliography). Experimental apparatus for the early utilization of the International Space Station will primarily be in facilities such as the Glovebox and Express rack (ISS versions of Shuttle middeck class experiments) followed by the Fluids/Combustion Facility after the completed assembly of the ISS. A high-capacity communications network supports Shuttle and ISS payload operations. Downlink channels enable users to monitor their instrument status and science data streams in real time. An uplink channel enables them to act on that information

B. DIAGNOSTIC MEASUREMENTS

The capability to characterize science experiments in reduced-gravity is essential to scientific progress in this program. NASA, in ground-based normal and reduced-gravity studies, is developing techniques for enhancing imaging and visualization, and improving measurements of temperature, velocity, and particle-size distributions. As these techniques mature, those most required by investigators will be reviewed for space flight development as part of the future flight equipment capability.

C. FLIGHT OPPORTUNITIES

Missions available for this program may include several Shuttle and missions on the International Space Station.

D. EXPERIMENT DEFINITION AND FLIGHT ASSIGNMENT PROCESS

Ground-based research is usually necessary to clearly define flight experiment objectives. This research may involve experimentation in NASA-provided ground-based facilities, including those which can provide a limited duration low gravity environment. (These facilities are described in Appendix B, Section II.) Successful proposals for flight opportunities will be supported for a ground-based definition phase before review for flight assignment. The amount of support (technical, scientific, and budgetary) and the length of the definition period (usually from 6 months to 2 years) will depend on the specific investigator needs and the availability of resources from NASA. However, in preparing their budget plan for this research announcement, all respondents should estimate their annual costs for four years.

Shortly after selection of projects for flight definition, NASA may use the Quality Functional Deployment (QFD) process to identify fundamental technical feasibility issues. The QFD concept provides small teams of engineers and scientists at the NASA field centers a means of translating customer (Principal Invesitgator) requirements into the appropriate experiment technical requirements. The result is a systems engineering approach which prioritizes and links the facets of the experiment development process assuring that the objectives of the experiment can be met. The QFD process will help determine whether there are any outstanding issues that would inhibit the success of the flight project, considering both technical challenges and required resources. At that point NASA may make a judgment as to whether a project will continue the flight definition process or revert to the Ground-Based (Research and Analysis) Program (see below).

1. Near-Term Flight Opportunities. Successful proposals for use of the existing instruments will be funded for a period of advanced definition work, after which time the investigator will generate a detailed SRD. The SRD, a detailed experiment description outlining the specific experiment parameters and conditions, as well as the background and justification for flight, must be prepared jointly by a NASA-appointed project scientist and the Principal Investigator and submitted for peer review. This formal review by both science and engineering panels will determine if space flight is required to meet the science objectives and if instrument capabilities can be provided to meet the science requirements. Following approval by the panels, subject to program resources, continuation support will be awarded and the hardware will be modified to meet the science requirements. NASA does not guarantee that any experiment selected for definition will advance to flight experiment status. Investigations with unresolved science or engineering issues at the review of the SRD may be placed in ground-based status with support of limited duration (normally from one to three years), and asked to submit a proposal to a subsequent solicitation for further support.

2. Future Flight Opportunities. Successful proposals for the development of new apparatus will be funded for a period of definition. The length of the definition period will be based on the experiment requirements, but will generally be from 6 to 24 months. At the end of the experiment definition phase, the investigator will generate a detailed SRD. Following successful peer review of the SRD by science and engineering panels, the experiment will proceed into flight development and be considered for flight. As with opportunities for existing instruments, NASA does not guarantee that any experiment selected for definition will advance to flight development status, and the possibility exists that investigations may be placed in ground-based status, with continuing support from NASA for a limited period.

3. Ground-Based Definition Opportunities. Promising proposals for experimental research which are not mature enough to allow development of an SRD after two years of definition, and proposals for development of theory in areas of current or potential microgravity experiments, may be selected for support in the MSAD Ground-Based or Research and Analysis (R&A) Program. R&A studies are funded for periods of up to four years. A new proposal to a future announcement is currently required in order to be selected for a flight opportunity or to continue R&A studies if appropriate. Proposals for development of new technologies for flight experiments that will provide new capabilities for fluid physics research are encouraged.

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 career development of undergraduate students by offering optional supplements of about $5,000 per student to approved research tasks for undergraduate student research projects. This supplement may be requested for each year of the proposed research. These projects should involve undergraduate students in a meaningful way in ongoing research programs or in related sub-projects specifically designed for this purpose.

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. Proposals for up to about two students should be a separate section (see information on proposal formatting in Section V, subsection B) of about two pages per student 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, subsection 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; and

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 progress.

V. PROPOSAL SUBMISSION INFORMATION

This section gives the requirements for submission of proposals in response to this announcement. The research project described in the typical proposal submitted under this announcement must be directed 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 MSAD Web Page:

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

Alternatively, 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 or Facsimile transmission is acceptable; the MSAD fax number is (202) 358-3091.

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.
- Intent to participate in the Undergraduate Student Research Opportunites, if appropriate.
- The equipment of interest listed in this NRA, if appropriate.

The Letter of Intent should be received at NASA Headquarters no later than February 18, 1997. The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. Institutional authorizations are not required. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. In the Letter of Intent, investigators may request more detail on the capabilities of the specific equipment (Appendix B) that might be used to accomplish their scientific objectives and/or items listed in the Bibliography (Appendix A, Section IX).

B. PROPOSAL

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.

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.

Fifteen copies of the proposal must be received at NASA Headquarters by March 18, 1997, 4:30 PM EDT to assure full consideration. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

Alexander D. Pline
c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-01)
300 D Street, S.W.
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA can not receive deliveries on Saturdays, Sundays or federal holidays.

Proposals submitted in response to this Announcement must be typwritten in English and contain at least the following elements (in addition to the required information given in Appendix C) in the format shown below:

- Title Page
- Table of Contents
- Executive Summary (replaces abstract) (1-2 pages)
- Research Project Description containing the following elements:
  - Statement of the hypothesis, objective, and value of this research.
  - Review of relevant research.
  - Justification of the need for low gravity to meet the objectives of the experiment.
  - Description of the diagnostic measurements that would be required to satisfy the scientific objectives of any proposed low gravity experiments.
  - Estimation of time profile of reduced-gravity levels needed for the experiment or series of experiments.
  - A clear and unambiguous justification of the need to perform the experiment in space as opposed to ground-based reduced-gravity facilities.
  - A description of a ground-based testing program that might be needed to complete the definition of the space flight experiment requirements in terms of experiment conditions, acceleration levels and durations, control and diagnostic measurement requirements, etc.
- Optional Undergraduate Student Research Opportunity (not counted in the 20 page limit)
- Management plan appropriate for the scope and size of the proposed project, describing the roles and responsibilities of the participants
- Prior Period of Support
  - For proposals for renewal of ongoing MSAD sponsored projects, a summary of the objective and accomplishments of the prior period of support.
- Appendices:
  - Budget plan estimating annual costs for four years. There should be at least one page for each of the four years and one page summarizing the total four-year budget. The information desired is explained below.
  - Summary of current and pending support for the Principal Investigator and Co-Investigators.
  - Complete current curriculum vita for the principal and Co-Investigators, listing education, publications, and other relevant information necessary to assess the experience and capabilities of the senior participants.
  - Forms and Signed Certifications (see below).

- **3.5 inch computer diskette containing electronic copy of 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 it is 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.

Each proposal should include the Solicited Proposal Application (Form A). Those requesting financial support should also include: Detailed Budget for 12-Month Period Direct Costs Only (Form B) for each year of funding; Budget for Entire Project Period Direct Costs Only (Form C); signed Certifications regarding Drug-Free Workplace Requirements (Form D); Debarment, Suspension and other Responsibility Matters (Form E); Lobbying (Form F). Copies of these forms may be found at the end of this document.

<u>Proposal Cost Detail Desired</u>. Sufficient proposal cost detail and supporting information will facilitate a speedy evaluation and award. Dollar amounts proposed with no explanation (e.g., Equipment: $58,000, or Labor: $10,000) may cause delays in evaluation or award. The proposed costing information should be sufficiently detailed to allow the Government to identify cost elements for evaluation purposes. Generally, the Government will evaluate cost as to reasonableness, allowability, and allocability. Enclose explanatory information, as needed. Each category should be explained. Offerors should exercise prudent judgment as the amount of detail necessary varies with the complexity of the proposal.

VI. <u>NRA FUNDING</u>

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 award purposes 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, we have assumed that the Microgravity Science and Applications Division will fund up to 5 flight experiment definition proposals. These definition-phase proposals will be funded on an average of $175,000 per year. Approximately 15-20 ground-based study proposals will be funded, at an average of $100,000 per year, for up to 4 years. Approximately 20-30 ground-based study proposals will be funded at an initial level of an average of $60,000 per year. The initial fiscal year (FY) 1998 funding for all proposals will be adjusted, if required, to reflect partial fiscal year efforts. The proposed budget for ground-based studies should include researcher's salary, travel to science and NASA meetings (for a flight investigation, roughly eight meetings per year with NASA should be anticipated, though travel activity will vary over the development of the experiment), other expenses (publication costs, computing or workstation costs), burdens, and overhead. During subsequent years, NRA's similar to this NRA will be issued, and funds are planned to be available for additional investigations.

VII. <u>GUIDELINES FOR NON-U.S. PARTICIPATION</u>

NASA accepts proposals from all countries, although this program does not financially support Principal Investigators in countries other than the U.S. Proposals from non-U.S. entities should not include a cost plan. 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. Such endorsement should indicate:

1. The proposal merits careful consideration by NASA.
2. If the proposal is selected, sufficient funds will be made available, from the country from which the non-U.S. participant is proposing, for their participants to undertake the activity as proposed.

Special instructions apply to non-U.S. proposals. In addition to sending the orginal 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-01
Space Flight Division
Code IH
National Aeronautics and Space Administration
Washington, DC 20546-0001
USA

All proposals must be typewritten in English. All non-U.S. proposals will undergo the same evaluation and selection process as those originating in the U.S.

Sponsoring non-U.S. 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's Office of External Relations, Space Flight Division, should be advised when a decision on endorsement can be expected.

Successful and unsuccessful proposers will be notified by mail directly by the NASA program office coordinating the NRA. Copies of these letters will be sent to the sponsoring government agency. Should a non-U.S. proposal or U.S. proposal with non-U.S. participation be selected, NASA's Office of External Relations will arrange with the non-U.S. sponsoring agency for the proposed participation on a no-exchange-of funds basis, in which NASA and the appropriate government 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:

1. A letter of notification by NASA; and
2. An exchange of letters between NASA and the sponsoring government agency.
3. An agreement or memorandum of understanding between NASA and the sponsoring government agency.

VIII. EVALUATION AND SELECTION

A. EVALUATION PROCESS

The evaluation process for this NRA will begin with a scientific and technical peer review of the submitted proposals. NASA will conduct an engineering review of the potential hardware requirements for proposals that include flight experiments. The external peer review and internal engineering review panels will be coordinated by the NASA Enterprise Scientist for Fluid Physics. 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. NASA will also evaluate the cost of the proposal. Upon completion of deliberations, offerors will be notified regarding proposal selection or rejection. Offerors whose proposals are declined will have the opportunity of a verbal debriefing with a NASA representative regarding the reasons for this decision. Additional information on the evaluation and selection process is given in Appendix C.

B. EVALUATION FACTORS

The following section replaces Section 13 of Appendix C. The principal elements considered in the evaluation of proposals solicited by this NRA are: relevance to NASA's objectives, intrinsic merit, and cost. Of these, 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. 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, 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 of the cost of a proposed effort includes consideration of the realism and reasonableness of the proposed cost, and the relationship of the proposed cost to available funds.

IX. BIBLIOGRAPHY

Background materials are available to NRA proposers upon written request to:

Dr. Nancy J. Shaw
MS 500-102
Microgravity Science Division
Lewis Research Center
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, OH 44135-3191
(216) 433- 3285

Documents that may provide useful information to proposers are listed below:

1. Microgravity Science and Applications Division Homepage, http://microgravity.msad.hq.nasa.gov

2. Microgravity Science and Applications Apparatus and Facilities, NASA Marshall Space Flight Center.

3. STS Investigators' Guide, NASA Marshall Space Flight Center.

4. Microgravity Science and Applications Program Tasks and Bibliography, NASA Technical Memorandum 4735, 1996, https://peer1.idi.usra.edu/taskbook/taskbook.html

5. Second Microgravity Fluid Physics Conference Proceedings, NASA Conference Proceedings 3267, June 1994.

6. Third Microgravity Fluid Physics Conference Proceedings, NASA Conference Proceedings 3338, June 1996.

7. Microgravity Research Facilities and Fluid Physics Flight Experiments, Microgravity Science Division Homepage, NASA Lewis Research Center, http://zeta.lerc.nasa.gov

APPENDIX B
NRA-96-HEDS-01

HARDWARE AND FACILITY DESCRIPTIONS

The Microgravity Science and Applications Division (MSAD) is pursuing a program for the development of Space Shuttle and International Space Station (ISS) payloads that can be configured (or reconfigured) to accommodate multiple users. This evolutionary program is expected to meet the science requirements of increasingly sophisticated microgravity investigations and to permit the eventual development of experiment payload technologies for research throughout the era of the ISS.

I. CURRENT AND PLANNED FLIGHT HARDWARE

The experimental apparatus described in this section have been developed or are under development for flight on a series of Space Shuttle missions and/or ISS. 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. 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. ISS FLUIDS/COMBUSTION FACILITY (FCF)

The ISS Fluids/Combustion Facility (FCF) is a multi-rack facility designed to support implementation of fluid physics experiments on the International Space Station during , at least, a decade of space operations. The FCF supports each experiment with core capabilities including conditioned power, complementary cooling (water and air flows), vibration isolation, digital image acquisition and storage, and central command/control capabilities. At the Fluids Module level, the facility provides capabilities for illuminating fluids samples (white light, coherent light, including light sheets for flow tracking in seeded samples), digital imaging systems (standard to high resolution, variable framing rates, adjustable field of view, zoom capability), capability for thermal control, capability for control of automatic cameras and positioners. At the experiment level, adequate volume is available to implement experiment-specific capabilities for containment, sample manipulation, local thermal control, precision optical systems, etc.

The Experiment Work Area (EWA) of the Fluids Module consists of an enclosed volume with front rack access that provides a dedicated volume and stringent environment in which the Principal Investigator (PI) specific hardware is integrated. This enclosed volume also contains the necessary cameras, lenses, and mirrors to support imaging of PI specific test cells. An average volume of approximately 70 liters is available for PI specific hardware utilizing the standard EWA diagnostic capabilities. This volume is expandable up to the total EWA volume of approximately 280 liters if standard imaging services are not required. The EWA consists of an enclosed, 4-sided thermally controlled optics bench to maximize equipment reconfigurability and upgradeability. Standardized interface services are provided to facilitate experiment integration including power (also conversion from 28 VDC), data acquisition, vacuum/vent and GN2. The optics plate utilizes science standard spacing for accommodation of off-the-shelf optical components.

The EWA can be outfitted with PI specific hardware located on the containment door (temporary mount). This interface can also accommodate limited glovebox operations and provisions for experiment unique hardware.

Imaging is the primary diagnostic tool of the Fluids Module with standard services including color imaging, black & white high resolution imaging, and high frame rate capability. Facility cameras are changeable and upgradeable. Specialized PI provided cameras compatible with the Image Processing and Storage Units (IPSUs) can additionally be accommodated. Image data is stored digitally on 9 GB hard drives located in the IPSU.

Various optics, white light and laser illumination are provided as standard services for collection of quality video imagery. The Laser Light capability provides sheet or beam laser light to support specialized imaging diagnostics. All light is provided via optical fiber.

Experiment diagnostic support is accommodated through a PI specific data acquisition and control interface with overall experiment control provided by the Fluids computer. The computer has provision for motion and temperature control, and interfaces for specialized devices such as Photomultiplier Tubes and Avalanche Photodiodes. Signal conditioning will be used to support measurement devices such as RTDs and thermocouples and transducers to measure pressure, strain, force and flow. The computer provides a generic motor driver support to PI specific hardware. The Fluids Module will support automated output beam alignment, scanning and camera focusing utilizing motorized positioners. These instruments will contain optical components, namely beam manipulating optical packages and mirrors. Three types of devices will be implemented nominally including linear translation stages, rotation stages, and gimbal optic mounts.

Environmental control capabilities include interface with the FCF water loop with specific assemblies cooled by the Air Thermal Control System. In the EWA, PIs have access to coldplates to allow for cooling of components directly mounted to the optics bench. Additionally, a generic water interface is available for PI specific heat rejection. Air flow within the EWA shall nominally be avoided; however, air cooling can be accommodated for less sensitive experiments with the addition of an air/water heat exchanger-fan package which can interface to the EWA internal water connection.

B. CAPILLARY AND CONVECTIVE FLOW APPARATUS (CCFA)

1. CCFA Baseline Capabilities. This hardware is currently designed to study thermocapillary flows induced by either local heating of the free surface of the test fluid using a CO_2 laser, or internally with a resistance type heater. Measurement capabilities include flow visualization, surface temperature distribution using non-intrusive, bulk fluid temperatures and free surface deformation (deviations from flat). The hardware is currently designed to accommodate silicone oil as the test fluid but use of other test fluids should be possible with proper safety considerations.

The hardware consists of an avionics package, containing power conditioning, data acquisition, and computer control alongside an experiment package containing the experiment test chambers, fluid delivery system, and optical diagnostic systems and cameras. The experiment test chambers and the test fluid delivery systems are contained in removable test modules which are installed on-orbit. The current modules contain cylindrical test chambers with diameters of 1.2, 2, and 3 cm for both the laser heating case and the internal heating case and all with an aspect ratio of one. Chambers up to 10 cm diameter can be accommodated. The CO_2 laser beam diameter and power are adjustable as well as the internal heater power.

Qualitative flow visualization is achieved by illuminating the entire fluid volume with a visible laser and imaging reflected light from tracer particles seeded in the fluid. Surface temperature distribution with a nominal accuracy of 0.5° C is measured using an infrared imager fitted with a zoom telescope. The surface deformation from a nominally flat surface is measured using a Ronchi test optical instrument which produces surface slope information and is sensitive to slopes between 5 and 30 micrometers/mm. This system uses the same laser beam as the flow visualization system. All of the optical systems can be adjusted to accommodate the different chamber diameters. The standard video output from these cameras is recorded on an experiment-provided 3-deck Hi-8mm videocassette recorder. Bulk fluid and boundary temperatures are measured using thermistor probes and are recorded digitally using an experiment provided data acquisition system.

The experiment can be operated either manually through interfaces on the front panel or can be automated via computer control, with ground commanding possible. Video and data downlink are also available.

2. CCFA Enhanced Capabilities. Possible enhancements of the CCFA include the use of alternate test fluids which are compatible with Spacelab safety requirements. Modifications to the test modules to include other geometries and chamber sizes are possible. Reconfiguring of the heating systems could allow variations in the imposed heating profiles and temperatures within the test chamber walls to provide uniform and asymmetric temperature boundary conditions. The addition of a second flow visualization camera could provide quantitative flow measurements using 3-D Particle Image Velocimetry. The Ronchi system could be reconfigured to provide fluid density gradient information. Repackaging of CCFA hardware as PI specific hardware for the ISS Fluids/Combustion Facility is also possible.

C. BUBBLE, DROP AND PARTICLE UNIT (BDPU)

The Bubble, Drop and Particle Unit (BDPU) is a facility developed by the European Space Agency (ESA). Its main objective is to study microgravity fluid physics phenomena in transparent liquids. The BDPU is a modular multi-user facility and is designed to be integrated into the Spacelab facility for Space Shuttle flights. The BDPU is a forerunner of more advanced facilities being developed for the International Space Station. There are a variety of diagnostic systems available to the PI on the BDPU. These include red and white background illumination systems; a cine film camera and two orthogonal video observation systems; and point defraction interferometry plus Wollaston interferometry, and Schlieren diagnostic systems. The heart of the facility is the experiment specific test container (TC) which contains the fluid cell. The TC's overall dimensions are approximately 400 x 154 x 247 mm. This volume not only contains the fluid cell, but also subsystems particular to the experiment science operations. The containers are exchanged between experiments. These TC's have had specific subsystems such as bubble/droplet injectors and extractors, thermally controlled hot/cold surfaces, curtain retraction devices, and stirring mechanisms. Experiments conducted in the two flights of the BDPU so far have studied bubble/droplet thermocapillary migration, nucleate boiling, flow instabilities in multi-layered fluids, electrohydrodynamic phenomena -- liquid cylinders, and bubble interactions in advancing solidification fronts. This facility flew eight (8) test containers (representing seven investigators) on the IML-2 mission in July 1994; and flew nine test containers (representing six investigators) on the LMS mission in June, 1996. This facility may be flown again in the future.

D. LASER LIGHT SCATTERING HARDWARE

A versatile, miniature, modular light scattering instrument has been developed at NASA Lewis Research Center for use in microgravity. Development of an enhanced multiangle Laser Light Scattering (LLS) facility is in the process. 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 (See Glovebox Laser Light Scattering). 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° to 170° with 0.25° resolution; small angle scattering from 0.10° to 10° with 0.25° resolution; Bragg scattering from 10° to 60°; and ability for sample rotation and oscillation. Flight hardware for use on the ISS is in the planning phase.

E. PHYSICS OF COLLOIDS IN SPACE APPARATUS (PCSA)

An apparatus is being developed at NASA Lewis Research Center to study colloidal phenomena in the microgravity environment of the Space Shuttle the International Space Station. In its first flight the PCS apparatus will help study fractal phenomena, growth of super-lattice structures from binary (two-component) solutions of hard-sphere colloidal particles, and behavior of polymer-colloidal mixtures (e.g. depletion flocculation). The PCS apparatus is not limited to these studies only. It offers a much broader scope in studying a wide range of fundamental problems in colloid physics, physical chemistry, chemical physics, materials science, and biological fluids.

The PCS apparatus is comprised of four basic modules. These include non-invasive dynamic light scattering (DLS), static light scattering (SLS), Bragg scattering, and rheological measurements. The apparatus also provides in-situ mixing of colloidal samples and sample images via a CCD color camera. In PCS apparatus the DLS and SLS measurements can be performed at scattering angles of 11° to 169° with a 0.1° resolution. The low angle light scattering and Bragg scattering measurements can be performed from 0.5° to 60° with a 0.25° resolution. Rheological measurements can be performed at an oscillation amplitude of 1.5° from 2-7 Hz with 0.2 Hz interval and from 7-17 Hz at 0.5 Hz interval.

F. PHYSICS OF HARD SPHERES APPARATUS (PHSA)

1. <u>PHSA Baseline Capabilities.</u> The Physics of Hard Spheres Apparatus is a general purpose laser light scattering and rheological instrument developed at NASA Lewis Research Center for probing the essential features of the hard-sphere disorder-order transition and the properties of the ordered solid phase. Measurements can be made during the disordered fluid phase, through the coexistence region, into the fully crystalline solid, and finally to the glassy phase. The suspensions that have been used are monodisperse colloidal hard spheres (0.65 to 1.0 micrometers diameter) made of polymethylmethacrylate in an index matched decalin/tetralin fluid.

The instrument is capable of accommodating 7 different fixed concentrations or suspensions and one calibration/alignment cell. Multiple types of measurements (static light scattering, dynamic light scattering, high resolution 2-D Bragg scattering, linear rheology) can be performed on the same sample cell, in the same state. Experiments can be conducted remotely and progress can be monitored via downlinked color video signal. Utilizing the instrument capabilities the investigator can determine the shear modulus and viscosity, cooperative and self-diffusion, equilibrium structure(s), thermodynamic interactions from electrostatic forces, nucleation and growth of crystallites, and atomic-level phase transitions on a macroscopic scale.

2. <u>PHSA Enhanced Capabilities.</u> Enhanced capabilities will include integration into the Fluids/Combustion Facility, on the International Space Station. The enhanced version has similar capabilities as the baseline with some notable refinements. Included in the enhanced version are non-linear rheological measurements, extended crystal growth periods greater than two weeks, ability to change the cell concentration.

G. POOL BOILING APPARATUS (PBA)

1. <u>PBA Baseline Capabilities.</u> The PBA is a microgravity fluids apparatus developed at NASA Lewis Research Center capable of autonomous operation that initiates, observes, and records nucleate pool boiling phenomena. Parameters that can be varied include heat flux and fluid subcooling. The present heat flux range is 0.5 to 8 w/cm^2, and subcooling levels from 0.3 to 22 deg. C can be achieved. This stand-alone apparatus, currently designed as a Getaway Special payload, provides its own battery power, and provides no external communication or control during flight. In its current configuration, the apparatus

accommodates fluorocarbon refrigerant R-113 as the test fluid.

The heater consists of a thin gold film applied to a fused quartz substrate. Because the gold film is semitransparent, photography of the vapor bubbles from beneath the heater surface is achieved. The present heater dimensions are 1.9 cm x 3.8 cm. The heater temperature can be determined through measurement of heater voltage, current, and subsequent calculations. To obtain a range of liquid subcooled temperatures before initiation of heating, the apparatus provides independent bulk fluid temperature and pressure control within 0.2 C and 0.7 kPa using a bellows.

Boiling phenomena are recorded by 16 mm motion picture photography at a maximum frame rate of 100 fps with a 40 mm lens and fine grain film resolution capability of 0.02 cm within the current field of view. The test chamber allows simultaneous side viewing of the heater surface and bottom (or underside) viewing though the heater/substrate window. The two views are then placed side by side onto photographic frame.

2. PBA Enhanced Capabilities. Possible PBA enhancements include the study of bubble nucleation using high speed video in the 1000 fps range. Also, studies of simultaneous boiling could be conducted using two side-by-side heaters (this an be accommodated in the existing system with only minor changes to the software). The effect of different heater geometries could be investigated. Initial research in forced convection boiling could be conducted by using variable speed stirring (this can currently be achieved with minor hardware modifications). PBA could be further enhanced to accommodate other test fluids such as water although a new test chamber made of stainless steel would be required. Repackaging of PBA hardware as PI specific hardware for the ISS Fluids/Combustion Facility is also possible.

H. TWO-PHASE EXTENDED EVALUATION IN MICROGRAVITY (TEEM)

A Shuttle flight apparatus has been developed by NASA Johnson Space Center to study flow characteristics of two-phase flow (liquid/vapor) using HFC-134a as a working fluid. Adiabatic pressure drop and flow regime studies (via high-speed photography) can be conducted in three long, straight tubes (0.249", 0.625", and 0.750" IDs) for extended durations. Flow development in "U" turns can also be studied in the 0.625" ID tube. Finally, wall shear stress and local void fraction measurements can be acquired from the 0.750" ID tube. Other section types and sizes for testing are possible.

I. CRITICAL FLUID LIGHT SCATTERING INSTRUMENT (CFLSI)

The CFLSI is a single sample facility. That is, more than one experiment could be run during a mission, but only one sample can be configured for the mission. It was developed by the University of Maryland for the Space Shuttle cargo bay Mission Peculiar Support Structure (MPESS) carrier.

CFLSI allows thermal control at temperatures near 290 K stable to less than 3 µK for 5 hours with 1 µK/cm spatial gradients. The fluid volume can be on the order of 1 cm^3. The thermal control range is roughly 283-298 K, and the thermostat relaxation time is 1-2 minutes for less than 10 mK steps and as much as 30 minutes for greater than 1K steps.

The thermostat is a multishell cylinder with optical end windows for dynamic light scattering angles of approximately 12 and 168 degrees. It uses two photomultipliers and two logarithmic time base correlators. There are two possible light paths through the cell that may be equal or unequal in their intensity. Transmission intensity is recorded by photodiodes with 16 bit A/D and one bit noise floor. The instrument supports real-time data down-link and command up-link during the mission. (There is a passive vibration isolation system that can isolate the instrument from Shuttle g-jitter over the frequency range form 10 Hz to a few hundred Hz.)

J. EXTENSIONAL RHEOLOGY INSTRUMENT

A flexible and adaptable scientific instrument that can accommodate various classes of non-Newtonian liquids is currently being developed at NASA Lewis Research Center. For example, to perform direct unambiguous measurements of the uniaxial extensional viscosity of a viscoeleastic polymer solution, and to characterize systematically how this fundamental non-Newtonian material varies with time and imposed deformation rate.

The apparatus allows for the stretching of a freely suspended cylindrical column of fluid (Boger fluid) by gripping the column with a drive mechanism that imposes the correct kinematics, eliminating unwanted shear gradient in the fluid and generating an homogeneous uniaxial stretching flow. The column is supported by a fixed and a moving endplate. The stationary endplate will have a reducing diameter device to achieve a 4:1 reduction in endplate diameter during the stretch to minimize shear stresses in the fluid. The end plate of the column will have a very sensitive force transducer capable of measuring forces in the range of 1 to 1,000,000 dynes.

Diagnostics include a digital particle image velocimetry system using CCD cameras and a laser light sheet to record fluid motion near the endplates and a two point flow-induced birefringence measurement system for non-invasive probing of the molecular level of stress generated by the extensional flow.

This apparatus is currently being developed for flight on a sounding rocket, although modifications can possibly be made to accommodate this hardware on the ISS Fluids/Combustion Facility.

K. MECHANICS OF GRANULAR MEDIA APPARATUS (MGMA)

The MGMA, developed by NASA Marshall Space Flight Center, will use the weightless environment of orbital flight to study the dynamics of soil columns confined by water under very low pressures of 1,300, 520, and 52 Pascals. Information to be examined will be load, deformation, and fluid pressure data gathered during testing, as well as changes in the soil structure, including the formation of shear bands and change in density.

The heart of the MGM apparatus is a set of three prismatic test cells, each containing a 7.5 cm in diameter by 15 cm sleeves of Ottawa F-75 banding sand, a natural quartz sand (silicon dioxide) with fine grains and little variation in size. The soil specimen, mixed with either air or water, is contained in a latex sleeve that is 0.3 mm thick and printed with a grid pattern so cameras can record changes in shape and position. The sample is held between a fixed and a movable plate driven by a stepper motor and is viewed by an array of three CCD cameras illuminated with banks of small light-emitting diodes. Each camera observes through a different side of the Lexan prism to provide full coverage of the specimen. The MGMA video control system electronically interleaves the images and delivers the video signal to a portable video recorder.

The stepper motor can be commanded, via a laptop computer, to drive the platen against the specimen in a cyclic manner at speeds of 35-1000 mm/hr. The latex sleeve will move with the sand so the grid pattern changes shape, thus revealing changes to the cameras. At the same time, additional air will be pumped into the specimen, and excess water will be removed from the jacket, to maintain specified test pressures.

L. MILLIKELVIN THERMOSTAT (MITH)

1. MITH Baseline Capabilities. This is a microgravity materials science and fluids apparatus, developed at NASA Lewis Research Center, 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 charged 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 activates 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 alpha-numerically 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 located 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.

2. <u>MITH Enhanced Capabilities.</u> 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 possible 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.

M. ANALYSE DES LIQUIDES CRITIQUES DANS L'ESPACE (ALICE-II)

This hardware is used for the study of transport phenomena and hydrodynamic instabilities in near critical fluids under variable gravity conditions. Optical means are mainly used to explore a fluid which is thermostated around its critical temperature. The fluids are contained within two 1 cm^3 sample cells mounted within 12 mm diameter windows which allow the diagnostic beams to reach the fluid under study. One of the two cells is equipped with a Mach Zender Interferometer. The two cells are set on a sample cell holder system located within a high precision thermostat which provides for reaching and maintaining the required temperature with a high degree of stability. The sample cells are installed in the thermostats before launch. During each mission the required number of thermostats are placed successively in ALICE II by a crew member and may undergo one or several experimental cycles, lasting 48 to 96 hours, and is defined before the flight by means of a cassette installed in the instrument. The data are comprised of video images and of scientific and technological parameters. The images are recorded on HI-8 type video cassettes and one is needed for each experimental cycle. The numerical data are recorded on PCMCIA cards or the programming cassette.

The response of the near critical fluid to calibrated temperature ramps and heat pulses, given by a thermistor, are explored by the means of the following diagnostic equipment: transmissivity measurement, small angle scattering, interferometry, full field observation, grid shadow graph, and microscopic observation. Typical fluid working temperatures are 30-70 C with a temperature stability of about 40 μK/hour. Quench capability is also included.

N. GLOVEBOX

The overall philosophy of the Glovebox program is to provide the ability to conduct smaller, less complex science experiments or technology demonstrations in a microgravity environment in a faster, better, and cheaper manner. The hardware development cycle runs approximately 2-3 years. The Glovebox is intended to be used a generic platform for conducting a wide range of experiments. It is especially well suited for experiments that require containment of materials, both fluid and solid. Experiments developed for the Glovebox are expected to be relatively small and self-contained yet can be of a sophisticated nature using state of the art diagnostics. Various services are available in the Gloveboxes including power, video, still photography, a laptop computer for experiment control and data acquisition, and cleaning supplies. In general these experiments are less automated and require significant crew involvement in their operation and in the scientific decision making process. At this time, 12 Glovebox Investigations in the disciplines of materials science, fluid physics, biotechnology, and combustion science are under development. Several versions of Gloveboxes have been flown on the Shuttle Spacelab and Middeck as well as the Russian Mir Space Station. A Microgravity Science Glovebox for the International Space Station is currently under development.

The Middeck Glovebox (MGBX) facility is an enclosed volume that provides physical isolation of various experiments from the middeck and enables crew member manipulation of these experiments through gloveports. The MGBX provides containment of powders, splinters, liquids, flames, or combustion products which may be produced from experiment operations. The MGBX occupies two standard lockers in the space shuttle middeck. The MGBX door opening to insert or retrieve experiment hardware is about 20.3 cm by 19.4 cm. The working volume is about 35 liters and is approximately 45 cm wide, 30 cm deep, and 25 cm high.

An air filtering system protects the middeck environment from experiment products. Forced air cooling can withdraw a maximum of 60 watts of experiment generated heat. Up to 60 watts of experiment power can be provided via a protected 28 VDC line. A power converter box is also available which can provide +24, +5, +12, and -12 VDC lines.

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. Airtight gloves or non-sealed cuffs are mounted in the two gloveports. Multipurpose filters remove particles, liquids, and reaction gases from the recirculated air. Pressure, humidity, and temperature sensors are utilized to monitor filter performance.

Video and 35 mm cameras are the primary method utilized for gathering data. The MGBX has three CCD video cameras. The camera control electronics are contained within the MGBX, while the camera heads can be mounted external to the MGBX and positioned to view through the specialized video ports, or through the large window on top of the MGBX. The videoports allow the camera heads to swivel to view the entire working area. Both black and white and color videocameras are available. Three video recorders provide data storage, with digital data stored in the audio channels (up to three audio and three discrete channels of data can be recorded). 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 determined on a mission-by-mission basis. Adjustable lighting, video port plugs, a backlight panel, a halogen flashlight, and a stray light window cover provide different photographic options.

The Microgravity Science Glovebox (MSG) will be a larger version of the Middeck Glovebox. The MSG will have a larger work area to allow larger size and mass experiments to be conducted inside the Glovebox.

The MSG will provide up to 1000 watts of experiment power, a vent connection, a nitrogen connection, an airlock, illumination, color and black and white video cameras and recorders for viewing, recording, or downlinking, and miscellaneous tools and cleaning supplies. It is envisioned that experiments will be conducted in the areas of fluid physics, combustion science, materials science, and biotechnology. The MSG will be developed by the European Space Agency and will be available for use soon after the deployment of the US Laboratory Module of the ISS.

O. GLOVEBOX EXPERIMENT HARDWARE

1. Glovebox Laser Light Scatterer. A compact instrument has been designed that is capable of both static and dynamic light scattering. This instrument was designed to operate in the various versions of the 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° 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 (approximately 30°-160°). Test samples can be oscillated about the cell axis with affixed 2° 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.

2. Typical Fluid Physics Glovebox Experiments:

a. Oscillatory Thermocapillary Flow Experiment (OTFE) is a small scale version of the CCFA used to study surface tension driven flows in cylindrical geometries.
b. Interface Configuration Experiment (ICE) explores certain aspects of liquid/vapor interface behavior, primarily the uniqueness of certain mathematical predictions of fluid configurations in the absence of gravity.
c. Colloidal Disorder-Order Transitions (CDOT) uses colloidal suspensions of microscopic solid plastic spheres as a model of atomic interactions.
d. Binary Colloidal Alloy Test (BCAT) investigation will conduct fundamental studies of the formation of colloidal superlattices and large scale fractal colloidal aggregates/gels.
e. Colloidal Gelatin (CGEL) investigation is to conduct fundamental studies of the formation and structure of colloidal superlattices, large scale fractal colloidal aggregates and colloid-polymer mixtures by investigating the physical properties and dynamics of these formations.
f Angular Liquid Bridge (ALB) investigation is to observe the discontinuous behavior phenomena for liquid bridges including the shape and stability of angular liquid bridges, the rate of spreading of liquid in a wedge vertex, the corner discontinuity for interfaces on interior corners, and the effects of hysteresis on the predicted discontinuous behaviors.
g. Capillary Heat Transfer (CHT) investigation is to gain an improved understanding of the mechanisms leading to unstable operation of and failure of capillary pumped heat transfer devices in low gravity and demonstrate that instabilities with an evaporating meniscus are responsible for unreliable operations.
h. Internal Flows in a Free Drop (IFFD).
i. Bubble and Drop Non-linear Dynamics (BDND).

P. MULTI-PHASE FLOW APPARATUS (MPFA)

The MPFA would be developed for the study of a pressure or pump driven liquid and gas mixture flowing in a conduit. The MPFA could accommodate study of two-phase flow patterns, interfacial stability, and multiple bubble and droplet hydrodynamics by measuring void fractions, film thickness, pressure drop, and flow rates. Although the MPFA might be developed for use in either the Spacelab or the International

Space Station laboratory module, the eventual need for long straight conduit sections will probably require its implementation in the Shuttle cargo bay.

The test section would be photographed with high speed video cameras. The MPFA would supply two, or possibly three test fluids, as well as air or N_2. Gas velocities within the MPFA test section could vary between 0.05 m/s and 20 m/s and liquid velocities could vary between 0.05 m/s and 1 m/s. The apparatus is expected to support either step-changed or ramped flow rates. Variables such as the test section pressure drop, film thickness, and void fractions could be monitored using standard instrumentation or advanced diagnostics. One possible MPFA configuration would consist of two parallel test sections, each with separate cameras and lights.

II. 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 fluids program include two drop towers at the Lewis Research Center (LeRC), and an evacuated drop tube at the Marshall Space Flight Center (MSFC), and parabolic flight research aircraft. A variety of specialized test rigs have been constructed and used to conduct a wide range of microgravity fluid physics research. In general these rigs have been developed to accommodate specific individual investigator's requirements. In addition, other capabilities have been developed which have the potential for use by multiple investigators/investigations. These include: two-phase flow test rigs, a computational lab, complex fluids cell flight hardware lab, and quench furnace with x-ray. In general, these facilities provide a variety of capabilities which investigators can select to support their series of experiments.

A. 2.2-SECOND DROP TOWER

The 2.2 Second Drop Tower is a heavily utilized reduced gravity facility at LeRC that plays a key role in the support of Microgravity Science. It routinely supports over 1000 test drops per year (the daily test schedule allows up to 12 drops). The facility consists of a shop for experiment buildup, integration and testing; several small laboratories for experiment preparation and normal gravity testing; electronics support rooms and an eight story tower in which the drop area is located.
The Drop Tower at LeRC provides 2.2 second of low gravity test time for experiment packages with payload weights up to 139 kg. Rectangular experiment packages are dropped under normal atmospheric conditions from a height of 79 ft. Air drag on an experiment is minimized by enclosing it in a drag shield. A gravitational acceleration level of less than 10^{-4} g is obtained during the drop as the experiment package falls freely within the drag shield. The only external force acting on the falling experiment package is the air drag associated with the relative motion of the package within the enclosure of the drag shield. A drop is terminated when the drag shield and experiment assembly impact an air bag. The deceleration levels at impact have peak values of 15 to 30 g.

Data can be acquired by high-speed motion picture cameras as well as video cameras. Video signals are transmitted to remote video recorders via a fiber optic cable that is dropped with the experiment. Onboard data acquisition and control systems also record data supplied by instrumentation such as thermocouples, pressure transducers, and flowmeters.

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 300 kilograms are mounted in a one meter diameter by 3.4 meter high drop bus. Gravitational 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 ramps up to 65 g (in 150 milliseconds). Visual data is acquired through the use of on-board, high-speed motion picture cameras and 8mm video recorders. Also, other data such as pressures and temperatures are recorded on board with various data acquisition systems. Deceleration data are transmitted to a control room by a telemetry system. Due to the complexity of drop chamber operations and time required for pump-down of the drop chamber, only one or two tests are performed per day.

C. 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 with ceramic or glass materials.

D. PARABOLIC FLIGHT RESEARCH AIRCRAFT

The parabolic research aircraft can provide up to 40 periods of low gravity for up to 25-second intervals each during one flight. The aircraft accommodate a variety of experiments of different sizes and is often used to refine space flight experiment equipment and techniques and to train crew members in experiment procedures, thus giving investigators and crew members valuable experience working in a weightless environment. The aircraft obtain a low gravity environment by flying a parabolic trajectory. Gravity levels 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 bay dimensions are approximately 3 meters wide and 2 meters high by 16 meters long. Several experiments, include a combination of attached and free-floated hardware (which can provide effective gravity levels of 10^{-3} g for periods up to 10 seconds) can be integrated in a single flight. Both 28 VDC and 100/115 VAC power are available. Instrumentation and data collection capabilities must be contained in the experiment packages.

E. TWO-PHASE FLOW TEST RIGS

Two gas-liquid flow loops exist that have been used to conduct testing aboard parabolic flight research aircraft at gravity levels of 0.01, 0.05, 0.17 (lunar), 0.33 (martian) and 0.50 g's are available. Both of these flow loops are blowdown types of systems whereby the liquid (water, a water-glycerin solution to ascertain the effects of the viscosity, and a water-surfactant solution to ascertain the effect of surface tension) and gas (air) are delivered from supply tanks to a collector tank via an instrumented test section. One flow loop can be used for testing with a 1.27 cm inner diameter test section, and the other flow loop can be used for testing with a 2.54 cm inner diameter test section. The liquid is recirculated between tests and the gas is vented into the aircraft cabin.

The air and liquid are metered into a mixer and flow into the test section that can be instrumented with conductivity probes, which necessitates the use of "conductive" liquids, differential pressure transducers and hot film anemometers. Data acquisition rates of up to 1000 Hz are possible. Photographic data can be recorded at rates of 400 frames per second. Superficial gas velocities of 0.1 to 25 m/s and liquid velocities for 0.1 to 1.1 m/s are possible. Tests are conducted at atmospheric pressure. Adiabatic as well as sensible heat transfer tests can be conducted with the appropriately designed test sections.

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velocities for 0.1 to 1.1 m/s are possible. Tests are conducted at atmospheric pressure. Adiabatic as well as heat transfer tests can be conducted with the appropriately designed test sections.

F. COMPUTATIONAL LABORATORY

A laboratory for numerical modeling fluid flows as influenced by thermal gradients, concentration gradients, surface tension, magnetic fields gravitational acceleration, g-jitter, and other driving forces have been established at NASA Lewis Research Center. The emphasis is on physically based models giving quantitative flow descriptions. The lab has commercial and specialized software operating in a workstation environment with access to mainframes as necessary. It is available to funded investigators and their graduate students or modeling service may be requested of the staff.

G. QUENCH FURNACE WITH X-RAY

The Quench Furnace with X-Ray is also available for ground-based low gravity research at NASA Lewis Research Center. 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 an x-ray scanning and high resolution CCD camera.

H. LOW TEMPERATURE FURNACE WITH QUENCH

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

I. COMPLEX FLUIDS CELL FLIGHT HARDWARE LAB

This lab at LeRC has been used to build test cells for a variety of complex fluids instruments. The lab is capable of designing, building, filling, and 1-g testing optical cells for liquid-vapor critical fluid experiments. Cells are assembled to interferometric requirements and filled to <0.3% of the critical density for a 0.1 cm^3 fluid volume. Leak rate tests as low as $3x10^{-10}$ std. cc/sec can be performed. Lab thermostats are capable of ±0.1 mK control for samples above room temperature in both wet and dry thermostats. Interferometry, light transmission, light scattering, and optical imaging tools are also available. The CFLSI flight hardware is maintained in this lab.

The lab has performed electric field experiments on critical binary mixtures with voltages up 50 kV using light scattering. Acoustic experiments have been performed in liquid-vapor critical fluids employing continuous wave and pulse excitation and detection in this lab.

III. MICROGRAVITY FLUID PHYSICS DIAGNOSTIC/MEASUREMENT CAPABILITY

NASA has adapted or developed a number of diagnostic/measurement techniques for microgravity fluid physics research. Techniques currently under development that are expected to become available in the near future or are currently available are described below.

A. 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 range of operating conditions while automatically compensating for gross surface motion. 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 it optical an electronic building blocks developed for the laser light scattering program at NASA Lewis along with several unique surface light scattering components and new algorithms.

B. COMMON-PATH INTERFEROMETRY (CPI)

Because of a great need for measuring two-dimensional temperature/density distribution in transparent fluids used in many fluid physics experiments, the CPI is being developed and tested for some ranges of flow conditions. The CPI is a new, robust, compact, quantitative common-path interferometer that could use a low power He/Ne laser as a light source. The instrument has a minimum number of optical components which can be used for ground-based and flight experiments. It can be easily converted into Schlieren/or shadowgraph instruments capable of handling a variety of fluid experiments. This includes real-time, steady, and non-steady fluid flow conditions.

C. 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.

D. BIREFRINGENCE MEASUREMENTS

A system for measuring flow-induced birefringence in a transient extensional flow has been packaged for microgravity experimentation. The system uses modulation techniques with AC detection and a single wavelength source to simultaneously measure the retardance and extinction angle in order to determine the conformation of polymer molecules. The apparatus also provides a simultaneous measurement of the diameter of the polymer solution.

E. ADDITIONAL TECHNIQUES

The following techniques are in already in use or currently under development:

1. Two dimensional particle imaging velocimetry
2. Rainbow Schlieren for measurement of temperature distributions
3. Light sheet flow visualization and/or velocimetry
4. Miniaturized laser doppler velocimetry
5. Liquid surface temperature and vapor phase concentration measurements via Exciplex Fluorescence

APPENDIX C
NRA-96-HEDS-01

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS FOR SOLICITED PROPOSALS

(June 1995)

1. Foreword

a. These instructions apply to NASA Research Announcements. The "NASA Research Announcement (NRA)" permits competitive selection of research projects in accordance with statute while preserving the traditional concepts and understandings associated with NASA sponsorship of research.

b. These instructions are Appendix I to 1870.203 of the NASA Federal Acquisition Regulation Supplement.

2. Policy

a. Proposals received in response to an NRA will be used only for evaluation purposes. 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.

b. 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 supplement documents identified as "NASA Research Announcements." The NRAs contain programmatic information and certain requirements which 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 NRAs.

4. Relationship to Award

a. A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. 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. Contracts resulting from NRAs 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 mandatory forms or formats for preparation of responses to NRAs; however, it is requested that proposals conform to the guidelines in these instructions. 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, 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.

6. NRA-Specific Items

a. Several proposal submission items 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.

7. Proposal Contents

a. The following information is needed in all proposals in order to permit consideration in an objective manner. NRAs 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 other organizations that are currently evaluating a proposal for the same efforts;

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

(7) Dollar amount requested , 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**

Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on 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 contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

NOTICE --- Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

d. **Abstract**

Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective 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; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to

be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is 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 arrangements for ensuring a coordinated effort should be described. Intensive working relations with NASA field centers that are not logical inclusions elsewhere in the proposal should be described.

g. Personnel

The Principal Investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch 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.

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

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; consultants; subcontracts; other 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. If the research requires access to or may generate security classified information, the submitter will be required to comply with - Government security regulations.

k. **Current Support**

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

l. **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. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which 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 may renew an effort either through amendment of an existing contract or by a new award.

9. Length

Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. - Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. 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. Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

b. Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which 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 received after the date or dates specified in an NRA may 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. Offerors 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) Offeror's 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 critical in achieving the proposal objectives.

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

d. Evaluation of the cost of a proposed effort includes the realism and reasonableness of the proposed cost and the relationship of the proposed cost and 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 proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house 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. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, 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. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a de-briefing.

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. 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 to cancel this NRA. 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.

APPENDIX D
NRA-96-HEDS-01

NASA RESEARCH ANNOUNCEMENT (NRA) SCHEDULE

MICROGRAVITY FLUID PHYSICS:
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 EDT). 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 3, 1996

Letter of Intent Due: ....February 18, 1997

Proposal Due: ....March 18, 1997

Submit Proposal to:

Alexander D. Pline
c/o Information Dynamics Inc.
Subject: NASA Research Proposal (NRA-96-HEDS-01)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

Final Selections: ....October 20, 1997

Funding commences: ....November 20, 1997
(dependent upon actual selection and procurement process)

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	12. COSTS REQUESTED FOR FIRST 12-MONTH BUDGET PERIOD		13. COSTS REQUESTED FOR ENTIRE PROPOSED PROJECT PERIOD	
	12a. Direct Costs	12b. Total Costs	13a. Direct Costs	13b. Total Costs
From: Through:	$	$	$	$

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)*		**EFFORT ON PROJECT**	**SALARY**	**FRINGE BENEFITS**	**TOTALS**
NAME	**ROLE IN PROJECT**				
	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*** *completely. Check only 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.***

Mailing list updates may also be submitted electronically via E-Mail or World Wide Web to the following addresses:
E-Mail: list@hq.nasa.gov
World Wide Web: https://peer1.idi.usra.edu/

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: ____

Org. (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

☐ Please send me notifications of announcements via E-Mail only.

PLEASE TAPE (DO NOT STAPLE)

PLACE STAMP
HERE
POST OFFICE
WILL NOT
DELIVER
WITHOUT PROPER
POSTAGE

INFORMATION DYNAMICS, INC.
300 D STREET, SW
SUITE 801
WASHINGTON, DC 20024

NASA
OFFICIAL MAILING LIST
UPDATE