

"MICROGRAVITY SCIENCES APPLICATION VISITING SCIENTIST PROGRAM"

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QUARTERLY PROGRESS REPORT

MICROGRAVITY SCIENCES APPLICATION VISITING SCIENTIST PROGRAM

CONTRACT NAS8-38785

December 20, 1991 - February 23, 1995

Statement of Work

Marshall Space Flight Center pursues scientific research in the area of low-gravity effects on materials and processes. To facilitate these Government performed research responsibilities, a number of supplementary research tasks were accomplished by a group of specialized visiting scientists. They participated in work on contemporary research problems with specific objectives related to current or future space flight experiments and defined and established independent programs of research which were based on scientific peer review and the relevance of the defined research to NASA microgravity for implementing a portion of the national program.

The programs included research in the following areas: protein crystal growth, X-ray crystallography and computer analysis of protein crystal structure, optimization and analysis of protein crystal growth techniques, and design and testing of flight hardware.

Objective

USRA established, managed, and maintained a broad program for visiting scientists to benefit the ongoing and evolving research needs of Marshall Space Flight Center in the area of microgravity science and applications. These visiting scientists contributed in continuing research in the areas of crystal growth, metals and alloys, fluid dynamics, protein crystal growth and analysis, biotechnology, chemistry, and polymeric materials for non-linear optics, as well as appropriate new areas relevant to the discipline. Technical work on all listed tasks began at the award of the contract. Individual sub-tasks (research programs) were accomplished on independent schedules dictated by funding and technical considerations.

USRA recruited quality research and technical personnel from the general university or industrial community to accomplish specific research programs within a definite time frame.

Although the specific research conducted under this contract was intended to be responsive to evolving scientific perspectives, certain specific, core research programs were required. Also, such as:

- Determination of the structure of human serum albumin and other biomedically important proteins.
- Analysis of thermodynamic properties of various proteins and models of protein nucleation.
- Development of experimental techniques for the growth of protein crystals in space.
- Study of the physics of electrical double layers in the mechanics of liquid interfaces.
- Computational analysis of vapor crystal growth processes in microgravity.
- Analysis of the influence of magnetic fields in damping residual flows in directional solidification processes.
- Crystal growth and characterization of II-VI semiconductor alloys.

- Production of thin films for nonlinear optics.
- Analysis of metals and alloys research and applications.
- Develop peltier pulsing for flight experiment.
- Analysis of combustion science.

It was not intended that the programs be necessarily limited to this set at any one time. The visiting scientists accomplishing these programs served on-site at MSFC to take advantage of existing laboratory facilities and the daily opportunities for technical communications with various senior scientists.

Occasionally, USRA scientists established new and well defined scientific theoretical and experimental research programs in the general microgravity disciplines of chemistry and polymeric materials, electronic and photonic materials, and biotechnology. The identification of these programs was based on the evolving requirements to maintain space flight science and applications programs on Spacelab and Space Station.

USRA had the responsibility to assure the best application of limited resources through the effective identification of research areas and personnel.

To assure the most authoritative sources and information were utilized in decisions concerning scientific approaches and the development of visiting scientists' research, USRA participated in established science reviews and conferences concerning applicable NASA research programs and provided expertise to these groups as dictated by the contemporary progress in the fields. In addition, the USRA supplemented these existing reviews, as necessary, with special topical reviews by appropriate government, university, or industrial scientists for the purpose of evaluating specific materials processing in space problems related to the visiting scientists' programs. In association with this task, USRA maintained a summary of important scientific results related to the visiting scientists' research. This task was considered a key element in the effective development of research tasks and the scientific progress of individual research personnel.

Finally USRA performed administrative functions for employees and activities related to the visiting scientist program.

Visiting Scientists

The following Visiting Scientists performed research studies of the Protein Crystal Growth (PCG) and separation methods used to purify proteins and other biological samples prior to studies such as PCG; solid materials characterization for the electronic materials branch; and research in synthesis and characterization of non-linear optical materials, for the electronic and photonic materials branch. They are listed in alphabetical order:

Andrew Gregory, student research assistant (5/17/93-8/18/93)

Dr. Richard Grugel, optical microscopy, SEM, TEM, directional solidification techniques, and the use of organic analogs to simulate phenomena occurring in metallic systems; (7/5/94-2/3/95)

Ms. Elizabeth Forsythe, protein solubilities, purification, separation and crystallization; (10/20/91-2/3/95)

Mr. Spencer Guthrie, student laboratory assistant, (5/23/94-2/3/95)

Dr. Joseph Xiao-min Ho, crystal growth;(10/20/91-8/26/94)

Ms. Emilie Johnson, student laboratory assistant; (2/17/94-2/3/95)

Dr. Merrill King, combustion study and analysis of various chemical programs; (2/1/93-2/3/95)

Dr. Manfred Lichtensteiger, growth and characterization of electronic materials; (11/15/93-2/3/95)

Ms. Laurie Matthews; student laboratory assistant; (2/26/94-1/5/94)

Mr. Rick McConnell, program management; (11/15/93-2/3/95)

Mark Steven Paley, synthesis and characterization of non-linear optical materials; (10/20/91-2/3/95)

Dr. Narayanan Ramachandran, fluid dynamics; (10/20/91-2/3/95)

Dr. Terry Rolin, characterization of superconductors; (4/19/93-2/3/95)

Dr. Yi-Gao Sha, crystal growth; (12/1/92-2/3/95)
2/3/95)

Dr. Laurent Sibille, protein solution chemistry; (10/20/91-2/3/95)

Till Rosenberger, student research assistant (7/10/92-7/30/93)

Dr. Ching-Hua Su, solid materials characterization;(10/20/91-8/29/94)

Ms. Pamela Twigg, protein crystal growth; (10/20/91-2/3/95)

Activities Performed

Ms. Elizabeth L. Forsythe completed the following tasks:

Chicken egg white lysozyme was the standard test material utilized to investigate protein crystal growth and nucleation and the determination of protein solubilities is one typical way to study the macromolecular crystal growth process. A rapid technique to determine protein solubilities was developed at Marshall Space Flight Center, MSFC, in 1988. Using this technique, Ms. Forsythe has extensively studied the solubility of lysozyme at various conditions. The phase diagram of orthorhombic or the high temperature form of lysozyme was completed and published in 1994. This work was presented as a poster at the Fifth International Conference on the Crystallization of Biological Macromolecules in August of 1993. Earlier in 1993, the solubility phase diagram for tetragonal lysozyme with sodium bromide as the precipitating agent was initiated. However, this work was temporarily suspended in order to complete the orthorhombic study. In addition, a phase diagram for the same protein was initiated in order to study the effects of buffer concentration on the solubility.

A continuous search for the crystallization parameters of various proteins has always been a priority. Without a complete understanding of protein crystal growth and nucleation, crystallization trials are only a broad attempt to coax the proteins into a crystallizable form. In the past three years, Ms. Forsythe has worked on crystallization conditions for several proteins such as prothrombin, ovostatin, concanavalin A, edestin, ribonuclease, ovotransferrin, and lysozyme. Ovostatin, ovotransferrin and lysozyme are proteins that are available from chicken egg whites. Concanavalin A and edestin are storage proteins from seeds such as Jack Bean and Hemp.

Prothrombin is a clotting protein from cow blood. The biochemical functions of several of the proteins, such as ovostatin, lysozyme and prothrombin, are equivalent to their human protein counterparts.

During the course of this contract, Ms. Forsythe studied lysozyme extensively and has conducted crystallization trials involving mineral substrates. These substrates provide controlled nucleation sites for proteins. She has also experimented with various precipitating agents such as sodium bromide, sodium iodide, rubidium chloride and lithium nitrate in order to study ionic effects. Another interesting experiment involving lysozyme was completed recently in which the purity of the protein was evaluated. This study included purification and crystallization trials at basic pH. The manuscript is complete and was submitted January 31. A few weeks ago, a study involving the storage of proteins was initiated with lysozyme and other suitable proteins. This information will be used for future flight experiments on the space shuttle and the space station.

The overall effects of solution parameters such as pH, temperature, salt (precipitant), and buffer concentrations on protein crystal growth have been studied with a unique computer-controlled apparatus assembled at MSFC. Using this apparatus, Ms. Forsythe produced ~500 experimental runs in the past 2½ years. These experiments supply data concerning nucleation and aggregation that supports the modeling of a growth mechanism. Our mechanism for lysozyme crystal growth involves the formation of an aggregate growth unit (octamer), the mass transport of the growth unit to the crystal interface and faceted crystal growth by growth unit addition.

Secondary responsibilities included duties such as monthly eye wash testing, procurement, reporting equipment failures, and a yearly chemical inventory. In addition, a chemical hygiene plan for the Biophysics Branch (ES 76) was prepared with the collaboration of Donna Donnelly and Pam Twigg.

As the Hazardous Waste Officer, Ms. Forsythe served as primary interface with the Hazardous Waste Branch at MSFC in order to identify and maintain hazardous waste streams. She also supported the lab (Room 411) by assisting in training new personnel and preparing a standard operating procedure manual.

Dr. Joseph Xiao-Min Ho completed the following tasks:

He participated in Protein Crystal Growth Project, assessed qualities of crystals grown from a number of Space Shuttle missions, and results have been published in scientific literature.

In the capacity of Co-Investigator, Dr. Ho developed new micro-gravity protein crystal growth hardware (PCAM), which has been test flown successfully on Space Shuttle Mission STS-62.

Dr. Ho solved the difficult and important protein structure of serum albumins and published extensively on this subject in NATURE, SCIENCE and many other scientific journals (See Publications and Presentations Section of this report). He initiated a new approach for analyzing molecular thermal vibrations using diffraction data. The results were published in major crystallographic journal.

Dr. Ho determined the structure of the first human monoclonal antibody against the HIV-1 virus transmembrane GP41, the information is being used to develop more effective AIDS test kits. He also solved the structure of protein glutathione s-transferase fused with HIV-1 epitope. This structure has significance both in the AIDS study and in research for infectious disease Schistosomias.

Dr. Richard Grugel completed the following tasks:

He organized the laboratory to perform experiments and became familiar with the facilities and personnel to conduct research regarding the influence, or lack, of gravity on microstructural development during the solidification of metals and alloys.

He used a reasonable casting furnace and a furnace and drive unit capable of performing controlled directional solidification experiments. Some cursory investigations of monotectic and eutectic alloys were completed and, in view of microstructural examination, the assembly appears to be in good working order. Some supplies, primarily refractories and small machine parts, have been ordered and received.

In addition to beginning experimental work, discussions with a number of collaborators were initiated with the aim of responding with strong proposals to NASA NRA's. Consequently, in response to NASA's 1994 Innovation Research Proposal NRA 94-OSS-16, two proposals have been submitted. The titles are "Encapsulation of Soft Metals for Slide Bearing Applications" (co-investigators are Dr. Taylor G. Wang Professor of Applied and Engineering Sciences and Director, Center for Microgravity Science and Applications, Vanderbilt University, Center for Microgravity Research and Applications, P.O. Box 6079-B Nashville, TN 37235; Dr. Lucien N. Brush, Assistant Professor, University of Washington, Department of Materials Science and Engineering, Seattle, WA 98195 and; Ms. Carol Mackus, Senior Experimental Metallurgist, Electromotive Division of GM, 9301 West 55th Street, La Grange, IL 60525) and "Novel Solidification Processing of Hypermonotectic Alloys" co-investigator is Dr. J. Iwan D. Alexander, Associate Research Professor of Physics, The University of Alabama in Huntsville, Research Institute M-41, Huntsville, AL 35899).

Ms. Emilie Johnson completed the following tasks:

she prepared elastomer tops for flight hardware and cut them out. She made buffers for setting up crystallization plates and made sodium azide water for the laboratory. She also assisted with other small projects.

Dr. Merrill King completed the following tasks:

He served as a Senior Visiting Scientist assigned by USRA to NASA Headquarters to define program goals and objectives for the Microgravity Combustion activity as part of the Microgravity Sciences and Application Division. He established priorities, determined manpower and funding requirements to achieve the objectives, and supervised NASA field center (Lewis Research Center in the case of the combustion program) and university projects. As part of this activity, he managed a peer review process of proposals submitted in response to a NASA Microgravity Combustion Research Announcement (to be described in more detail below) and was involved in several reviews (Concept Design Reviews, Requirements Definition Reviews, and Preliminary Design Reviews) for eight projects in the Flight/Flight Definition activity. In terms of planning activities, he participated in an MSAD Science Branch Meeting held in Boulder, CO, in late 1993 and another such meeting in Huntsville, AL, in late 1994. He also participated in a Program Operating Plan Review at Lewis Research Center.

In the flight experiment program area, Dr. King developed scientific rationale for proposing programs to enter Flight Definition, and, as mentioned above was quite active in the ongoing review of such programs; as part of this activity, he carefully reviewed the Science Requirements Document generated by each Principal Investigator in the Flight Definition Program, often suggesting changes as needed. In addition, as a participant in the flight program reviews mentioned above, he selected Science Review Panel members from the outside combustion community and, in concert with these panelists, derived requirements for improvements in these programs before passing them on to the next stage of development. Dr. King was the internal reviewer for flight programs and was also active in review of programs planned for Glovebox experiments (e.g., USML-2 Glovebox Review, held in September, 1993).

In the area of peer review of proposals, Dr. King was involved heavily in the development of NRA-93-OLMSA-01, "Microgravity Combustion Science: Research and Flight Experiment Opportunities", issued on June 11, 1993. As part of this activity, he developed a set of mailing lists, ensuring that anyone who might have any interest in this solicitation would receive a copy of the NRA. In addition, announced the NRA in the Commerce Business Daily on May 20, 1993. Once the NRA had been issued, he fielded numerous questions from potential bidders and collected a list of approximately 140 letters of intent to propose. In parallel to this activity, he generated a file of approximately 300 possible reviewers, broken down by combustion research subcategories. By late September (proposal due date), Dr. King had logged 98 proposals into the NASA system and, after reading each of them, broke them down into three major categories for panel review (one panel for each category) and formed panels of peers from the academic and industrial community to review these proposals. He then forwarded each a package consisting of the proposals, review forms, and instructions.

The first panel, consisting of eleven reviewers and covering 36 proposals in the gas flames area met on Nov. 8-9, 1993, at NASA Headquarters to separate the proposals into "Highly Qualified," "Qualified," and "Unqualified" categories along with assigning numerical scores to each. A second panel with nine external reviewers, covering 30 proposals in the areas of droplets, sprays, particles, and dust clouds similarly met at NASA Headquarters on Dec. 2-3. A final panel with ten external reviewers, covering 32 proposals in the areas of surface combustion, smoldering, and combustion synthesis met on Dec. 13-14. Following these three panel reviews, Dr. King selected thirteen of the most favorably rated proposals for consideration for Flight Definition, and submitted these to an Engineering Panel at Lewis Research Center for review of their suitability for various potential carriers. After this panel completed its review, he met with the Combustion Program Manager, the Chief Scientist of MSAD, and two representatives from Lewis for discussion of their findings and down-selecting of those proposals being considered for Flight Track (those so eliminated from contention for immediate entry to the Flight Track still remaining eligible for the Ground-Based program).

Next, he carefully reread the top fifty proposals (all rated by the review panels as Highly Qualified or Qualified) along with the detailed written reviews provided by the panelists and factored in questions of program priorities and balance to come up with a "straw-man" list of suggested Principal Investigators for both Ground-Based and Flight Definition funding, to be reviewed by the entire Science Branch of the Microgravity Science and Applications Division. As part of this preparation, he generated one-page summaries of proposal content, peer review panel findings/ratings, his recommendations, and the rationale behind them for each of these fifty remaining proposals. In addition, he generated a table indicating how questions of program

balance entered into his recommendations and additional budget tables indicating how the proposals being recommended would fit within the planned allocations. From the final MSAD meeting, 33 proposals were selected for the Ground-Based program, while six were selected for Flight Definition. Subsequent to these decisions, Dr. King generated award and declination letters in mid-March, 1994. In addition, a list of successful proposers was assembled for a Press release. Finally, he generated a document describing the activities involved in the entire process, to be used as a guide in future procurements.

As indicated above, Dr. King supplied each proposer panel summaries regarding his/her proposal, "cleaned-up" copies of each individual panelist's reviews, and a brief summary of his considerations. Several proposers did call to express regret at not being selected. One case requested a four-page letter with more details regarding the declined decision.

Another of Dr. King's functions at NASA involved providing data and information acquired by investigators in the Microgravity Combustion program to various NASA planning committees to aid in the examination of the feasibility of future research and development directions. In this area, he actively developed (and continuously updated) individual files for each Principal Investigator and cataloged information on their programs. Of particular importance in this area, was his continuing interaction with the Microgravity Combustion Discipline Working Group. His most recent meeting with this advisory group was held in March, 1994, with topics including presentation of a status report on awards from the most recent Combustion NRA, discussion of the next Microgravity Combustion Workshop and NRA release (scheduled for the spring of 1995), review of NASA/LeRC archiving efforts, and discussion of the Microgravity Combustion Discipline Science Plan Appendix which Dr. King generated. Also in this area, he reviewed on a regular basis the Experiment Data Packages for various flight programs (e.g., Candle Flames, Wire Inflammability, Microgravity Smoldering Combustion, and Solid Surface Combustion Experiment); it was very important that these plans be carefully put together to ensure that data obtained in our flight experiments are made available to other investigators in the field.

As indicated earlier, another very important aspect of Dr. King's position involved continuous reviewing/monitoring of the various programs being funded in the Microgravity Combustion program, particularly those in the Flight/Flight Definition area. As part of his responsibilities in this area, Dr. King recommended action on contracts and grants in his discipline and evaluated progress on ongoing tasks, recommending (with the aid of external peer review panels) changes or solutions to problems and/or redirection of effort as required. In this activity, he administered, reviewed, and obtained necessary approvals for any changes or modifications to selected investigations or change in any investigator's status. Dr. King was heavily involved in reviews at various levels on the CM-1 (Combustion Module) and the two investigations (Laminar Soot Processes and Structure of Flameballs at Low Lewis Numbers) planned for it. This activity included selection of Science Panels for review of the science involved, conduct of Requirements Definition Reviews, review of Science Requirements Documents, and participation in a recent Preliminary Design Review.

As part of this activity, Dr. King prepared packages for the Lewis Project Scientists regarding what was needed to be done to finalize the Science Requirements Documents for these two programs based on results of the Requirements Definition Reviews, relying particularly on inputs from the science review panels involved. In addition, he was involved in several reviews (informal and formal) on the Droplet Combustion Experiment, on which considerable scientific progress

was made over the last year. Further, he was involved in reviews for the Spread Across Liquids Program (Sounding Rocket), the DARTFire Program (Sounding Rocket), the Microgravity Smoldering Combustion (GASCAN), and the Turbulent-Gas-Jet-Diffusion Flame (GASCAN) programs over the last year. On several of these, Dr. King generated "Authority to Proceed to Flight Development" letters for signature by MSAD management, while on others, he recommended delay until certain shortcomings were corrected.

As Program Scientist for the Microgravity Combustion program, Dr. King, via interactions with the Program Manager, the Chief Scientist, and others within MSAD recommended efforts and funding in related areas (e.g., Advanced Technology Development) whose output can be beneficial to the Microgravity Combustion program. In this realm, he participated in the Graduate Student Research Program Reviews and Advanced Technology Development Program Review and Proposal Decision Meetings as well as reviewing letters-of-intent to the annual (generic) NRA. In addition, he reviewed annual reports from these various programs. He participated as an inhouse expert in a Non-Advocate Review for Code C on a Fire-Safety experiment.

Dr. King increased his knowledge regarding cutting-edge research in the area of combustion, reading background papers from the various Principal Investigators in the program and related work by others on a time-available basis. As part of this effort, he conducted a literature search and identified approximately 100 of what he believed to be important papers in the area. In addition, he collected and read a number of textbooks and meeting proceedings in the area of combustion, particularly as related to Microgravity Combustion. In one specific area, while he was trying to establish program balance in recommending proposals from the most recent NRA for funding, Dr. King conducted a thorough review of existing and proposed programs in the area of ignition and flame spread across surfaces; an excessive number of proposals were rated in the Highly Qualified and Qualified areas and this review enabled him to choose those which would best lead to program balance to avoid concentration of too large a fraction of our limited resources in this one combustion sub discipline.

Another important aspect of Dr. King's assignment was that of forming liaisons with combustion personnel in other agencies. In this area, he arranged several meetings between representatives of the New Energy and Industrial Technology Development Organization (NEDO) and various members of MSAD (including the Chief Scientist and the Division Director) to explore possible collaborative efforts in the Microgravity Combustion area between our organizations. As part of this effort, he drafted a charter for a Microgravity Combustion Working Group between the two agencies, walked it through several drafts involving NASA's International Division and the principals from both agencies, and finalized a charter which was signed by MSAD's Division Director and the corresponding Japanese official in June 1994; an initial meeting of this Working Group was held at NASA/Lewis in September 1994.

In addition, he arranged initial discussions with personnel from the National Science Foundation, and very recently drafted a Memorandum of Understanding (currently under review at NASA) for possible collaborative activities in the areas of Biotechnology, Combustion, Fluid Physics, and Material Sciences between MSAD and the Directorates for Engineering and for Mathematical and Physical Sciences at NSF. Through discussions with two Russian scientists, he initiated establishment of possible areas in which Russian scientists could become involved in our Microgravity Combustion program; as part of this effort, he attended a Zeldovich Memorial Combustion Conference held in Moscow in September 1994, and participated there in a Round

Table Discussion on Combustion Processes Under Microgravity Conditions (serving as co-chairman of that session). Finally, he continued a practice which began while at NSF of keeping combustion program managers at other US government agencies (NSF, AFOSR, ONR, ARO, and DOE) informed regarding the content of our program, providing them with lists of our investigators and program titles.

Dr. King has also been active in communicating the scope, content, status, and direction of the Microgravity Combustion Program to NASA management, the Office of Management and Budget, and the Congress.

Several examples of his efforts in this area are as follows: First, Dr. King prepared an input of approximately 1500 words on what has been accomplished in the Microgravity Combustion Program during 1993 for the Annual Report. In addition, he generated an Appendix for the Microgravity Science Plan, alluded to earlier, and had it reviewed by the Discipline Working Group, modifying it to satisfy their minor concerns. He generated inputs for various of the Out-Reach documents on an as-needed basis, generated an input to a "MSAD Accomplishments Thru History" document for the OLMSA Associate Administrator, and wrote a "primer" on the Microgravity Combustion Program to be used in support of management and congressional staff presentations. He worked on preparation of material for the Associate Administrator to use in his Congressional testimony, and prepared a data package regarding combustion investigations over the past five years for the staff of Senator Mikulski. Recently, Dr. King integrated two major documents summarizing the 1994 accomplishments of the Microgravity Science and Applications Division for use by Congressional staffers.

In terms of contacts with the external combustion community, Dr. King was quite active in professional societies dealing with combustion phenomena and has actively participated in domestic and foreign scientific conferences and symposia, representing NASA. He has remained quite active in the Combustion Institute, having reviewed six papers submitted to the 25th International Symposium on Combustion, being held in Irvine, CA in August, 1994; in addition, he chaired a session on Microgravity Diffusion Flames at that meeting and also reviewed papers for two major combustion journals, Combustion and Flame, and Combustion Science and Technology, averaging about 5 papers a year between these two journals. Dr. King remains active in the American Institute for Aeronautics and Astronautics, reviewing papers for the Journal of Propulsion and Power and being active on the Space Processing Technical Committee.

Dr. King also found himself organizing and chairing sessions at the Aerospace Sciences Meeting each January. During this time, he authored a survey paper entitled, "Erosive Burning of Solid Propellants" published in the Journal of Propulsion and Power. He has also authored another paper entitled, "Modeling Study of Effects of Temperature Profiling on CVI Processing of Woven Graphite Performs with Dimethyldichlorosilane," published in the Journal of Materials Research. He submitted a third paper, "Examination of Chemical Approaches to Stabilizing Composite Propellant Combustion" to the Journal of Propulsion and Power. Through his activities within these societies, he was able to maintain strong personal contacts in the combustion community and contribute to coordinating events and interchanging ideas, concepts, and research development information.

Dr. Manfred Lichtensteiger's studies are defined below:

Passing well-defined electrical pulses of approximately $20\text{A}/\text{cm}^2$ current density across the solid-melt interface in a growing crystal introduces localized changes in the dopant segregation behavior at the interface. High quality polishing and careful etching of the crystal grown will make these changes visible by optical methods (Nomarski interference contrast). Thus, the shape of the interface, and with knowledge of the pulse repetition rate instantaneous microscopic growth rates can be established throughout the grown material: a fact of not only theoretical but also practical importance.

This technique can be complemented by high resolution electrical measurements in the μm range (spreading resistance measurements) which yields localized dopant concentration changes. A combination of these two techniques make possible the development of a dynamical theory of crystal growth correlating instantaneous growth rate changes with dopant segregation behavior.

This is the ultimate goal of this experiment which has been named IDFT (Interface Demarcation Flight Test). This non-peer reviewed investigation will be conducted during the USML-2 flight mission.

Since Dr. Lichtensteiger's arrival, his work has been directed towards the engineering implementation of the design of an ampoule containing a $\langle 111 \rangle$ oriented single crystal of gallium doped germanium in a hermetically sealed quartz ampoule. Approximately 25 ampoules based on this design are to be tested at Teledyne Brown Engineering facilities. Finally, three of these assemblies are to be designated as flight ampoules.

The design evolved from discussions with members of the GTE-OSRAM technical staff during a number of visits, and discussions with numerous professionals in the field of Materials Science and Engineering. Some of the design concepts were adapted from the solidification experiment MA-060 which was flown during the Apollo-Soyuz mission.

It employs a modular approach, using 0.8 mm \varnothing platinum wire electrical feed-through with a compressed molybdenum foil quartz seal, cup-shaped graphite electrodes which are both mechanically and electrically connected to the feed-through rated at 150 W continuous power. A highly doped (Ga) germanium single crystal oriented along the $\langle 111 \rangle$ growth direction, first machined to approximate dimensions, followed by chemical etching to precise dimensions is used in the assembly. This crystal is inserted (class A fit) into the graphite electrodes to ensure optimal electrical contact, and the whole assembly is sealed in a quartz sleeve *via* a ring seal at the end of either feed-through.

Evacuation and sealing-off completes the ampoule assembly whose dimensional and electrical tolerances are prescribed by TBE (reference the enclosed ICD document 340ICD0140). Minor modifications had to be made to the basic design: specifically changes to maintain concentricity, and improvements in the somewhat awkward mechanical/electrical mating of the graphite electrode to the feed-through (See photograph in Appendix 1). Without the benefit of a previous flight experiment, testing of an initial set of ampoules was only partially successful since the thermal characteristics of the CGF furnace were unknown. The thermal model derived for this unit (the former USML-1 flight furnace) did not take into account its reconfiguration with a 0.040 inch heat extraction plate, hence the thermal gradient zone was ill-defined. Likewise, the time to

reach quasi-steady state conditions ($\delta T/\delta t=0$), in the presence of Joule heating effects of the interface demarcation pulsing sequence chosen, was unknown. (The pulse sequence is described as follows: 75 msec pulses with 40 A amplitude at 5 sec repetition rate, followed by a 1 sec separation double pulse every minute, and an opposite polarity marker pulse every hour of the same amplitude and duration; see micro-photograph of interface cusp at approximately 3 hours growth).

This resulted in the initial solid-melt interface located just at the boundary of the gradient zone near the start of the cold zone moving towards or into the graphite electrode cup area, producing a definitely curved melt interface shape (see plot of initial solid-melt interface shape). Interestingly enough, the curvature of this interface is opposite the expected value which casts some doubts on the validity of the thermal model *per se*. Hence, efforts were made to ensure that steady state conditions in the furnace were reached before starting re-growth by defining an modified time-line within the time window allotted for this experiment. (This time-line allows for growth at a 8 $\mu\text{m/s}$ translation rate after 3 hours of equilibration with the pulsing system operative, followed by a 3 $\mu\text{m/s}$ translation rate leading into 'virtual' growth at the end of the growth sequence).

In all instances, the instantaneous growth rate in the growth system never reaches steady-state and resulted in a progressively curved interface concave as seen from the melt with the absolute location of the solid-melt interface regressing ever further into the cold zone of the furnace ($f\Delta$ ($g/t \times t$)). This then leads to excessive faceting and early breakdown of the growth interface (See photo-micrograph of growth region at this time in Appendix 1). It should be noted that the scientific information contained in these experiments is preserved in the successfully regrown regions of the crystals.

If given the opportunity to conduct additional tests, Dr. Lichtensteiger feels that a change in the chosen thermal parameters of the CGF will correct these problems.

Many, if not all of the required facilities to accomplish this research are not available at MSFC: The degree of surface finish required prior to etching ($\lambda/6$ desirable) after slicing a specimen along its (211) crystallographic plane is just not attainable with the available equipment.

The surface topographical features, *i.e.* interface demarcation lines, are similar to an etched MESA-structure which is of the order of nm. Nomarski differential interference contrast, using monochromatic light, is the only method to successfully bring out the required details to make interface demarcation useful as a diagnostic tool. Therefore, it requires a very intense light source (xenon arc light). The presently available light source requires approximately 1000 s exposure for a 400 ASA rated film which Dr. Lichtensteiger calls candlelight microscopy. SRP (Spreading Resistance Profiling) is the only available spatial high-resolution technique to determine local impurity/dopant concentration.

Ms. Lorrie Matthews completed the following tasks:

She prepared buffers and azide water, siliconized coverslips, washed laboratory glassware, made elastomer PCAM tops, etc. She assisted in the move of the laboratory equipment and materials from building 4481 to 4464. She also assisted in setting up protein crystallization plates and in attempting to grow crystals using a mock-up of the VDA flight hardware.

Mr. Rick McConnell completed the following tasks:

He supported the USML-2 mission by performing many tasks throughout the course of this contract. The tasks consisted of compiling and distributing the updated personnel directory and the minutes of the Fourth Investigator Working Group (IWG) meeting; attended status and flight operations meetings and noted action items for the mission scientist team; coordinated with Boeing TV the videotaping of two experiments at the Payload Crew Training Complex (PCTC); prepared mission scientist team references and documentation and participated in the first cadre simulation; worked with NASA personnel to process accreditation requests for international participants; and prepared, published and distributed the minutes and presentations of the seventh IWG.

During January 1 - March 31, 1994, Mr. McConnell compiled and published a two volume review of the science results and made distribution to scientists and managers involved in IML-1. For IML-2, he performed the following activities: attended status and flight operations meetings and noted action items for the mission scientist team; prepared for and participated in two flight simulations and debriefs; prepared science tracking charts and logs to be used during the mission; worked with Boeing Television on the production of an IML-2 video; distributed mission brochures to project scientists and principal investigators; continued work with NASA personnel on the final accreditation list for international participants; prepared charts for principal investigator training; worked with NASA Headquarters personnel on an agenda and announcement for the Science Directors' Readiness Review; worked with McDonnell Douglas personnel on the editing of KSC's STS-65 Payload Handbook; and worked with Teledyne Brown Engineering personnel on methods and procedures for reporting science activities during the mission.

During April 1 - June 30, 1994, he attended flight status and operations meetings and noted action items for the mission scientist team; prepared for and participated in four flight simulations and debriefs; completed science tracking charts and logs to be used during the mission; worked with NASA personnel on the final accreditation list for international participants; finalized with Teledyne Brown Engineering personnel the methods and procedures for reporting science activities during the mission; and organized documentation, procedures, and schedules for the mission scientist team.

During July 1 - September 30, 1994, Mr. McConnell worked as the Mission Scientist on console July 6-22, 1994, (7:00 am-8:00 pm). His duties included: working real-time problems; replanning future shifts; maintaining records of science accomplished and lost; compiling science reports from the 19 facilities; writing science summaries for uplink to the crew; and answering calls to the Mission Scientist.

After the mission, he attended debriefs with the operations cadre and flight crew and presented Mission Scientist team comments. Other IML-2 activities included:

- organizing with European Space Agency representatives a post flight meeting in Darmstadt, Germany, November 1-2, 1994;
- preparing the agenda, and distributing information on the meeting to principal investigators, project scientists, and program scientists.

He also worked on the MSFC portion of the "MSAD Program Tasks and Bibliography for FY94," distributing information and updating forms for the 92 microgravity projects. For IML-1, he distributed information to principal investigators and project scientists concerning the compilation of a reprints document composed of published articles discussing the scientific results of the mission.

During the period of October 1 - December 31, 1994, he finalized with ESA personnel, the arrangements for an IML-2 postflight meeting at the European Space Operations Center in Darmstadt, Germany, November 1-2, 1994. He began the compilation of reports on the preliminary results of the 82 IML-2 experiments and compiled the 91 principal investigator reports comprising the MSFC portion of the "MSAD Program Tasks and Bibliography for FY94"; and transferred the data base files to NASA Headquarters. He began the compilation of published articles discussing the scientific results of the IML-1 mission and started a personnel data base files for the LMS and MSL-1 missions and updated the USML-2 and USMP personnel data base files; assisted the LMS Mission Scientist in the organization and distribution of information concerning the first Investigator Working Group (IWG) meeting November 15-17, 1994.

Mr. McConnell attended the first IWG of the LMS mission, collected personnel data base information, and worked with foreign nationals on accreditation procedures and assisted the USML-2 Mission Scientist in the organization and distribution of information concerning the seventh IWG meeting, December 13-14, 1994. He attended the seventh IWG of the USML-2 mission, took the minutes of the meeting, and participated in the timeline splinter sessions; prepared and distributed an updated USML-2 personnel directory, IWG minutes, and copies of presentations; assisted the MSL-1 Mission Scientist in the organization and distribution of information concerning the first IWG.

During the last quarter, January 1 - February 3, 1995, Mr. McConnell completed the arrangements for the MSL-1 IWG and prepared the minutes of the meetings, gathered information for the personnel data base, and distributed the minutes to the attendees. He continued the compilation of reprints of IML-1 results and the compilation of IML-2 preliminary results. He also assisted the LMS Mission Scientist in the organization of an IWG to take place in May at ESA's European Space Research and Technology Centre in Noordwijk, The Netherlands.

Dr. Mark Steven Paley completed the following tasks:

His primary research for the past 4 years has focused on polydiacetylenes for nonlinear optical (NLO) applications, and the effects of gravitational factors on thin film growth of these materials both in the vapor and solution phases. He has been working closely with Dr. Donald O. Frazier's group at SSL/MSFC. Polydiacetylenes are among the best organic NLO materials known, and for applications, high quality thin films possessing minimal inhomogeneities and defects are required. Gravitational forces such as convection affect heat and mass transport processes during the growth of these films, hence this is an area where microgravity science can play a role.

Dr. Paley's first significant project was in collaboration with Dr. Sam McManus at UAH. He carried out the synthesis and characterization of some novel diacetylene derivatives of pyrrole. These compounds were used to test and verify a computational method for predicting the chemical and optical properties of diacetylene monomers, especially, their ability to polymerize in

the solid-state. The success of this method allows the search for potentially interesting and useful compounds to be carried out in a more pedagogical fashion, and is essential for saving time and labor in the laboratory. This work was published (See Publications and Presentations Section of this report).

Dr. Paley then turned his attention to diacetylenes and polydiacetylenes that have potential as both second and third-order NLO materials, specifically, to a compound derived from MNA, a well-known organic NLO material. He grew polycrystalline thin films of the monomer, DAMNA, onto various substrates to determine the effects on the orientation of the films. These films were polymerized in the solid-state with UV light to give the corresponding polydiacetylene (PDAMNA) film. He found that ordered teflon substrates had an ability to induce orientation into the PDAMNA films, and films grown onto teflon showed greater second-order nonlinearity than films grown onto other substrates. This work was published (See Publications and Presentations Section of this report).

Dr. Paley discovered a very novel property of DAMNA, previously unknown to diacetylenes. He found that solutions of DAMNA, when irradiated with UV through glass or quartz, photopolymerized and deposited thin amorphous PDAMNA films. These films have excellent optical quality (superior to vapor grown films), grow to thicknesses of about 1 micron, and exhibit good third-order NLO properties. Furthermore the process can be carried out with a laser to form polymeric circuits. The results so far are very exciting; this process has real potential for producing polydiacetylene films for NLO applications such as wave guides and integrated optics. Dr. Paley is involved in extensive ground-based studies of the fundamental science (surface and solution chemistry) governing this new and intriguing reaction. Preliminary results have been published as a communication in *Chem. Mater.*, and a full paper has been sent to *J. Am. Chem. Soc.* Also, a patent application has been filed for this process.

Because photo-deposition from solution has potential as a technologically feasible means of forming polydiacetylene films, Dr. Paley is very interested in the effects of gravity on this process. Specifically, he is interested in the effects of convection on the kinetics of film growth, and on the morphology and properties of the films obtained. Films grown in 1-g contain small particles of solid polymer form in the bulk solution, get transported by convection to the surface of the growing film, and become embedded. These particles are defects that can scatter light and lower the optical quality of the films. In microgravity, where convection is negligible, both the formation and transport of these particles should be greatly reduced. Also, films grown in microgravity should have more uniform thicknesses and may exhibit greater molecular orientation, which could enhance their NLO properties. Preliminary flight experiments are scheduled in 1995 on the KC-135 aircraft and on a Shuttle gascan.

Dr. Narayanan Ramachandran completed the following tasks:

He worked in the area of fluids and during his tenure was funded in part through the Center Director's Discretionary Fund for numerical modeling was pursued to identify 3-4 glovebox type experiments. Experimental parameter ranges and science requirements were established in part in this effort. A complementary effort to measure the diffusion coefficients of salts used in the above effort was undertaken. The work is in collaboration with Dr. Donald Reiss, ES 76.

Physical Vapor Transport (PVT) modeling work was continued to support the experimental work of Dr. Ching Hua Su, ES75. A compressible fluid flow model was successfully completed and 3-D modeling was initiated.

Numerical work in the area of vibrational and g-jitter convection was continued. An application of this research was found in the area of fluids mixing.

The proceedings of the " L+1 Science Review of USML-1 and USMP-1 with the Microgravity Measurement Group" : NASA CP -3272, were prepared for electronic access.

Dr. Ramachandran completed a journal paper on Space Shuttle acceleration measurements and their impact on thermo-solutal fluid mechanics. He performed tests to check if the effect of Mach number on three hole (Cobra) probes was undertaken. A previous test to document the effect of high Reynolds numbers indicated some Mach number dependency of the probe pressure coefficients. An ad-hoc test rig was assembled for this purpose and the results showed Mach number effects in the range $0.6 < Ma < 0.9$. A recommendation was made to calibrate the probes in this Mach number range.

In response to a possible flight opportunity on USML-2 (scheduled for fall 1995), work was initiated on a simple science experiment that will respond to the vibrations present on the Space Shuttle. The experiment, a derivative of the already funded effort under the Center Director Discretionary Fund project, involves the thermal response of a fluid to g-jitter. Two scenarios were investigated, a model liquid chosen and experiment parameters determined. An interferometer system is being set up for optical di.

Work continued on the measurement of diffusion coefficients of salts to be used in the fluid diffusion experiment - a candidate for glovebox experimentation.

A new order of magnitude analysis was formulated to obtain estimates of g-jitter convection in constant heat flux situations.

Dr. Terry D. Rolin performed activities in the following areas:

Crystal Growth Furnace (CGF) Project Science

His primary task has been to act as the technical interface between project management and the Principle Investigator's (PI) to insure that the hardware is built to meet each PI's need without impacting cost, schedule or the other PI's science. This has required inventing engineering solutions for cartridge and furnace design issues. An example of a furnace design issue was the request by one of the PI's to increase the thermal control plate thickness in the furnace. Dr. Rolin ran a thermal model of this furnace to determine the optimal thermal control plate thickness for the furnace. His computations suggested that a change would not necessarily help the requesting PI but definitely impact the others. One experiment was run and his calculations were confirmed. Because the model and experimental results agreed, no further tests were needed to increase confidence, thereby saving the program additional cost and time.

Additional project science duties have involved inspections of all incoming ampoules and their cartridge assemblies including the assembly of Current Pulse Interface Demarcation (CPID)

Sample Ampoule Cartridge Assembly's (SACA) at Teledyne Brown Engineering (TBE). Dr. Rolin also supported every test of the SACA's at TBE including Ground Control Experiment Laboratory (GCEL) and Flight Simulation tests. Once processed, the ampoules are removed from the SACA's and returned to the appropriate PI's, completing the ampoule processing cycle.

Interface Demarcation Flight Test (IDFT)

Another significant portion of Dr. Rolin's time has been devoted to the success of IDFT. This is a non-peer reviewed engineering test that was mandated by NASA Headquarters and handed to MSFC in late fall of 1994. Unlike other PI's who typically get two years notice, the IDFT team was only given a few months to produce a flight-like ampoule. Dr. Lichtensteiger and Dr. Rolin worked aggressively to meet each deadline imposed and is happy to announce that each was met (all other teams have not had such a success rate). Dr. Rolin's support of this project has included assisting in the design of the ampoule and piece parts and to a small degree with the actual ampoule assembly (mostly done by Gene Nelson, the glass blower at UAH). As with any flight ampoule, many documents and drawings are required for various reasons (e.g., interface control document, data requirements document, contract end item specification document). He worked at great length to insure that such documents and any drawings were created to the satisfaction of TBE, MSFC and the IDFT team leader. This has allowed all the IDFT ampoules to flow smoothly through the MSFC and TBE systems. Currently he has all the flight ampoules (3 of 3) and most of the qualification ampoules (4 of 7) built and ready for assembly. No other PI's have this many ampoules ready for assembly at this point in time. Finally, Dr. Rolin supported at great length each test of IDFT at TBE. Based on the results of testing at TBE and at MSFC, a robust, flight ready ampoule has been produced. Dr. Rolin and Dr. Lichtensteiger are very excited about the upcoming USML-2 mission on which IDFT is manifested for processing in the CGF.

More IDFT ampoules must be built to support all the required qualification testing. Furthermore, Manfred has asked for additional GCEL tests. If accepted, more ampoules will have to be assembled. As project scientist activities slow, Dr. Rolin intends to devote more time to IDFT, particularly in the area of characterization of the processed crystals.

With respect to the USML-2 mission, many training sessions are required and it has been suggested that Dr. Rolin attend these sessions so that he can adequately support IDFT during the mission as both team member and project scientist.

Magnetic Damping Furnace (MDF)

The third project which Dr. Rolin has worked on is the Magnetic Damping Furnace project of which Frank Szofran is the PI. His primary task was to measure thermophysical properties of various compounds in order to fully understand the behavior of these materials during their growth in a magnetic field. Of primary interest is the electrical conductivity of the liquid phase, since this parameter appears in most dimensionless numbers governing magnetic damping processes. To determine the electrical conductivity, he built an apparatus and assembled the necessary supporting equipment with very little expenditures. This apparatus was calibrated and checked with a standard and found to be extremely reliable compared to literature data. With this confidence, the electrical conductivity of molten $\text{Ge}_{0.95}\text{Si}_{0.05}$ was measured and the results have been submitted to the Journal of Crystal Growth for publication. In addition, the electrical

conductivity of InGaSb has also been measured. The data is currently under analysis and a publication submittal is forthcoming.

Dr. Rolin was also involved in another significant effort under this project, namely the design of a flight quality magnetic furnace. This has required him to carry out very difficult calculations in order to establish the adequate design parameters for the magnet. He has completed these calculations and a final report has been prepared. One copy was submitted with a previous quarterly report and extra copies are available upon request.

Unfortunately, the MDF project failed to pass from the ground-based stage to the flight readiness stage by the end of the contract.

Dr. Yi-Gao Sha completed the following tasks:

His work was primarily with Dr. Sandor Lehoczky on the flight project entitled, "Crystal Growth of Selected II-VI Semiconducting Alloys by Directional Solidification." He performed various tasks including materials synthesis, ampoule preparation, crystal growth, and crystal characterizations related to the ground-based studies and the preparation of USML-2 experiment of meltback and regrowing of HgZnTe. His activities on each task are described below.

Prepared Optical Cells for Thermal Diffusivity Measurements of HgZnTe Melt

HgZnTe samples of various composition were synthesized and homogenized from the elements and sample powder were loaded into special optical cells. Each cell was heated up to above the liquidus temperatures and the thermal diffusivity of the melt was measured at several temperatures by shining a laser beam on one side of the sample and recording the temperature response on the other side. Total HgZnTe optical cell prepared: 6 (excluding 4 failures). Each required 12-14 days.

Perform DTA Measurements of HgZnTe

Several HgZnTe samples of different composition were synthesized from the elements, homogenized, and quenched to reserve the composition uniformity. Differential thermal analysis were performed and solidus and liquidus temperatures were determined for several compositions. Total sample: 6. Each required 7 days to prepare and 3-5 days to complete DTA measurement.

Growth Ampoule Preparation

The original design of the growth ampoule consisted of a homogenized HgZnTe ingot of about 12 cm long. The material was synthesized in the graphitized growth ampoule from the elements, then rocked while it was in molten condition and quenched to preserve the composition uniformity. The ampoule was then shortened by resealing. Total ampoules prepared: 20. Each required 7-9 days.

The current ampoule/sample configuration for growing HgZnTe in space consists of growing a 2 cm long ZnTe seed in the graphitized ampoule by physical vapor transport, opening the ampoule, filling the ampoule with precast HgZnTe ingots of known composition, and then resealing of the ampoule. In order to optimize the PVT growth of ZnTe, ZnTe source material was pre-treated

with hydrogen under dynamic vacuum to reduce the oxygen content and then was baked out under high temperature to improve its stoichiometry. Several ZnTe seeds have been grown. Except for one, all meet the requirements of having either a slanted interface or disappearing graphite film after the growth. The former was caused by a combination of a possible radial temperature gradient in the growth furnace and an improper positioning of the ampoule relative to the furnace bore. The latter problem was caused by the oxygen residue in the source material and has been eliminated essentially by the hydrogen treatment. Total number of ZnTe seed grown: 15, each required 8-10 days.

Several ampoules of HgZnTe ingot were cast to provide these ingots with the composition in a finished ampoule which should meet a profile that simulates a freeze-in diffusion boundary layer. The cast ingots were cut into segments of various length and the composition of each segment was determined by precision density measurement and energy dispersive x-ray spectroscopy (EDX). Since the cast ingots have a dendritical structure, the EDX results were rather scattering because it usually measures the composition of a very small surface area, whereas the density measurement gives the average composition of a segment. This causes some difficulty in confirming the actual composition of the segments. Total ingot cast: 8, each required 7 days. Total ampoules prepared: 7.

Crystal Growth Experiment

Growth experiments were performed for both ampoule configurations in SSL. Different growth parameters were used in order to determine the optimal growth condition. Growth was also performed in a magnetic field to investigate the magnetic damping on the convective flow in the melt. The experiments for the current ampoule configuration were to control the precise meltback to the ZnTe seed. Total crystals grown: 7. Each required 15-50 days. The growth experiments were also conducted in CGF GCEL and Flight units to test the reproducibility of the desired results.

Crystal Characterizations

The crystal/melt interface was examined by cutting the grown ingot along the growth axis. The axial compositions of samples were measured by precision density measurement of slices cut perpendicular to the growth axis and by EDX on the surface and on the centerline of the ingot. The radial composition distribution was mapped by EDX on slices cut perpendicular to the growth axis.

Due to the dendritical structure of the quenched material, the composition profile measured by EDX was scattered. Annealing of these materials below the solidus temperature removed the original composition segregation and the subsequent EDX results showed a much smoother composition profile. The grown crystals were oriented by x-ray Laue diffraction method. Chemical etching on oriented and polished surface revealed structural defects of the crystals.

Dr. Laurent Sibille performed activities on the following tasks:

Protein Aggregation Experiment Aboard NASA KC135 Aircraft

The experiment conducted in August 1994 was reviewed to prepare for a future flight by Dr. Sibille. Data gathered during nearly 200 parabolas show that the light scattering signal recorded is subject to the variations of the magnitude of the gravitational forces. Given the experimental conditions of that first experiment, it is not possible at this stage to conclude what causes the signal variations. Several possibilities are being examined: 1) Fallout of large aggregated particles out of the beam; 2) Dissociation of formed aggregates during the high G flight; 3) Inadvertent drainage of the solution in the cell during high G.

A redesign of the experiment based on these observations is underway and will be carried into the follow-on by performing extensive runs in the lab to prepare for another flight. The project is also being linked informally to other proposals addressing aggregation of different materials in microgravity (aerosols for example).

Phase-Shifting Interferometry

Work was performed on an experiment using phase-shifting interferometry to visualize and measure concentration gradients around a growing protein crystals. Installment of the optical setup was conducted in William Witherow's laboratory at ES76. The manufacture of a thermostatted cell has been ordered through the ES71 machine shop. The cell, initially designed to follow face growth rates of protein crystals, was used to grow crystals under controlled temperature and allow close-up monitoring through a large glass front window.

Dr. Ching-Hua Su completed the following tasks:

He served as Co-Investigator of the flight experiment "Crystal Growth of Selected II-VI Semiconducting Alloys by Directional Solidification" on USML-1 (United States Microgravity Laboratory) STS-50 mission in June 1992 and is scheduled to be flown on USML-2 mission, performed post-flight analyses on the space-grown crystal.

He served as a member of the science team in the USMP-2 (the 2nd United States Microgravity Payload) mission and conducted payload operation ground control duty. A crystal of $\text{Hg}_{0.8}\text{Cd}_{0.2}\text{Te}$ was grown in the AADSF (Advanced Automated Directional Solidification Furnace) between March 4-14, 1994.

He served as Co-Investigator of the awarded proposal "Investigation of Contactless Crystal Growth by Physical Vapor Transport" in response to NASA NRA 93-OSSA-12.

He also performed extra duty as Acting Director for USRA/Huntsville Microgravity Science and Application Program from October 1993 to June 1994. More detail of Dr. Su's accomplishments are located in previous quarterly reports.

Ms. Pamela D. Twigg accomplished the following tasks on this project:

Microgravity Science

- Screened and optimized Serum Albumin crystallization conditions for flight on Shuttle Flight STS-44
- Served as member of Flight Hardware Loading Team for Protein Crystal Growth on Shuttle Flight STS-44 in January 1992
- Screened and optimized Serum Albumin crystallization conditions for flight on Shuttle STS-50
- Served as member of Flight Hardware Loading Team for Protein Crystal Growth on Shuttle STS-50 in June 1992
- Manned communications console at MSFC for STS-50 as Scientific Support for USML-1 (U.S. Microgravity Laboratory) in Protein Crystal Growth samples to co-Investigators after STS-50
- Screened and optimized Serum Albumin crystallization conditions for flight on Shuttle Flight STS-57 in June 1993
- Began work with preliminary design of new generation Protein Crystal Growth flight hardware in July 1993
- Coordinated writing and mailing of packet announcing upcoming flight opportunities for Protein Crystal Growth implementing new hardware developed in this laboratory
- Conducted research into equilibration rates for vapor diffusion experiments for protein crystal growth using an array of precipitants and experiment configurations for the purpose of characterizing the equilibration properties of new Shuttle flight hardware to be flown on upcoming missions STS-63, STS-67m STS-73. This information was provided to the co-investigators to allow them to screen crystallization conditions for their proteins prior to flight.
- Coordinated invitation of scientists to serve on the Protein Selection Committee for upcoming flights (i.e. suggested names, contacted them by phone, drafted a letter of invitation, designed and put together packets of proposals and forms for the followed up with phone contact, etc.
- Designed forms for co-Investigators to submit to Johnson Space Flight Center Safety Office with crystallization conditions. Forwarded list of proposing co-Investigators and forms to Dr. Martin Coleman at JSC.
- Set up a number of crystallization screens with well-characterized proteins using new wicking materials in standard laboratory hardware to determine whether there is an impact on crystallization time or quality.
- Designed forms and drafted informative brochures for users of new Protein Crystallization Apparatus for Microgravity (PCAM). Drafted letter of acceptance for co-Investigators being offered the opportunity to fly experiments on Shuttle missions STS-63 and STS-67.
- Put together and shipped co-Investigator testing kits for co-I's to begin screening crystallization conditions for upcoming Shuttle Flights STS-63 and STS-67
- Coordinated co-Investigator participation on Shuttle flights STS-63 and STS-67 by compiling and providing listings of accommodations, assisting overseas co-I's with questions about travel and experimental preparations, preparing packets of security clearance forms, sample loading forms and sample preparation instructions.
- Obtained U.S.D.A. permits for overseas co-I's shipping regulated proteins into the U.S. for Shuttle experiments.

- Served as member of Flight Hardware Loading Team for Protein Crystal Growth on Shuttle Flight STS-63 in February 1995

Structural Biology

- Crystallized several forms of serum albumin, including Equine serum albumin (structure published in 1993)
- Joined with other members of Laboratory for Structural Biology in major collaboration with Intracell (formally American Biotechnologies) involving crystallization of recombinantly produced HIV and HTLV related proteins
- Appointed chemical hygiene officer and biohazardous waste point of contact-drafted chemical hygiene plan and standard operating procedures for laboratory.
- Science Representative to Building Committee for construction of new NASA/MSFC laboratory
- Designed biochemistry wet lab for new building
- Designed layout of new building
- Responsible for coordinating relocation of Protein Crystallography Lab to new computers, equipment, phones, furniture and personnel
- Prepared drug binding assays with serum albumin to determine binding constants
- Co-crystallized albumin-drug complexes as part of Laboratory collaborations with several major drug companies and universities
- Supported x-ray crystallographic data collection by mounting protein crystals and initiating data collection procedures on the equipment
- Organized and presented tours of the Laboratory for Structural Biology to such groups as high school students, college students, visiting scientist, U.S. Congressman, NASA center directors, NASA Headquarters representatives, teachers, and one group of hearing-impaired Space Camp delegates.

Additional Significant Accomplishments

- NASA Group Achievement Award-Protein Crystal Growth Team, June 1994
- NASA Certificate of Appreciation, March 1993
- Fire Marshall/Safety Monitor for NASA/MSFC Laboratory for Structural Biology
- Chemical Hygiene Officer for NASA/MSFC Biophysics Branch
- Biohazardous Waste Point of Contact for NASA/MSFC Biophysics Branch

Publications and Presentations

A complete list of publications and presentations, prepared by Ms. Dannah McCauley, Administrative Assistant of the Microgravity Science and Applications Program, is attached as Appendix 1.

Consultants

John G. Albright	Texas Christian University
Timothy F. Anderson	University of Florida
Ali Arabshahi	Mississippi State University
Norbert Babsan	Miskolc University in Hungary (6 months for Hungarian furnace)
Klaus J. Bachmann	North Carolina State University

Michael Banish	University of Alabama in Huntsville
Oleg Barabash	Institute of Metal Physics, Ukrainian Academy of Sciences, Ukraine
Paul Barczy	University of Miskolc, Hungary
Osman Basaran	Oak Ridge National Laboratory
Johannes Baumgartl	Institut für Werkstoffwissenschaften, Erlangen, Germany
Michael Bello	Sunnyvale, CA
V. Bredikhin	Institute of Applied Physics, Russian Academy of Sciences, Russia
Robbie Cameron	Samford University
Beatriz Cardelino	Spellman College
Douglas Carlson	M/A Com, Inc.
William M. Carson	University of Alabama-Birmingham
Elena Casale	Independent Consultant
Peggy Cebe	Massachusetts Institute of Technology
Michael Clifton	Universite Paul Sabatier, France (6 months for RAMSES experiment)
Jon A. Dantzig	University of Illinois
Mark K. Debe	3M Corporation
Dr. Lawrence J. DeLucas	University of Birmingham
Jeffrey J. Derby	University of Minnesota
Michael A. DiGiuseppe	ATT Bell Laboratories
Laura Douglas	University of Illinois
Howard Einsphar	Bristol-Myers Squibb
Alexander Feonychev	Moscow Aviation Institute, Russia
J. G. E. M. Fraaije	University of Groningen, The Netherlands
Mark Garner	National Institute of Child Health and Development
Krzysztof Graszka	Institute of Electronic Materials Technology, Warsaw, Poland
Richard Grugel	Vanderbilt University
Angus Hellawell	Michigan Technological University
Richard Hopkins	Westinghouse Science and Technology Center
Sandra Howard	University of Alabama in Huntsville
Y. Huang	National Tsing Hua University, Taiwan
John Hurt	National Science Foundation
J. Milton Jessup	Harvard Medical School
Robert Karbel	Sunnybrook Health Science Centre, Canada
Merrill K. King	National Science Foundation
Vsevolod Lapchinskii	Paton Welding Institute, Ukrainian Academy of Sciences, Ukraine
David Larson	Grumman Aerospace Corporation
Manfred Lichtensteiger	Massachusetts Institute of Technology
Hong Lin	University of Alabama in Huntsville
Daniel W. Mackowski	Auburn University
Peter Makk	Miskolc University, Hungary
Seth R. Marder	California Institute of Technology
David C. Martin	University of Michigan
Lon J. Mathias	University of Southern Mississippi
Rodney McKee	Oak Ridge National Laboratory
Alexander McPherson	University of California-Riverside
Eric Monberg	ATT Bell Laboratories
Arunan Nadarajah	University of Alabama in Huntsville
Vladimir Nikora	Institute of Geophysics, Kishniva, Moldova
Hasan Oguz	Johns Hopkins University
Witold Palosz	NRC Senior Research Association
Rekha Pattanayek	Vanderbilt University
John Perepezko	University of Wisconsin
Vladimir Polezhaev	Institute for Problems in Mechanics, Moscow, Russia
Malcolm Polk	Georgia Institute of Technology
Dennis W. Readey	Colorado School of Mines
Liya Regel	Clarkson University

Glyn Roberts	Independent Consultant
Tamas Roos	Miskolc University, Hungary (1 month for Hungarian furnace)
Dudley Saville	Princeton University
Robert J. Schaefer	National Institute of Standards and Technology
Geoffrey V. F. Seaman	Western Biomedical Research Institute
Subhayu Sen	University of Alabama
A. Serebrov	NPO Energia, Kaliningrad, Russia
N. B. Singh	Westinghouse Electric Corporation
Robert Sokolowski	Intermagnetics General Corporation
Frans A. Spaepen	Harvard University
Hendrik R. Stark	ESA/ESTEC
Paul Steen	Cornell University
Julian Szekely	Massachusetts Institute of Technology
Raymond Taylor	Thermal Physical Properties Research Laboratories
David Tiede	Argonne National Laboratory
Jos Tissen	University of Groningen, The Netherlands
Rohit Trivedi	Iowa State University
Robert Turnbull	University of Illinois
John W. Vanderhoff	Lehigh University
Peter Vekilov	University of Alabama in Huntsville
Frank B. Von Swol	University of Illinois
Peter Voorhees	Northwestern University
Ameae M. Walker	University of California-Riverside
Francis Wang	Independent Consultant
Harry Wiedemeier	Rensselaer Polytechnic Institute
John M. Wiencek	Rutgers University
William R. Wilcox	Clarkson University
George O. Williams, Jr.,	George Williams Scientific
William Wilson	Mississippi State University
Howard Einsphar	Briston-Myers Squibb-Pharmaceutical Res. Inst. in Princeton, NJ
J. Milburn Jessup	Harvard Medical School-Deaconess Hospital in Boston, MA
Gary E. Wnek	Rensselaer Polytechnic Institute
M. K. Wu	National Tsing Hua University, Taiwan
Bernhard Wunderlich	University of Tennessee
Zheng Long Xiao	Rice University
E. Zharikov	General Institute of Physics, Russian Academy of Sciences, Russia

Workshops

1. Flight Science Readiness Review, MSFC, AL, March 11, 1992.
2. Materials Discipline Working Group, MSFC, AL, July 30-31, 1992.
3. Science Review of Experiments on the Second International Microgravity Laboratory (IML-2), MSFC, AL, January 29, 1993.
4. Investigators Working Group for the Second United States Microgravity Laboratory (USML-2), MSFC, AL, March 15-17, 1993.
5. Final Science Review for the First International Microgravity Laboratory (IML-1), New Orleans, LA, April 7-9, 1993.
6. Investigators Working Group for the Second United States Microgravity Payload (USMP-2), Washington, DC, April 14-16, 1993.
7. Protein Crystal Growth Conference, Panama City, FL, April 23-26, 1993.

8. Organic and Polymeric Materials Workshop, MSFC, AL, April 27-28, 1993.
9. Joint "L+1" Science Review for the First United States Microgravity Laboratory (USML-1) and the First United States Microgravity Payload (USMP-1) with the Microgravity Measurement Group, Huntsville, AL, September 22-24, 1993.
10. Investigators Working Group for the Third United States Microgravity Payload (USMP-3), MSFC, October 29, 1993.
11. Investigators Working Group for the Second International Microgravity Laboratory (IML-2), Howard Johnson, Cocoa Beach, FL, November 8-10, 1993.
12. Investigators Working Group for the Second United States Microgravity Payload (USMP-2), MSFC, November 19, 1993.
13. Science Concept Reviews, MSFC, AL, April 25-27, 1994.
14. Microgravity Science Working Group IRI Module 2 Meeting, MSFC, AL, April 28, 1994.
15. Meeting with Russian Scientists held in conjunction with the Microgravity Materials Science Conference, Huntsville, AL, May 23, 1994.
16. Microgravity Materials Science Conference, Von Braun Civic Center, Huntsville, AL, May 24-25, 1994.
17. Glass and Ceramics Research in Microgravity Workshop held in conjunction with the Microgravity Materials Science Conference, Huntsville, AL, May 25, 1994.
18. Materials Science Discipline Working Group, Washington, DC, August 9, 1994.
19. Microgravity Science Planning Conference, Huntsville, AL, September 26-27, 1994.
20. Investigators Working Group for the Third United States Microgravity Payload (USMP-3), MSFC, AL, September 28, 1994.
21. Science Concept Reviews, MSFC, AL, September 29-30, 1994.
22. Biotechnology Discipline Working Group, Washington, DC, October 25, 1994.
23. Investigators Working Group for the First Life and Microgravity Spacelab Mission, Huntsville, AL, November 15-17, 1994.
24. Investigators Working Group for the Fourth United States Microgravity Payload (USMP-4), MSFC, AL, December 6, 1994.
25. Science Concept Review, Princeton University, December 8, 1994.
26. Investigators Working Group for the Second United States Microgravity Laboratory (USML-2), Huntsville, AL, December 13-14, 1994.
27. Investigators Working Group for the First Microgravity Sciences Laboratory (MSL-1), MSFC, AL, January 24-25, 1995.

New Technology Disclosures

Paley, M., David N. Donovan, Donald O. Frazier and Samuel P. McManus. Solution Growth of Thin Films of a Polydiacetylene Derivative of 2-Methyl-4-Nitroaniline that Exhibit Outstanding Phase Conjugation. Disclosed to NASA in 1993.

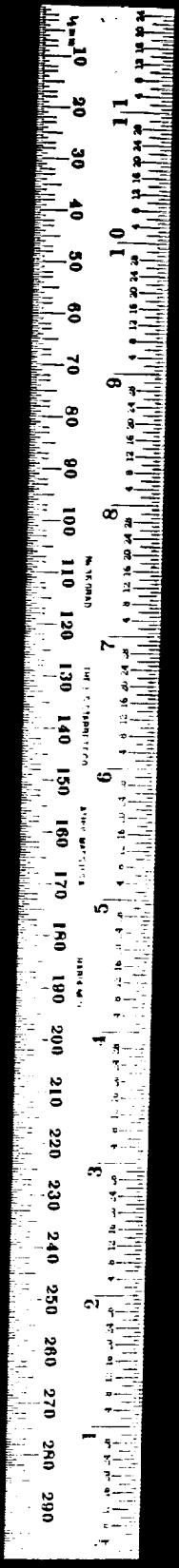
Subcontracts

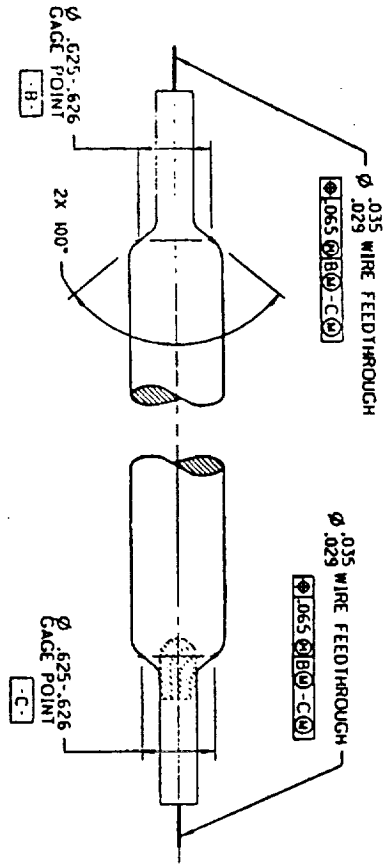
The subcontract with the University of Alabama in Huntsville for Dr. James Van Alstine for contract oversight expired February 2, 1995.

Financial

Total Contract Value:	\$3,093,467 (includes revenue from conference registrations)
Funded Value:	\$3,063,585
Available Funding to Contract's Completion:	\$200,000

APPENDIX 1





- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
 2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ON DECIMALS
.XX ± .03
ANGLES: ± 10°
 3. TIPOFF SHALL NOT EXTEND BEYOND INDICATED ENVELOPE.
 4. FEEDTHROUGHS AND TIPOFF SHALL BE IN THE SAME PLANE WITHIN 15° TOTAL.
 5. SEE TABLE 5.1 FOR DETAIL PARTS.

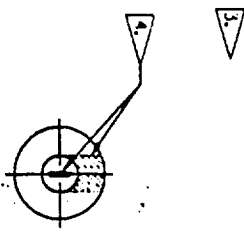
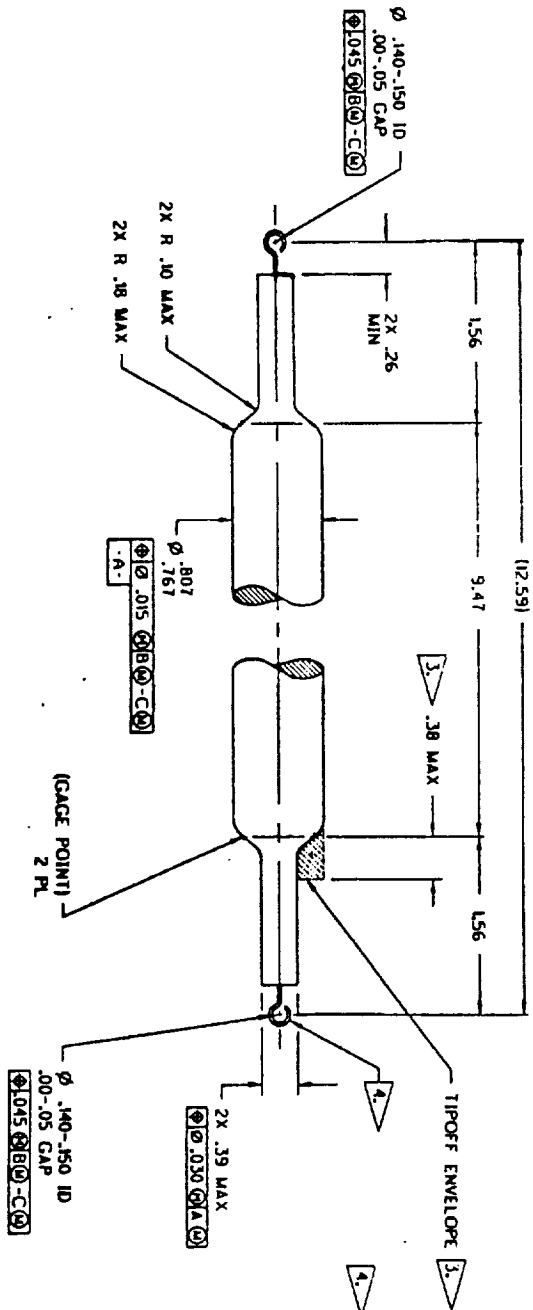
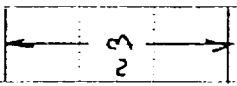


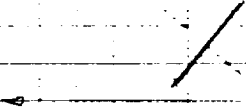
FIGURE 5.2
SAMPLE AMPPOLE
MECHANICAL INTERFACE
IDENTIFICATION AND CONTROL
PARAMETERS

INTERFACE CONTROL DOCUMENT	
SAMPLE AMPPOLE TO CARTRIDGE ASSEMBLY IDFT	3401CD00140

FSF-2 meltback IF

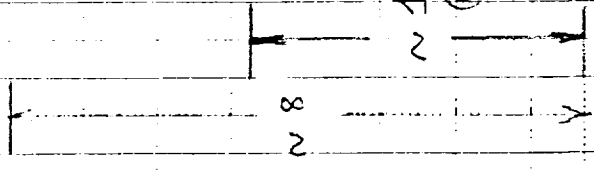


[100 $\mu\text{m}/\text{cm}$]



translation
direction
 $\pm 2^\circ$
(111)
crystal center

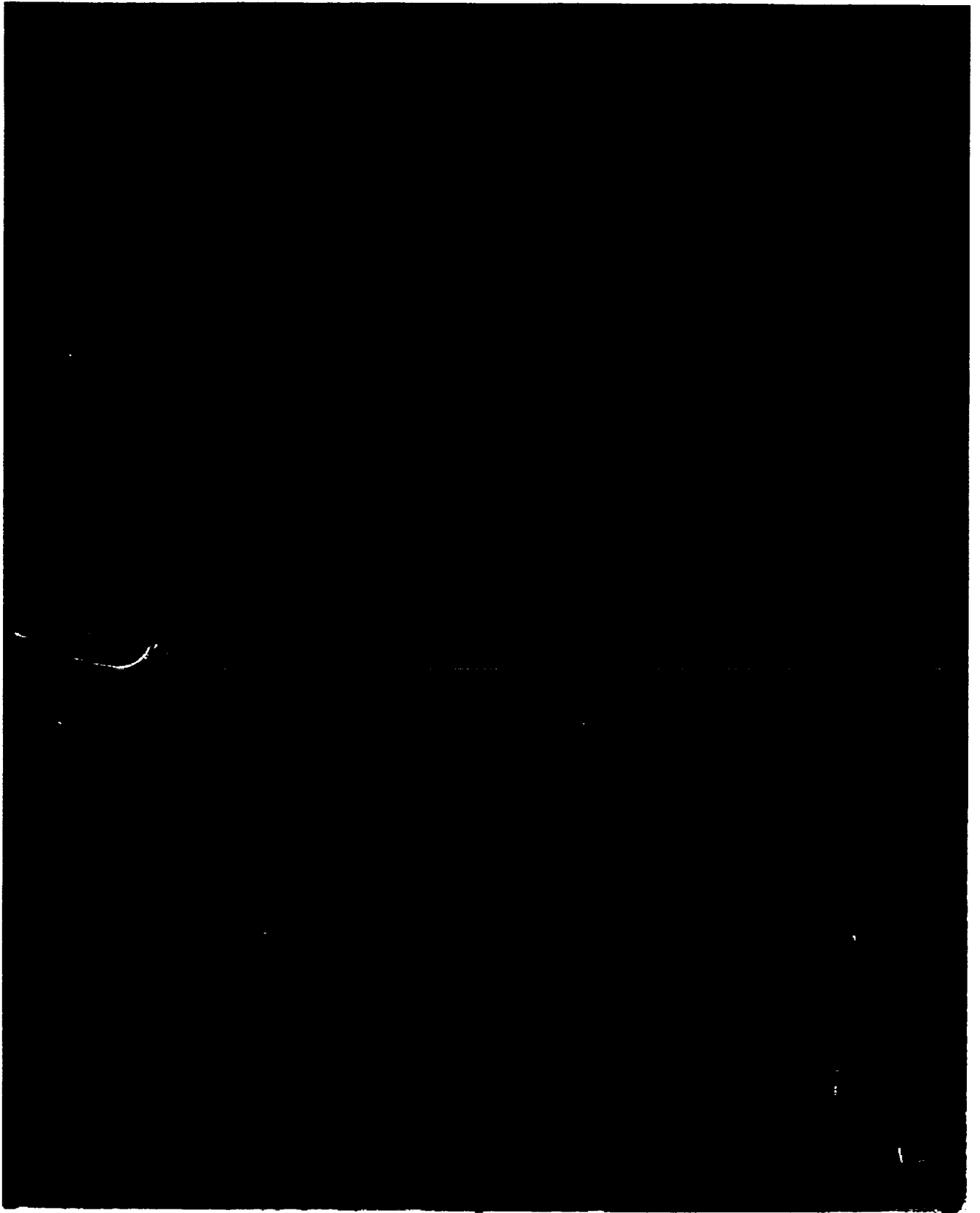
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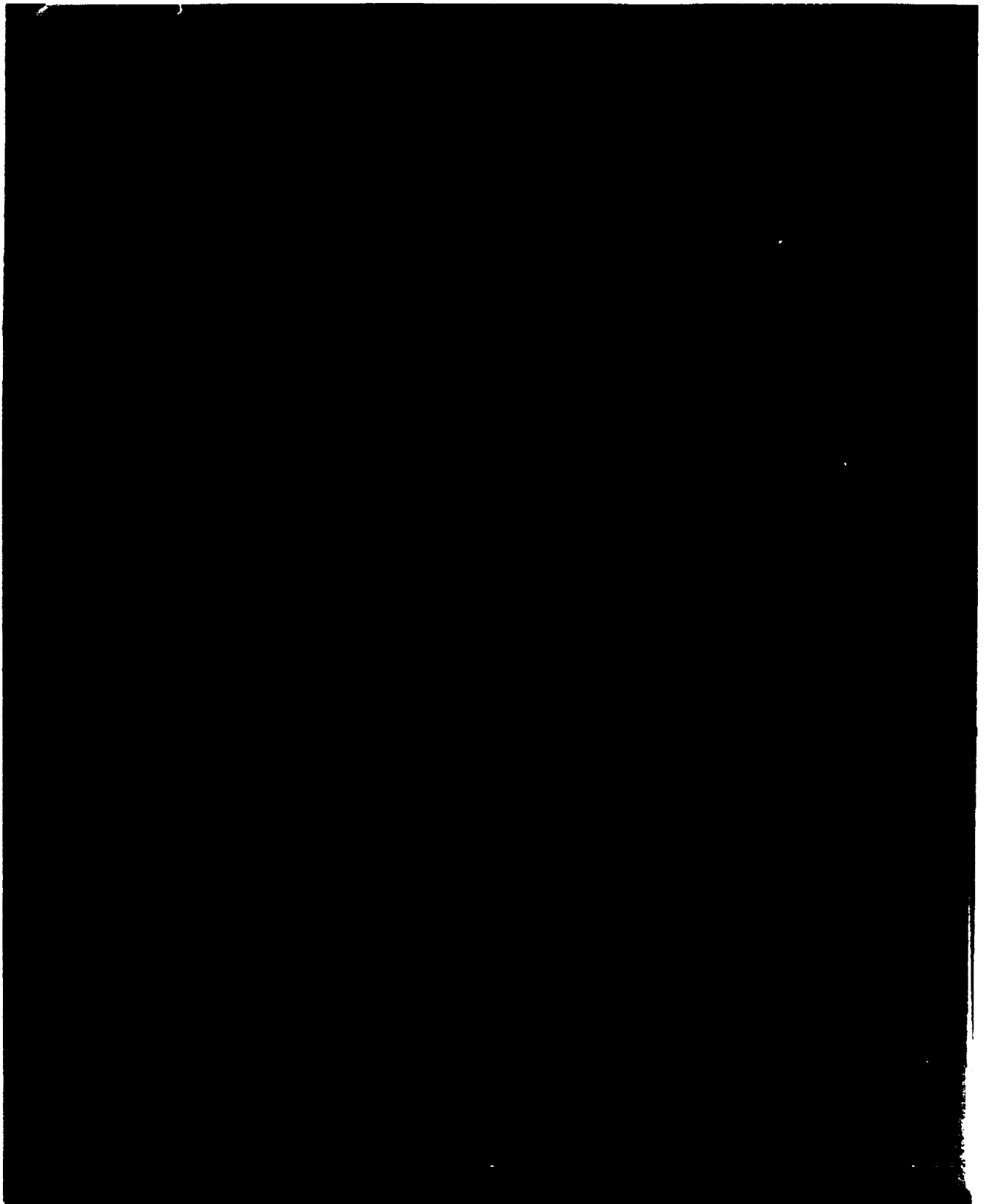


$\sim 1 \text{ min}$
8 $\mu\text{m}/\text{s}$

[1000 $\mu\text{m}/\text{cm}$]

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APPENDIX 2

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UNIVERSITIES SPACE RESEARCH ASSOCIATION

***MICROGRAVITY SCIENCE AND APPLICATIONS
PROGRAM***

NAS8 - 38785

***BIBLIOGRAPHY
1992 - 1995***

**Compiled by
Dannah McCauley
January 1995**

UNIVERSITIES SPACE RESEARCH ASSOCIATION
PUBLICATIONS AND PRESENTATIONS BY VISITING SCIENTISTS
MICROGRAVITY SCIENCE AND APPLICATIONS PROGRAM
NAS8-38785
MARSHALL SPACE FLIGHT CENTER, ALABAMA
1992 - 1995

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NASA Technical Memorandum Contributions - 1	1
NASA Conference Publications Contributions - 2	1
NASA Technical Briefs Contributions - 3	1
Refereed Journal Articles Contributions - 39	1
Contributions to Books, Monographs, Conference Publications, etc. Contributions - 15	4
Published Abstracts Contributions - 14	6
Presentations Contributions - 41	7
Invited Presentations Contributions - 12	11
Submitted Contributions - 19	12
USRA Patent Applications Applications - 1	13

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20. Ramachandran, N., Yeh, Y.-P., Heaman, J. P., and Smith, A. W. 1993. Experimental Study of Injection-Induced Flow From Porous Walls With High Blowing Fraction. AIAA 24th Fluid Dynamics Conference, July 6-9, 1993. (ES71)
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Invited Presentations

1. Lehoczky, S. L., Szofran, F. R., Gillies, D. C., Cobb, S. D., Su, C.-H., Sha, Y.-G., and Andrews, R. N. 1993. Bulk Growth of II-VI Semiconducting Compounds. Ninth American Conference on Crystal Growth Proceedings, August 1-6, 1993. (ES75)
2. Lehoczky, S. L., Szofran, F. R., Gillies, D. C., Cobb, S. D., Su, C.-H., Sha, Y.-G., and Andrews, R. N. 1993. Crystal Growth of II-VI Semiconductors in Microgravity. Third International Union of Materials Research Society (IUMRS) International Conference on Advanced Materials, Tokyo, Japan, August 31 - September 4, 1993. (ES75)
3. Su, C.-H., Sha, Y.-G., Volz, M. P., Gillies, D. C., Lehoczky, S. L., Zhou, W., Dudley, M., Liu, H.-C., Brebrick, R. F., and Wang, J. C. 1994. Ground Based Research on the Growth of II-VI Compound Semiconductors by Physical Vapor Transport. 32nd AIAA Aerospace Sciences Meeting, paper no. 94-0564. (ES75)
4. Van Alstine, J. M. 1992. Two Bioseparations Methods Under Development. Center for Cell Research, Pennsylvania State University, College Park, January 1992. (ES76)
5. Van Alstine, J. M. 1992. Three New Bioseparation Techniques. Naval Research Laboratory, Washington, DC, March 27, 1992. (ES76)
6. Van Alstine, J. M. 1992. New Cell Separation Methods. Systemix Corporation, Palo Alto, California, July 6, 1992. (ES76)
7. Van Alstine, J. M. 1992. Electrokinetic Characterization of Polymer Coatings. American Chemical Society National Meeting, Washington, DC, August 23-28, 1992. (ES76)
8. Van Alstine, J. M. 1992. Current Research. Alabama Materials Research Conference. Auburn University, Auburn, Alabama, October 7, 1992. (ES76)

9. Van Alstine, J. M. 1992. Polymer Coatings to Control Surface Phenomena in Biotechnology. Department of Biomedical Engineering, University of Alabama, Birmingham, Alabama, October 20, 1992. (ES76)
10. Van Alstine, J. A. 1994. Use of Microparticle Electrophoresis to Characterize Hydrophilic Polymer Coatings. Center for Surface Chemistry, University of Lund, Sweden, May 18, 1994. (ES76)
11. Van Alstine, J. A. 1994. Inhibition of Complement Surface Activation. Institute for Surface Chemistry, Stockholm, Sweden, August 16, 1994. (ES76)
12. Van Alstine, J. A., 1994. Polymer Derivatives to Improve Separations. CellPro, Seattle, Washington, February 2, 1995.

Submitted

1. Burns, N. L., Van Alstine, J. M., and Harris, J. M. Poly(ethylene glycol) Grafted Onto Quartz: Surface Analysis Via a Site Dissociation Model of Electroosmosis. *Anal. Chem.*, to be submitted.
2. Cardelino, B. H., Moore, C. E., Paley, M. S., and Frazier, D. O. Static Third-Order Polarizability Calculations for Large Molecular Systems; A Study of Pyrrol Diacetylene Derivatives. *J. Phys. Chem.* (ES74)
3. Chen, K.-T., George, M. A., Zhang, Y., Burger, A., Su, C.-H., Sha, Y.-G., Gillies, D. C., and Lehoczky, S. L. Selenium Precipitation in ZnSe Crystal Grown by Physical Vapor Transport. *J. Cryst. Growth.* (ES75)
4. Ewing, F. L., Forsythe, E. L., and Pusey, M. L. The Effects of Purification on the Crystallization of Lysozyme at Basic pH. *J. Cryst. Growth.* (ES76)
5. Knox, R. J., Burns, N. L., Van Alstine, J. M., Harris, J. M., and Seaman, G. V. F. Automated Analytical Particle Electrophoresis: Control of Electroosmosis via Polymeric Wall Coatings. *Anal. Chem.* (ES76)
6. Malmsten, M. and Van Alstine, J. M. 1995. Adsorption and Protein Rejection of Poly(ethylene glycol) Esterified Fatty Acids. *J. Colloid Interface Sci.* (ES76)
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8. Paley, M. S., Frazier, D. O., Abdeldeyem, H., and McManus, S. P. Photo-Deposition of Amorphous Polydiacetylene Films from Monomer Solutions onto Transparent Substrates. *J. Am. Chem. Soc.* (ES74)
9. Price, M. W., Andrews, R. N., Su, C.-H., Lehoczky, S. L., and Szofran, F. R. Effect of a Transverse Magnetic Field on the Microstructure of Directional Solidified CdTe. *J. Cryst. Growth.* (ES75)
10. Ramachandran, N., Naumann, R., and Baugher, C. Effects of Steady and Time Dependent Acceleration on Protein Crustal Growth. *J. Cryst. Growth.* (ES71)

11. Rolin, T. D. and Szofran, F. R. Determination of the Electrical Conductivity of Liquid $\text{Ge}_{0.95}\text{Si}_{0.05}$. *J. Cryst. Growth.* (ES75)
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14. Van Alstine, J. M., Alred, P. A., McElhaney, R. N., and Brooks, D. E. Effect of Membrane Lipid Alteration on the Partitioning Behavior of *Acholeplasma laidlawii* B Cells in Aqueous Polymer Two-Phase Systems. *Biochim. Biophys. Acta.* (ES76)
15. Van Alstine, J. M., Chiu, B., Alred, P., and Brooks, D. E. Amphipathic Surface Properties of Platelet Discocytes and Echinocytes. *J. Chromatog.* (ES76)
16. Van Alstine, J. M. and Malmsten, M. 1995. Surface Associate Behavior of Poly(ethylene Glycol) Amphiphiles Relation to the Use of PEG-Ligands in Biotechnology. *J. Biol. Chem.* (ES76)
17. Van Alstine, J. M., Sorrenson, P. B., and Brooks, D. E. Effect of Lipid Phase Transition on the Partition of Dimyristoyl Phosphatidylcholine Small Unilamellar Liposomes in Aqueous Polymer Two Phase Systems. *Biochim. Biophys. Acta.* (ES76)
18. Yeh, Y. P., Ramachandran, N., Heaman, J., and Smith, A. 1994. Water Flow Simulation of the Flow in Solid Rocket Motors Using Porous Walls. *Experiments in Fluids.* (ES71)
19. Yeh, Y. P., Ramachandran, N., Heaman, J., and Smith, A. 1994. Cold Flow Simulation of the Port Flow in Solid Rocket Motors. *Experiments in Fluids.* (ES71)

USRA Patent Applications

Scientist: Paley, Mark Steven, David N. Donovan, Donald O. Frazier and Samuel P. McManus
 Title of Patent: Solution Growth of Thin Films of a Polydiacetylene Derivative of 2 Methyl-4-Nitroaniline that Exhibit Outstanding Phase Conjugation.
 NASA Case No.:
 Serial Number:
 Patent File No.:
 Contract No.: NAS8-38785
 Date: Disclosed 1993
 Disposition: