REVIEW AND EVALUATION OF SPACE PROCESSING APPLICATIONS

(NASA-CR-178703) REVIEW AND EVALUATION OF SPACE PROCESSING APPLICATIONS Final Report (Universities Space Research Association) 21 p HC A02/MF A01 CSCL 22A

N86-20434

Unclas G3/12 05445

Contract No. NAS8-35768

Program Manager: Henry Leidheiser, Jr.
Lehigh University

Submitted to:

George C. Marshall Space Flight Center
Huntsville, Alabama 35812

by
Universities Space Research Association
American City Building, Suite 311
Columbia, MD 21044

January 7, 1986

Introduction

Materials research in space offers advantages in studying phenomena and preparing materials under conditions which cannot be realized in the gravity field of the earth. An increase in our basic understanding of materials processes will, in the future, enhance our ability to control them more effectively and to adapt them to new and more complex environmental conditions.

Many techniques are being developed to improve processing systems and reduce the effect of these gravitationally induced restrictions. Research opportunities exist using ground-based and unique space-based processing systems. The space-based devices take advantage of a wide range of low-gravity facilities including drop towers and tubes, aircraft and sounding rocket parabolic trajectories, simple materials experiment accommodations in the Space Shuttle, and more complex capabilities in Spacelab. All these systems are being used to not only produce novel materials but also to study materials processing under unique conditions.

The participation of the Universities Space Research Association (USRA) in NASA's Materials Processing in Space (MPS) program began in 1970. The program was designed initially to provide support to the MPS program at the Marshall Space Flight Center (MSFC). The program has continued to provide the organization and administration of colloquiums, science reviews, workshops, technical meetings, bibliographic services, and visiting scientist programs.

USRA's Materials Processing in Space program has two thrusts. Professor Henry Leidheiser, Jr., Lehigh University, directs the part of the effort that is directly involved with the Marshall Space Flight Center under this contract. Dr. Guy Rindone, Pennsylvania State University, directs the part of the effort that provides discipline working groups, seminars, workshops, and ad hoc study groups for NASA Headquarters.

In the paragraphs below, we discuss the components of USRA's program that are covered in the effort under the direction of Professor Leidheiser. The paragraphs are labeled by task, according to the designation in the statement of work. A description of the statement of work is provided in Appendix A.

Task A

USRA is responsible for the organization and administration of colloquiums, science reviews, workshops, and other such meetings in the various disciplines of

interest to materials processing in space. The purpose of such meetings is to promote interaction between the NASA-sponsored researchers, and those other agencies, universities, and organizations.

A lecture and seminar series was formulated to provide a forum for discussion and to stimulate interest in the MPS program. Seminars were presented to MSFC scientists by highly-qualified researchers in the fields of biochemical separation processes, solidification of metals and alloys, electronic materials, processing of biological materials, protein crystallization, fluid phenomena, and surface phenomena under microgravity. A complete list of seminars and colloquiums is included in Appendix B. Workshops have been conducted in various disciplines including fluid phenomena and electrophoretic separation.

An on-going activity of the contract is to support specific areas of research which are of interest to NASA by designated individuals, visiting scientists, and/or small ad hoc groups. An example of this was the establishment of the Space Station Advisory Group, under the leadership of Dr. Robert Naumann. The purpose of this group is to provide the initial science outfitting data to NASA and to evaluate requirement criteria for a microgravity module on the Space Station. Many members of the USRA Discipline Working Groups are members of this ad-hoc group. A list of members is included in Appendix C.

Task B

An activity which USRA has undertaken in the Materials Processing in Space program has been to maintain an extensive library on material sciences publications

The preparation of a bibliography on materials processing in space began in 1975 because it became necessary to provide background information on past research in the various disciplines to scientists who were actively working on current projects in the material sciences. The bibliography was organized from these publications and other additional information and was completed in March 1982. A revision of this bibliography has been published on an annual basis since 1982.

A continuing effort is being made to maintain an accurate up-to-date record of all material sciences publications. This is being accomplished by Ms. Elizabeth Pentecost, supported under another contract, and Ms. Selena Hamby, USRA/MSFC. Publications are added to the existing library on a continuing basis and are made available upon request to researchers in the field. From these publications, USRA has prepared several bibliographic

reports and summaries that tabulated contractual reports and publications in the open literature dealing with the effects of microgravity conditions on materials processing in space. (Materials Processing in Space Bibliography, 1983 Revision, NASA TM-82507, 1983; Microgravity Science and Applications Bibliography, 1984 Revision, NASA TM-86651, 1984).

Numerous scientific papers are submitted and published in the open literature or presented to national and international symposia by the visiting scientists at MSFC. One activity that USRA performed is the preparation of these papers for submission to the science journals. Since these publications must adhere to the editing and style guidelines provided by NASA, it became necessary for USRA to provide the expertise needed by using the word processing services of Ms. Shelby Morris and Ms. Kathy Payette. Ms. Judy Hughes provided these services under the contract to the Space Commercialization Office at MSFC.

Task C

USRA convened several meetings to provide technical information in both the basic and applied science aspects of the materials processing program. These meetings are determined jointly by USRA and MSFC. USRA met with MSFC representatives to plan future programs and to give advice on existing programs. It participated in numerous meetings including meetings of advisory committees concerned with experimental facilities for the Shuttle, design and fabrication of flight hardware, and organization of the space processing program.

Task D

An additional task was later added to the contract, support of visiting scientists at MSFC.

The visiting scientist activity is an essential part of the USRA involvement in the materials processing in space program. For the past ten years, USRA has provided highly qualified scientists in various disciplines, including cell separation, fluid physics, crystallization, solidification of metals and alloys, characterization of colloids, glass fabrication, and surface science.

During the contract period, there have been six USRA visiting scientists at the Marshall Space Flight Center working in subject areas including: behavior of fluids in the reduced gravity environment; preparation and characterization of solid state materials; biochemical separation processes; preparation and characterization of semiconductor materials; and protein crystallization.

Dr. Dipankar Chandra, Rensselaer Polytechnic Institute, began work at MSFC in December 1981. His appointment ended in December 1984. Dr. Chandra's area of interest concerned preparation and characterization of semiconductor materials.

Dr. William F. Kaukler, University of Toronto, began work at MSFC in October 1981. His appointment ended in October 1984. Dr. Kaukler's area of interest concerned characterization of solid state materials, critical point wetting.

Dr. Basil Antar, University of Tennessee Space Institute, began work at MSFC in December 1983. His appointment ended December 1984. Dr. Antar's area of interest concerned behavior of fluids in the reduced gravity environment of space.

Dr. James M. Van Alstine, University of British Columbia, began work as a USRA visiting scientist in January 1984. Dr. Van Alstine's area of interest concerns aqueous polymer two-phase partitioning of biological cells. He has set up a functioning two phase partitioning laboratory using equipment already in the Separation Processes laboratory. The laboratory includes an automatic thin layer counter-current apparatus for multiple two phase partition studies. The apparatus is capable of differentiating between cancer cells of unequal metastatic potential. Dr. Van Alstine has studied the ability of the partition technique to separate a number of macromolecular and particle populations which were previously studied by analytical and free-flow electro-phoretic methods.

Dr. Van Alstine has been actively involved in NASA's Phase Partitioning program. It currently involves groups at the University of Oregon and University of British Columbia, headed by Dr. D. E. Brooks, the University of Alabama Huntsville, headed by Dr. J. M. Harris, and the Marshall Space Flight Center, headed by Dr. Robert Snyder. The groups have acted in close concert to carry out both practical and theoretical studies involving particle separation in polymer two-phase systems. The theoretical work involved studying phase separation (normally controlled on Earth by gravity, due to density differences between the phases) in the low gravity environment of space. Results of one shuttle flight (STS 51-D) to date, suggested that unqiue particle separations may be obtainable in space and that much information of interest to Earth-bound phase separation scientists could also be obtained.

Dr. Van Alstine has published numerous papers in the open literature and has three patent applications pending. He has given numerous seminars on his research and has presented papers at international and national symposia.

Dr. Ching-Hua Su, University of Wisconsin-Milwaukee, began work at MSFC in January 1985. Dr. Su's area of interest is in two areas: (1) solidification of mercury cadmium telluride (HgCdTe). HgCdTe were solidified under a well-defined thermal condition using a two zone furnace. The compositional variations along the radial and axial directions were determined by infrared (IR) transmission, energy dispersion of x-ray (EDX), and density measurements; and (2) crystal growth of CdS by vapor transport. CdS was transported from the hot end to the cold end of a closed ampoule. The transport rate as a function of the configuration of the furnace (vertical or horizontal), the inside Ar pressure, and the composition of the starting materials were studied.

Dr. Mary Beth Broom began work at MSFC in September 1984. Her appointment ended in September 1985. Dr. Broom's area of interest concerned protein crystallization. Protein crystals large enough and of suitable quality for x-ray crystallographic analysis are often difficult to obtain. For unknown reasons, these crystals tend to be small and/or of poor quality. At MSFC, in collaboration with Dr. Charles Bugg's crystallography group at the University of Alabama-Birmingham, scientists are trying to determine and quantify the effects of the variables involved in the growth of protein crystals. A major part of this work has been the study of the effect of gravity on protein crystal growth. In microgravity, without convection currents and with smoother concentration gradients now perfect crystals might be produced. This would be especially important for protein crystals.

The first protein crystal growth experiment was flown on STS 51-D in April 1985. Most the research time from October 1984 to June 1985 was spent designing and testing shuttle flight hardware. In December and January, Dr. Broom supervised the initial KC-135 experiments which tested the syringe tip design of the precursors to the flight syringes.

Another aspect of Dr. Broom's research was the development of new crystallizing agents. One of the most successful crystallization agents currently used is the polymer polyethylene glycol (PEG). Dr. Broom tested other high molecular weight polymers such as Ficoll and Dextran in the crystallization of the protein lysozyme. Her results indictated that Ficoll apparently acted as a crystallizing agent similar to PEG for lysozyme. Ficoll has the added benefit of increasing the density of the solution more than PEG, thus reducing the convective flow as the crystals form. The results from these preliminary experiments are

intriguing and further studies in this areas will be pursued.

USRA visiting scientists submitted numerous papers for publication in scientific journals on their work at MSFC. This work spanned a wide range of disciplines, from semiconductor growth to cell separations. These publications were cited in various scientific journals, which indicated how important their work has become to the material sciences community. A complete list of publications in journals and books written by USRA visiting scientists is provided in Appendix D.

Financial

Total Estimated Cost of Contract: $169,593
Total Cumulative Funds: $176,581.30
% Complete: 104%
Remaining Funds: -$6,988.30

The contract NAS8-35768 originally did not cover the visiting scientist program. Modification 5 added a statement of work to include this task, however, it did not include any additional funds. Subsequently, 2.5 visiting scientists were added and funded through this contract. An additional task of supporting space station work was partially funded through this contract.

APPENDIX A

EXHIBIT "A"

SCOPE OF WORK

1. Work Statement

The Contractor shall accomplish the following tasks:

Task A

Studies concerning the Materials Processing in Space require analyses in disciplines such as biomedical separation processes; cell separations, proteins, superconductivity; foams; solid state colloids; containerless processes; solid solution semiconductors; vapor transport mechanisms; high purity materials; and fluid dynamics in low-gravity fields, depending upon the problem area. The Contractor will provide, utilizing the large university member institutions, the necessary expertise to solve specific materials processing in space problems with the frequency of need determined by the Technical Contracting Officer's Representative. This expertise can be in the form of colloquiums, science reviews, workshops, and/or discipline specialty people for a 1- or 2-day meeting with in-house materials processing in space personnel.

Task B

Provide the expertise for the bibliography update by searching the materials processing in space literature and adding pertinent items to keep the bibliography current. Areas of interest to the materials processing in space will be identified by the Technical COR Program Scientist and Program Manager. Reference reports will be prepared for distribution to committee members and others as selected by the Program Scientist.

Provide the expertise for the preparation of papers to be submitted to scientific and technical journals and technical reports and presentations to national and international symposia. This scientific documentation shall be prepared in both draft and final product form, utilizing editing and style guides and MSFC guidelines.

Task C

The dates, location, and participants of necessary meetings will be determined jointly by NASA/MSFC and USRA.

APPENDIX B

Seminars, Workshops, and Colloquiums Held During Contract Period at Marshall Space Flight Center

Dr. Hari H.P. Copley, SUNY-Buffalo, presented a seminar entitled "Fractionation of Cell Populations by Double Antibody Tagging" in July 1984.

Ms. Cindy Flenniker presented a seminar July 17, 1984 on "Metal-polymer Composites: Iron Pentacarbonyl Decomposition in Polymer Matrices."

Dr. William F. Kaukler, USRA Visiting Scientist, attended a workshop on Pattern Formation and Geomteric Aspects of Turbulence in August 1984.

Dr. James Van Alstine, USRA Visiting Scientist, presented a seminar at the University of Wisconsin, Department of Biology, August 10, 1984.

Dr. Marcus M. Vlass, Polytechnic Institute of Brooklyn, presented a seminar on materials processing in space at MSFC on September 27-28, 1984.

Mr. Ching-Hua Su, University of Wisconsin-Milwaukee, presented a seminar at MSFC on the preparation and electronic properties of mercury cadmium telluride in September 1984.

Support provided to Dr. John Sloyer, Cooper Diagnostics, and Dr. Hari H.P. Cohly, SUNY-Buffalo, to attend Electrophoresis Meeting in Tucson, Arizona on October 17-19, 1984. Dr. Sloyer described the hemoglobin and polysaccharide separations performed on Shuttle STS-6 flight and Dr. Cohly presented results carried out using continuous flow electrophoresis of mouse spleen cells.

Dr. Mary Beth Broom, USRA Visiting Scientist, presented a paper, "Drop Dynamics in Microgravity," at the Conference on Protein Crystal Growth in Microgravity, May 6-9, 1985 in Huntsville, Alabama.

Dr. James Van Alstine, USRA Visiting, presented a paper at the 5th European Symposium on Material Sciences under Microgravity in Schloss Elmau November 5-7, 1985.

Professor George Homsy, Stanford University, presented a seminar at MSFC on January 28, 1985 entitled "Theoretical Results of Marangoni Flow and Its Stability."

Dr. William Winter, Center for Sickle Cell Disease, presented a seminar at MSFC on February 1, 1985.

Dr. G. J. Abbaschian, University of Florida-Gainesville, presented a seminar at MSFC on March 19, 1985.

Dr. James Van Alstine, USRA Visiting Scientist, presented results of Shuttle 51-D phase partitioning experiments at polymer workshop in Cleveland, Ohio May 8-9, 1985.

The Space Station Science Advisory Group met at MSFC May 9-10, 1985, to provide the initial science outfitting data to Dr. Robert Naumann, Space Station Laboratory Module Project Scientist.

APPENDIX C

SPACE STATION ADVISORY GROUP
(Naumann)

Dr. Paul Todd, Director
Bioprocessing & Pharmaceutical Research Center
University City Science Center
3624 Market Street
Philadelphia, PA 19104
215/386-9600

Dr. Jack Sloyer
Bioprocessing & Pharmaceutical Research Center
University City Science Center
3624 Market Street
Philadelphia, PA 19104
215/386-9600

Dr. Robert Altenkirch
University of Kentucky
Mechanical Engineering Department
Lexington, KY 40506
606/257-2663

Dr. Bruce Peters
Program Manager, Combustion Research
Fluid Mechanics Dept., Rm 254
Research Engineering Bldg.
General Motors Research Labs
Warren, MI 48090-9056
313/575-2972

Dr. Lubek Jastrzebski
RCA
David Sarnoff Research Center
Princeton, NJ 08540
609/734-2655

Dr. Thomas Theis
IBM Watson Research Center
P. O. Box 218
Yorktown Heights, NY 10598
914/945-2244

Dr. Delbert Day
Materials Research Center
University of Missouri, Rolla
Rolla, MO 65401
314/341-4354

Dr. Abe Krikorian
Biochemistry Department
State University of New York
Stony Brook, NY 11794
516/246-5035

Dr. Martin Glicksman
Department of Materials Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181
518/266-6372

Dr. David Larson
Grumman Research Center
Research Department, Plant 26
Bethpage, NY 11714
516/575-4896

Dr. Franz Rosenberger
312 N Physics
University of Utah
Salt Lake City, UT 84112
801/581-8372

Dr. Julian Szekely
MIT
Room 4-117
Cambridge, MA 02139
617/253-3236

Dr. John Hart
Department of Astrophysics
University of Colorado
Campus Box 391
Boulder, CO 80309
303/492-8568, 8913

Dr. Joe Reynolds
Louisiana State University
115 Systems Bldg.
Baton Rouge, LA 70803
504/388-6118

Mr. Gary McCoy
AFWAL/AADR-1
Wright Patterson Air Force Base
Dayton, OH 45433
513/255-4234

Dr. Don Clifford
McDonnell Douglas Research Labs
E451-101-MEZ-B54
P. O. Box 516
St. Louis, MO 63166
314/232-2896

Dr. Chris Chow
Manager, Physics Research
3M Center
Science Research Laboratory
St. Louis, MN 55144
612/733-3551

Mr. Bob Pace
Microgravity Research Associates, Inc.
810 Regal Drive
Huntsville, AL 35802
205/881-6670

Mr. Olav Smistad
Mail Stop PD211
NASA Johnson Space Center
Houston, TX 77058
713/483-6426

Ms. Jeanne L. Crews
Code SN12
NASA Johnson Space Center
Hosuton, TX 77058
713/483-2781

Mr. Harry Atkins
Advanced Systems Office
Mail Code PS06
Marshall Space Flight Center
MSFC, AL 35812
205/453-3424

Dr. Taylor Wang
Mail Stop 183-401
JPL
Pasadena, CA 91109
818/354-6331

Mr. Jack Salzman
Mail Stop 500-217
NASA Lewis Research Center
Cleveland, OH 44135
216/433-4000, ext. 385

Capt. Brian L. Hoekstra
AFWAL/MLPO
Wright Patterson Air Force Base
Dayton, OH 45433
513/255-4474

APPENDIX D

Papers Submitted by USRA Visiting Scientists on Research Resulting from Activities at Marshall Space Flight Center, NASA Contract NAS8-35768

Bamberger, S., Brooks, D. E., Sharp, K. A., Van Alstine, J. M., and Webber, T. J., "Methods and Types of Apparatii," in Partitioning in Aqueous Two-Phase Systems, Chapter 2 (H. Walter, D. Fisher, and D. E. Brooks, eds.), Academic Press, in press.

Brooks, D. E., Bamberger, S., Harris, J. M., and Van Alstine, J. M., "Rationale for Two-Phase Polymer System Microgravity Separation Experiments," in Proceedings of 5th European Symposium on Materials Sciences under Microgravity, Results of Spacelab-1, Schloss Elmau, 1984, ESA SP-222, pp. 315-318.

Chandra, D., Szofran, F. R., Wang, J. C., Cothran, E. K., and Lehoczky, S. L., "Effect of Growth Parameters on Compositional Variations in Directionally Solidified HgCdTe Alloys," J. Cryst. Growth, 1985 (in press).

Curreri, P. A., Van Alstine, J. M., Brooks, D. E., Bamberger, S., and Snyder, R. S., "On the Stability of High Volume Fraction Immiscible Dispersions in Low Gravity," Met. Trans. A., 1985 (submitted).

Harris, J. M., Struck, E. C., Shannon, T. G., Paley, S. M., Yalpani, M., Van Alstine, J. M., and Brooks, D. E., "Synthesis and Characterization of Poly(ethylene glycol) Derivatives," J. Polymer Sci. Polymer Chem Edn. 22, 341-352 (1984).

Harris, J. M., Case, M. G., Hovanes, B. A., Van Alstine, J. M., and Brooks, D. E., "Purification of Biomaterials by Phase Partitioning with Poly(ethylene glycol) - alkyl Ethers," Ind. Engr. Prod. Res. Dev. 23, 86-88 (1984).

Herren, B. J., Shafer, S. G., Van Alstine, J. M., Harris, J. M., and Snyder, R. S., "Control of Electroosmosis in Coated Quartz Capillaries," J. Colloid & Interface Sci., 1985 (accepted).

Karr, L. J., Shafer, S. G., Harris, J. M., Van Alstine, J. M., and Snyder, R. S., "Immuno-affinity Partition of Cells," J. Chromato., 1985 (accepted).

Kaukler, W. F., "Hot Stage and Sample Cell Design for the Solidification of Transparent Materials with and without Forced Convection," Rev. Sci. Instrum. 55, 2643 (1984).

Kaukler, W. F., "Determination of the Phase Diagram for Carbon Tetrabromide and Hexachlorethane," Mat. Sci. Engr. 65, L1-L4 (1984).

Kaukler, W. F., Frazier, D. O., and Facemire, B. R., "Determination of the Succinonitrile-Benzene and Succinonitrile-Cyclohexanol Phase Diagrams by Thermal and UV Spectroscopic Analysis," NASA TM-82481, 1984.

Kaukler, W. F. and Frazier, D. O., "Observations of a Monotectic Solidification Interface Morphology," J. Cryst. Growth, 1985 (in press).

Sharp, K. A., Brooks, D. E., Van Alstine, J. M., and Bamberger, S., "Mechanisms of Cell Partition in Aqueous Polymer Two Phase Systems," Biophys. J., 1985 (submitted).

Smith, J. E., Frazier, D. O., and Kaukler, W. F., "A Redetermination of the Succinonitrile-Water Phase Diagram," Scripta Met. 18, 677-682 (1984).

Van Alstine, J. M., Harris, J. M., Snyder, R. S., Curreri, P. A., and Brooks, D. E., "Results of Initial Two-Phase Polymer System Microgravity Separation Experiments," in Proceedings of 5th European Symposium on Material Sciences under Microgravity, Results of Spacelab-1, Schloss Elmau, 1984, ESA SP-222, pp. 309-313.

Van Alstine, J. M., Snyder, R. S., Karr, L. J., and Harris, J. M., "Cell Separation with Countercurrent Chromatography and Thin-Layer Counter-Current Distribution in Aqueous Two-Phase Systems," J. Liq. Chromato. 8, 2293-2323 (1985).

UNIVERSITIES SPACE RESEARCH ASSOCIATION
600 MARYLAND AVENUE, SW SUITE 201 WEST WING
WASHINGTON, DC 20024 • (202) 547-2609

January 7, 1986

Contract NAS8-35768

Final Report
Distribution List

Quantity	
1	Code AP29F George C. Marshall Space Flight Center MSFC, AL 35812
3	Code AS24D George C. Marshall Space Flight Center MSFC, AL 35812
1	Code AT01 George C. Marshall Space Flight Center MSFC, AL 35812
2	Code ES71 George C. Marshall Space Flight C er MSFC, AL 35812
1	Code EM63-12 George C. Marshall Space Flight Center MSFC, AL 35812
1	Code ES01 George C. Marshall Space Flight Center MSFC, AL 35812
1	Contract Administrator USRA Headquarters American City Building, Suite 311 Columbia, MD 21044
1	Code EN-1 NASA Headquarters B233 Washington, DC 20546
1	Code CC01/L. Wofford George C. Marshall Space Flight Center MSFC, AL 35812

Subject: Enclosed is the Final Report for period December 1983 - December 1985, prepared under Contract No. NAS8-35768.