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OPPORTUNITIES FOR THE CHEMICAL INDUSTRY IN SPACE

Part I

DRA

Contract NASW-3826

PRESENTATION OF OPPORTUNITIES FOR THE CHEMICAL INDUSTRY TO BECOME INVOLVED IN SPACE EXPERIMENTATION

Part I

a portion of the study to encourage and facilitate industrial investment and involvement in space

FINAL REPORT

Contract NASW-3826

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA HEADQUARTERS

CODE ADB

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EXECUTIVE SUMMARY

The objective of this study was to carry out an in-house investigation of the chemical industry preparatory to making personal presentations to key members of that industry. The ultimate aim is to gain active industrial investigators from that industry who will pursue a program to use microgravity for their benefit.

The regime of chemical catalysis has been selected for spearheading the initial approaches. Twenty companies representing both makers and users of catalysts have been named. They appear in Table 1 in the body of the report.

A slide presentation has been developed for use to augment the personal presentation of this opportunity to industry personnel. Only production of the necessary slides remains to be done. The text of the slides appears as Appendix C.

The brochure to be given to each candidate will comprise a hard copy of the slides plus additional information extracted from a variety of NASA sources. Its contents is shown in Appendix D.

Objective

To define the most likely prospects in the chemical industry for an initial approach to encourage their investigation in space. A specific refinement is to identify twenty such candidates for subsequent visitation.

A further objective is to prepare material for an initial briefing at each of the twenty prospects. This material is to be in the form necessary to prepare both slide presentation and hard copy, leave-behind brochure.

Background

As NASA plans for the optimum use by the American economy of its carefully developed space transportation system embodied by the existing Space Shuttle, it has recognized the need to bring commercial enterprise into the system. Although the communications industry has made significant strides in "commercializing space" and can rightfully be labelled a success story, there are no other segments of industry which have progressed so far. Research, development and processing for the benefit of materials have been identified by many observers as a fruitful route to pursue in broadening the use of NASA's capabilities.

Materials are of such diverse nature that it is necessary to make some appropriate desegregation so meaningful programs can be designed. One approach is to examine a single industry segment to determine its pertinence and potential for entering into a substantive program with NASA. The objective of such a program would be the improvement of the productivity and economic viability of that industry segment. It is that approach which has been used in selecting the chemical/petrochemical industry for investigation.

Approach

With the single exception of the pharmaceutical industry, the chemical/petrochemical industry [hereinafter referred to simply as the chemical industry] devotes a larger percentage of its gross income to research and development than any other industry segment. The industry is deeply convinced that its future depends upon continued high investments of these funds to discover new products it can make and market and identify new processes to improve the profitability of its existing products. Much of the research and development is long term. Its support of basic research is virtually unique in industry and fully testifies to its conviction that research is its salvation for the future.

As the chemical industry is examined as a candidate for space investigations, it is readily seen that research and development in the space environment may lead to attractive commercial opportunities. On the one hand research may elucidate some critical feature of a chemical reaction and direct a program of terrestrial research which will improve an earth-bound process. On the other hand research may lead to either a product which cannot be made terrestrially or to a product of such improved performance on earth, that production could be economically justified in space for return and use of the product in a chemical process on earth.

Analysis of the Chemical Industry

The chemical industry is comprised of both huge and tiny companies which exist in an almost symbiotic relationship. For purposes of this investigation, size is not a controlling factor except for the limitation of large capital resources. The industry frequently is divided into two parts: a basic industry and a specialty products industry. This subdivision does not serve this investigation well because neither should be excluded from further consideration.

In terms of products which might be produced in space one is obliged to think of materials which can command a premium price because their value in use is very high. In terms of processes practiced terrestrially, one can imagine many sorts of improvements which may be signalled by new understanding of the fundamental behavior of the atoms and molecules as elucidated from space experiments. Any part of the industry may benefit from such enlightenment. Further, it may be possible to produce a highly leveraged intermediate or modifier to a chemical reaction such that its performance terrestrially is so enhance that its manufacture in the rarefied atmosphere of space is fully justified economically.

This analysis leads rather logically to consider catalysts as the prime area for investigation among chemical companies. This should not preclude that there may be other opportunities for these companies in space but because of the unique character of a catalyst, it is this single area chosen for initial approach.

Role of a Catalyst

A great majority of chemical reactions which are practiced commercially are influenced by, or indeed depend upon, catalysts. Catalysts control one or more of the following factors: yield of desired product, purity of desired product, generation or elimination of contaminating and/or toxic by-products, temperature at which desired reaction proceeds, pressure necessary for the reaction to take place, rate or speed of reaction and therefore productivity of equipment. Every catalyst has a finite life time and so must eventually be rejuvenated or replaced and thus any change which lengthens that life is economically important. It is for all these reasons that the preparation of the catalyst is critically important with the objective of increasing the economic viability of the chemical process.

Because the catalyst in the reaction is not an integral part of the reaction, a very small amount is required compared to the amount of product produced. The catalyst remains behind, chemically unchanged by the reaction which has taken place under its influence. It is used over and over again. This is where the high leverage comes from. In many very high volume production operations for chemicals which are most modestly priced, an improvement in yield of only a few tenths of a percent is highly treasured and valiantly sought after because that seemingly minor improvement can literally increase the profitability of that production unit by millions of dollars annually.

This fact introduces a consideration which NASA must be tuned to. It will be of utmost criticality, as industry moves into catalyst research in space, that proprietary rights be fully protected. Some significant part of catalyst technology is kept out of the patent literature simply because it is judged to be so sensitive. This is not to say there is no room for cooperation at some levels of the technology or even openness at other levels, but NASA must be adaptable to the concerns of this industry as it judges its needs for protecting its competitive position.

Catalyst Research

Most research carried out on catalysts involves the preparation of the catalyst with subsequent analysis of the catalyst. This analysis is of two distinctly different types. The one is an exhaustive physical analysis; the other, a chemical test of its influence on one or more candidate chemical reactions. The first type is relatively new but has become highly sophisticated with the development of many new analytical techniques. The analysis now is micro in character and indeed verges on the atomic. Chemical analysis is a macro technique practiced for scores of years but now refined so traditional micro quantities are all that is needed to characterize the experimental catalyst. This translates to mean that, today, although there are many more tests which researchers will run on a new catalyst, the quantity they need for a complete investigation is tiny, thereby contributing to the plausibility of research in space. Lest there be a misunderstanding, all these analytical tests would be performed terrestrially on catalysts brought back from space. This sort of capability is already well developed.

Elaborating on a statement appearing earlier, it is important to note that industry is already engaged in cooperative catalyst research. Both University of Delaware and Northwestern University have established catalyst research centers with substantial support from industry.

The older and larger of the two is the Center for Catalytic Science and Technology at the University of Delaware. It currently has eighteen industrial sponsors and contracts for research with both government and industry. It has a staff of twenty five professionals, four of whom are Adjunct Professors from industry. At present, forty-one projects are active.

Northwestern University is now undertaking the formalization of its program by establishing a Catalysis and

Surface Chemistry Research and Teaching Center. The University has been active in catalyst research for many years with projects in its various academic departments. At present thirty-two projects concerning catalysts are scattered among the Chemistry, Physics, Materials Science and Engineering, and Chemical, Electrical and Civil Engineering Departments. Northwestern currently has grants for catalyst research from seven companies as well as grants from several government agencies.

The University of California at Berkeley is the only other university with a concerted effort in catalyst research. Several West Coast companies have sponsored research at Berkeley for many years with the major thrust being the fundamental science of catalysis. A new factor at Berkeley is the establishment at the Lawrence Berkeley Laboratory - a U.S. Department of Energy facility operated by contract with the University of California - of a Materials and Molecular Research Division. One of the four program thrusts of this new facility will be Catalysis. Most of the faculty members working on catalysts at the University will hold dual appointments at the DoE facility. The DoE facility does not expect to pursue industrial sponsorship, at least not at the beginning. All funds will come from DoE. They do however anticipate "industry interaction."

Despite these university centered research efforts which are substantial, the fact remains that most research is carried out within the confines of industrial laboratories.

Selection of Twenty Candidate Companies

There are over one hundred companies in the chemical industry who are playing an active role in catalyst research in the U.S. A full listing of these companies appears as Appendix A.

Under the operative principle that the selection of twenty candidates from this total should represent both a spectrum of the industry as well as a choice of the more likely prospects to become involved in space research, Table 1 is presented. A few comments about this table will explain the modifiers for the companies as shown on the table. "A sponsor" indicates that the company currently supports research at one of the university centered research facilities. "Affiliated" or "unaffiliated" indicates if the catalyst producer and marketer is or is not an operation within some larger corporate entity.

An indication of the spectrum of industry represented can be seen in Table 2.

A back-up or fall-back selection of companies has been prepared and appears as Appendix B.

Preparation of Material for Slide Presentation

Two compelling considerations are involved in preparing a slide presentation suitable for its intended purpose. The audience will know little of the space program and secondly the information should be as sharply targeted to catalyst research as possible. To individualize each presentation as much as possible, it is concluded that personal, oral commentary accompany the slides, to the point that the slides be used simply as the visual message to augment the personal presentation. The alternate of preparing a "canned" tape to accompany the slides was

TABLE 1

TWENTY COMPANIES

SELECTED FOR CATALYST EXPERIMENTATION IN SPACE

Air Products and Chemicals, Inc.	a sponsor a chemical company manufactures a very broad line of catalysts
American Cyanamid Company	a sponsor a chemical company manufactures a broad line of catalysts
Amoco Oil Comapany	a sponsor a petroleum company
Catalytic Products International, Inc.	manufactures a very broad line of catalysts unaffiliated
Dow Chemical Company	a sponsor a chemical company
Engelhardt Corporation	manufactures a medium size line of catalysts unaffiliated
Exxon Chemical Company	a sponsor a petroleum company
Grace, W.R. & Co., Davison Company	manufactures a broad line of catalysts affiliated
Gulf Oil Corporation	a sponsor a petroleum company
Harshaw Chemical Company	manufactures a broad line of catalysts unaffiliated
Mallinkrodt, Inc., Calsicat Division	a sponsor manufactures a very broad line of catalysts affiliated
Met-Pro Corporation	manufactures a broad line of catalysts unaffiliated
Mobil Chemical Company	a sponsor a petroleum company manufactures a narrow line of catalysts

Pennwalt Corporation	a chemical company manufactures a medium size line of catalysts
Rohm and Haas Company	a sponsor a chemical company manufactures a narrow line of catalysts
Shell Chemical Company	a sponsor a petroleum company manufactures a broad line of catalysts
Texaco, Inc.	a sponsor a petroleum company
Union Carbide Corporation	a sponsor a chemical company manufactures a very broad line of catalysts
United Catalysts, Inc.	manufactures a very broad line of catalysts unaffiliated
Witco Chemical Corporation	manufactures a broad line of catalysts affiliated

TABLE 2

SPECTRUM OF INDUSTRY kEPRESENTATION

Companies selected represent -

12 of the 22 companies currently sponsoring catalyst research at the two university centers doing catalyst research

6 chemical manufacturers, 5 of whom are in the above group, all of whom produce catalysts for the commercial market as well as depend upon catalysts for their own use

6 petroleum refiners, all of whom sponsor university research, 2 of whom market lines of catalysts

8 catalyst manufacturers for the commercial market, only one of whom sponsors university research, 5 of whom have no other business affiliation

All 12 representatives of the chemical and petroleum industries are users of catalysts for their internal operations discarded for its inability to personalize and individualize each presentation.

The format for the slides is shown as Appendix C. A number of sources of the information has been used. The most valuable has been Rockwell International's presentations to industry. Twenty two of their slides fit right into the presentation here proposed and Rockwell has kindly granted permission to use them for this purpose. The other thirty six slides will require artwork prior to production of the slides.

Preparation of the Leave-Behind Brochure

The brochure will consist of a hard copy of the slides plus certain supplementary material. This supplement appears as Appendix D. All of this information is extracted from pertinent NASA publications.

The purpose of the brochure is to be evocative and leave a document to pore over and stir internal discussion. Several copies will be left with each company.

APPENDIX A

COMPANIES INVOLVED IN CATALYSTS

FOREWORD -

1. There are nearly 2000 companies in the U.S. identified as chemical companies. Perhaps half of these use catalysts in some internal operation. The 100 companies listed have clearly identified catalyst involvements

2. "Type" refers to the type of chemical reaction which will be influenced by the catalyst being offered for sale

3. Source of information on companies
   - A. H. Thomas Register
   - Chemical Week Buyers' Guide
   - University of Delaware
   - Northwestern University
   - Moody's Industrial Manual

4. Source of information on personnel
   - personal relationship
   - Commercial Development Association directory
   - Chemical Marketing and Economics directory of the American Chemical Society

Air Products and Chemicals, Inc., Box 538, 1493 Cedarwood Road, Allentown, PA 18104, [215]481-4911
Sponsor at University of Delaware
Type: cracking, custom, dealkylation, deoxidation, desulfurization, hydrogenation, organic synthesis, precious metals - palladium, platinum, polymerization, reforming, urethane
B. M. Rushton, Vice President - Research and Development
James F. Roth, Corporate Chief Scientist
Joseph G. Santangelo, Director - Corporate Business Development [215]481-6959
Herbert F. Strohmayer, Associate Director, Strategic Development Department, Industrial Chemical Division, [215]398-6767
Jeffrey D. Miano, Business Development Manager, Industrial Chemical Division

Allied Corporation, Allied Chemical Company, Box 1087-R, Morristown, NJ 07960
Type: alkylation, organic synthesis, polymerization
Lee W. Rivers, Vice President - Research and Development, [201] 455-2746 or 2745
Edward F. Landau, Assistant to Corporate Vice President - Research and Development, [201]455-3097
Morris B. Berenbaum, Vice President - Research and Development, Specialty Chemicals Division, [201]455-5668
David Hurwitz, Corporate Planning Manager, [201]455-3066
Richard D. Anderson, Director, Commercial Development

Aluminum Company of America, 1501 Alcoa Building, Pittsburgh, PA 15219 [412]553-4707
Sponsor at University of Delaware
Type: supports
Kalman E. Buckovecky, Manager, Chemicals and Ceramics Division, Alcoa Laboratories, Alcoa Center, PA 15069

Ambur Chemical Company, Inc., 1128 N. 28th Street, Allentown, PA 18104
Type: oxidation, precious metals - palladium, platinum

American Cyanamid Company, Chemical Products Division, 1 Cyanamid Plaza, Wayne, NJ 07470, [201]831-2000
Sponsor at University of Delaware
Type: acid, custom, dehydrogenation, desulfurization, hydrotreating, precious metals - platinum, reforming
Edward W. Cantrall, Director, Chemical Research Division
Larry Ellberger, Director - Planning and Business Development, Organic Chemicals Division, 86 N. Ashby Avenue, Livingston, NJ 07039, [201]831-2048

Amoco Oil Company, 200 E. Randolph Drive, Chicago, IL 60601
Sponsor at University of Delaware and Northwestern University
Keith W. McHenry, Jr., Vice President - Research and Development, Box 400, Naperville, IL 60566

Anderson Development Company, 1415 E. Michigan Street, Adrian, MI 49221, [517] 263-2121
Type: polymerization, urethane

Armak Company, Noury Chemical Corporation, Route 78, Burt NY 14028
Type: organic synthesis, polymerization, polyolefins, vinyl

Atlantic Richfield Company, Arco Chenical Company, 1500 Market Street, Center Square, Philadelphia, PA 19101
John van de Castle, Manager, Technology Acquisitions, 20 Fox Chase Drive, Watchung, PA 07060, [215]557-2684

Barnebey - Cheney, 835 N. Cassady Avenue, Box 2526, Columbus, OH 43216 [614]258-9501
Type: desulfurization, supports

BASF Wyandotte Corporation, 100 Cherry Hill Road, Parsippany, NJ 07054
Francis J. Honn, Director, Corporate Planning and Development, [201]263-5123

Bedford Chemical Division, Ferro Corporation, 7050 Krick Road, Bedford, OH 44146, [216]641-8580

Bram Metallurgical-Chemical Company, 18 Borbeck Street, Philadelphia, PA 19111
Type: precious metals

Carus Chemical Company, 1500 8th Street, LaSalle, IL 61301, [815]223-1500
Type: Oxidation
Arno H. Reidies, Director of Research

Caschem, Inc., 40 Avenue A, Bayonne, NJ 07002
Type: organic synthesis, polymerization, urethane

Catalyst Research Corporation, 1421 Clarkview Road, Baltimore, MD 21209
Alan A. Schneider, General Manager, [301]296-7000

Catalytic Products International, Inc., 3750 Industrial Avenue, Rolling Meadows, IL 60008
Type: alkylation, custom, dealkylation, dehydrogenation, deoxidation, hydrogenation, organic synthesis, oxidation, precious metals - palladium, platinum, ruthenium, supports

Catalytica Associated, Inc., 430 Ferguson Drive, Building 3, Mountain View, CA 94043
Frits Dautzenberg, Director of Engineering, [415]960-3000
Dror May, Manager - Commercial Development

Celanese Corporation, Celanese Chemical Company, P.O.Box 47320, 1250 W. Mockingbird Lane, Dallas, TX 75247
Howard L. Pilat, Vice President - Technology, [214]689-4860
Joseph A. Vona, Director, 86 Morris Avenue, Summit, NJ 07901, [201]522-7733 or [201]273-6600

Chemetics Systems, Inc., 2006 Gladwick Street, Compton, CA 94105
Type: urethane

Chemtech Industries, Inc., 1655 DesPeres Road, St. Louis, MO 63131 [314]966-9900
Type: alkylation

Chevron Chemical Company, 595 Market Street, San Francisco, CA 94105
[415]894-7700
Sponsor at University of Delaware
Thomas Hughes, Senior Research Scientist, 576 Standard Avenue, Richmond, CA 94802

Ciba-Geigy Corporation, Dyestuffs and Chemicals Division, Swing Road & Interstate 40, Greensboro, NC 27419
Type: polymerization

Cleveland Refractory Metals, Inc., 29855 Aurora Road, Solon, OH 44139
Type: precious metals

Colonial Metals, Inc., Triumph Industrial Complex, Box 726, Elkton, MD 21921
Type: precious metals

Cosan Chemical Corporation, 400 14th Street, Carlstadt, NJ 07072
Type: polymerization, urethane

Dart Industries, Inc., Catalyst Resources, Inc., 2190 N. Loop West, Suite 202, Houston, TX 77018
Type: custom, organic synthesis, polymerization, polyolefin, vinyl
Ronald A. Kent, Manager; Commercial Development, [713]682-5300

Degussa Corporation, Route 46 at Hollister Road, Teterboro, NJ 07480
[201]288-6500
Type: precious metals
Rudolf H. Fahnenstich, Executive Vice President

Dow Chemical Company, 2020 Dow Center, Midland, MI 48640
Sponsor at University of Delaware and Northwestern University
Philip E. Garrou, Group Leader - Catalysts, Central Research, New England Laboratory, Box 400, Wayland, MA 01778
C. Elmer Wymore, same address

E. I. duPont de Nemours & Co., Inc., 1007 Market Street, Wilmington, DE 19898
Sponsor at University of Delaware
Type: organic synthesis, polymerization, polyolefin, vinyl, supports
William C. Drinkard, Associate Director of Physical Research, Central Research and Development Department, Experimental Station, [302]772-4648

Dynamit Nobel Group, Kay-Fries, Inc., 10 Link Drive, Rockleigh, NJ 07647, [201]767-1660
Type: organic synthesis, polymerization, polyolefin, vinyl
Thomas Edward Maggio, Executive Vice President and General Manager, Stony Point, NY 10980
Peter Washtel, Director of Commercial Development, at Rockleigh address

Eagle-Picher Industries, Inc., 580 Walnut Street, Cincinnati, OH 45202, [513]721-7010
Type: supports from diatomaceous earth

Elf Acquitane, Inc., M & T Chemicals, Inc., Woodbridge Road and Randolph Avenue, Rahway, NJ 07065, [201]499-0200
Type: polymerization, organic synthesis, urethane

Engelhardt Corporation, Minerals and Chemicals Division, Menlo Park, CN28, Edison, NJ 08818, [201]632-6000
Type: cracking, dealkylation, desulfurization, oxidation, supports
Alan W. Tamarelli, Senior Vice Presidant, 49 Wexford Way, Basking Ridge. NJ 07920, [201]589-5000
Alex Markin, Vice President - Planning and Development, at Edison [201]632-6164

Ethyl Corporation, Chemicals Group, 451 Florida Blvd., Baton Rouge, LA 70801, [504]388-8011
Type: polymerization, polyolefin
John T. Balhoff, Director, Commercial Development

Exxon Chemical Company, 13501 Katy Freeway, Houston, TX 77079
Sponsor at University of Delaware and Northwestern University
Wim J. M. Pieters, New Venture Technology, 4 Pearl Court, Allendale, NJ 07401

Fehr Brothers, Inc., Chemical and Metal Division, 110 Wall Street, New York, NY 10005
Type: dehydrogenation

Formulated Resins, Inc., Box 508, Greenville, RI 02828
Type: polymerization

Freeman Chemical Corporation, a subsidiary of H. H. Robertson Company, 222 E. Main Street, Port Washington, WI 53074
Type: custom
G. H. MacDonald, President

General Motors Corporation, Technical Center, Warren, MI
Sponsor at University of Delaware

Getty Oil Company, 3810 Wilshire Blvd., Los Angeles, CA 90010
Jame S. Cutler, Planning and Economics Coordinator, [213]381-7151

Goldschmidt Chemical Corporation, Box 1299, 920 Randolph Road, Hopewell, VA 23860
Type: urethane

Grace, W.R. & Company, Davison Specialty Chemicals Company, Box 2117, Baltimore, MD 21203
Type: alkylation, cracking, custom, dehydrogenation, organic synthesis, oxidation, polymerization, polyolefin, supports
Paul J. Norris, General Manager, Market Development and Planning
Carl W. Orgell, Director - Commercial Planning, Research Division, Columbia, MD 21044

Guardsman Chemicals, Inc., 1350 Steele Street, SW, Grand Rapids, MI 49507, [616]957-2600
Type: acid

Gulf Oil Corporation, Box 2967, Pennzoil Place, Houston, TX 77253
Sponsor at Northwestern University
Francis E. Brown, Vice President - Technology, [713]754-3437
Philippe A. Michelon, Senior Director - Corporate Planning, P.O. Box 1166, Pittsburgh, PA 15230, [412]263-5559
Donald N. Demott, Director of Commercial Development, 909 Fannin Street, Room 4006, Houston, TX 77010, [713]754-2124

Harshaw Chemical Company, 1945 E. 97th Street, Cleveland, OH 44106
Type: alkylation, custom, degydrogenation, desulfurization, hydrogenation, organic synthesis, oxidation, supports
A. R. Garcia, Jr., Manager - Market Development, [216]721-8300 Ext. 263

Hercules, Inc., 1401 Market Street, Wilmington, DE 19894, [302]594-5000
Type: polymerization
Spencer H. Watkins, Director of Technology, [302]575-6416
Ralph H. Earle, Jr., Corporate Manager - Planning and Acquisitions, [302]575-5786

ICI Americas, Inc., Concord Pike and New Murphy Road, Wilmington, DE 19897
Gerald Gene Greth, Development Manager, Product Development Department, [302]575-8304
George O Rudkin, Associate Director, Specialty Chemicals, [302] 575-8301
Thomas J. Galvin, Manager - New Ventures, Corporate Resources, [302]575-3284

Industeel Company, 37th Street and Smallman, Pittsburgh, PA 15201
Type: custom

Isochem Resins Company, 99 Cook Street, Lincoln, RI 02865
Type: polymerization, urethane

Johnson Mathey, Inc., 4 Malin Road, Malvern, PA 19355, [215]648-8000
Type: custom, hydrogenation, precious metals - palladium, platinum, rhodium, ruthenium
William J. Quindlen, Vice President and General Manager, Catalytic Systems Division
Henry Connor, Commercial Director

Kaiser Chemicals, Inc., 300 Lakeside Drive, Oakland, CA 94643, [415] 271-3300
Type: cracking, custom, desulfurization, hydrotreating, supports

Katalco Corporation, 50% owned by Nalco, Inc., 2901 Butterfield Road, Oak Brook, IL 60521
Type: desulfurization, hydrogenation, hydrotreating, reforming, supports

King Industries, Inc., Science Road, Norwalk, CT 06852
Type: acid

MacKenzie Chemical Works, Inc., 1 Cordello Avenue, Central Islip, NY 11722
Type: organic synthesis, polymerization, oxidation, polyolefin, urethane, vinyl

Mallinkrodt, Inc., Calsicat Division, 1707 Gaskell Avenue, Erie, PA 16503
Sponsor at University of Delaware
Type: custom, dehydrogenation, deoxidation, hydrogenation, organic synthesis, oxidation, precious metals - palladium, platinum, ruthenium. supports, vinyl
Eugene F. Sanders

Metallurgical Industries, Inc., 1 Coldstream Way, Tinton Falls, NJ 07724, [201]542-5800
Type: custom

Met-Pro Corporation, Systems Division, 234 Cassel Road, Harleysville, PA 19438
Type: alkylation, custom, deoxidation, hydrogenation, organic synthesis, oxidation, precious metals - palladium, platinum, rhodium, ruthenium

Mobil Chemical Company, 1 Greenway Plaza, Houston, TX 77046
Sponsor at University of Delaware and Northwestern University
Type: polymerization, supports
Harry A. McVeigh, Manager, Central Research Division, Mobil Technical Center, Princeton, NJ 08540
George H. Garrison, Planning Associate, Petrochemicals Division, at Houston, [713]871-5759
Anthony J. Silvestri

Monsanto Company, 800 Lindbergh Blvd., St. Louis, MO 63167
S. Allen Heininger, Vice President - Corporate Plans and Business Development, [314]694-3080
L. Edward Klein, Director Technology Investments, Corporate Research and Development, [314]6948686
Roger W. Bucknell, Director, New Ventures Department, [314] 694-8661
Paul T. Bailey, Manager New Ventures, New Ventures Department, [314]694-8649
Gerard E. McAchran, Manager Technology Planning, [314]694-5952
Kenneth L. McHugh, Manager New Ventures Division, [314]694-8639

Mooney Chemicals, Inc., 2301 Scranton Road, Cleveland, OH 44113, [213]781-8383
Type: custom, organic synthesis, oxidation, polymerization, urethane

Morton Thiokol, Inc., Alfa Products, 152 Andover Street, Danvers, MA 01923, [617]777-1970
Type: hydrogenation, polymerization, polyolefin
Allan I. Stutz, Marketing Manager, [617]774-3100
Robert C. Wade, Senior Scientist

Morton Thiokol, Inc., Carstab Corporation, West Street, Reading, OH 45215, [513]733-2100
Type: polymerization

Noah Industries Corporation, Noah Chemical Division, 87 Gazza Blvd., Farmingdale, NY 11735
Type: organic synthesis

Norac Company, Inc., 405 S. Motor Avenue, Azusa. CA 91702
Type: polymerization

Norton Company, 1 New Bond Street, Wworcester, MA 01606, [617]853-1000
Type: custom, precious metals, supports

Olin Corporation, 120 Long Bridge Road, Stamford, CT 06904
Type: polymerization, urethane
Patrick N. Baker, Manager - Business Development, [203]356-2779
Maurice A. Raymond, Manager - Government Ventures, [203]356-2262

Organometallics, Inc., Route 111, E. Hampstead, NH 03826
Type: organic synthesis

Pacific Anchor Chemical Company, 6055 E. Washington Blvd., Los Angeles, CA 90040
Type: acid, organic synthesis, polymerization, urethane

Pelron Corporation, 7847 W. 47th Street, Lyons, IL 60534
Type: urethane

Pennwalt Corporation, Pennwalt Building, 3 Parkway, Philadelphia, PA 19102
Type: acid, organic synthesis, polymerization, polyolefin, vinyl
Luke R. Ocone, Senior Analyst - Commercial Development, [215] 587-7345

Phillips Petroleum Company, 166 Petroleum Laboratory, Bartlesville, OK 74004
Sponsor at University of Delaware
E. A. Zuech, Director - Petroleum Research

Platina Laboratories, Inc., 4301 S. Clinton Avenue, South Plainfield, NJ 07080
Type: custom, organic synthesis, precious metals - palladium, platinum, rhodium, ruthenium

Polymer Research Corporation of America, 2186 Mill Avenue, Brooklyn, NY 11234, [212]444-4300
Type: polymerization

Powell Metals and Chemicals, Inc., Box 5646, 1122 Milford Avenue, Rockford, IL 61125
Type: precious metals - palladium, platinum, rhodium

PPG Industries, Inc., Chemicals Operations, 1 Gateway Center, Pittsburgh, PA 15222
Type: organic synthesis, polymerization, polyolefin, vinyl
Richard J. Walton, Manager Commercial Development - Chemicals, [412]434-2587
Charles D. Taylor, Coordinator of Business Development, [412]434-4499

Pressure Chemicals Company, 3419 Smallman Street, Pittsburgh, PA 15201
Type: organic synthesis, precious metals - rhodium, ruthenium, supports

Quinn, K. J. & Company, Inc., 195 Canal Street, Malden, MA 02148, [617]321-3200
Type: urethane

Reichold Chemicals, Inc., 525 N. Broadway, White Plains, NY 10603, [914]682-5700
Type: oxidation

Reilly Tar & Chemicals Corporation, 1510 Market Square Court, 151 N. Delaware Street, Indianapolis, IN 46204, [317]638-7531
Type: urethane

Rhone Poulenc, Inc., Box 125, Black Horse Lane, Monmounth Junction, NJ 08852
Sponsor at University of Delaware
Type: desulfurization, supports

Rohm and Haas Company, Independence Mall West, Philadelphia, PA 19105
Sponsor at University of Delaware
Type: alkylation, organic synthesis, urethane
Joseph W. Nemec, Department Manager - Monomer Process Research, 727 Norristown Road, Spring House, PA 19477
Robert Hauser, [215]592-3396
Carl A. Panza, Business Development Manager, Corporate New Ventures 120 Timber Ridge Road, Newtown, PA 18940, [215]592-2344

RSA Corporation, 690 Sawmill River Road, Box 607, Ardsley, NY 10502
Type: organic synthesis

Sharpe Chemicals Company, 1116 S. Varney Street, Burbank, CA 91502
Type: palladium, platinum, ruthenium

Shell Chemical Company, Chemical Sales, 1 Shell Plaza, Houston, TX 77002, [713]241-4083
Sponsor at University of Delaware
Type: dehydrogenation, desulfurization, hydrogenation, organic synthesis, hydrotreating, oxidation, precious metals - palladium, platinum, supports
Robert W. Reineke, Sr., Financial Representative, Catalyst Business Center, [713]241-0891

Southeastern Adhesives Company, 815 D Virginia Street, Box 791, Lenoir NC 28645
Type: polymerization

Spex Industries, Inc., Box 798, Metuchen, NJ 08840, [201]549-7144
Type: precious metals

SST Corporation, 1373 Broad Street, Clifton, NJ 07015
Type: vinyl

Standard Oil Company (Ohio), Box 5155, Cleveland, OH 44101
Sponsor at University of Delaware
Robert K. Grasselli, Science Fellow, Head of Fundamental and Exploratory Catalysis, 4440 Warrensville Center Road, Cleveland, OH 44128
Kim McClain, Planner and Project Manager, Indulstrial Chemicals Sivision, [216]575-6593
Jared Schnall, Project Manager - Planning and Development, Industrial Chemicals Division, [216]575-5722

Stauffer Chemical Company, Specialty Chemicals Division, Catalysts and Intermediates, Nyala Farm Road, Westport, CT 06881
Sponsor at Northwestern University
Type: polymerization, polyolefin
George A. Castellion, Director of Marketing, [203[222-3246
Edwin S. Michaels, Manager - Development, Research Department, [203]222-3325

Strem Chemicals, Inc., 7 Mulliken Way, Newburyport, MA 01950
Type: dehydrogenation, hydrogenation, organic synthesis, precious metals - palladium, platinum, rhodium, ruthenium, supports

Sun Company, Sun Tech, Inc., Box 1135, Marcus Hook, PA 19061
Sponsor at University of Delaware
James Lyons, Senior Scientist and Group Leader
Albert T. Olenzak, Director - Strategic Planning, 461 Foxchase Lane, Media, PA 19063, [215]293-6474

Syn Met, Inc., 8608 GSRI Avenue, Baton Rouge, LA 70808
Type: custom, organic synthesis, precious metals - palladium, platinum, rhodium, ruthenium

Teledyne McCormick Selph, Box 6, Hollister, CA 95023
Sponsor at University of Delaware

Tenneco Chemicals, Inc., Box 365, Turner Place, Piscataway, NJ 08854
Type: organic synthesis, polymerization, urethane

Texaco, Inc., Box 509, Beacon, NY 12508
Sponsor at University of Delaware
Harry Chafetz
E. Robert Kerr

Union Carbide Corporation, Molecular Sieve Department, Old Ridgebury Road, Danbury, CT 06817, [203]794-2000
Sponsor at Northwestern University
Type: alkylation, cracking, custom, dealkylation, desulfurization, hydrogenation, organic synthesis, hydrotreating, oxidation, precious metals, urethane
Samuel W. Tinsley, Director of Corporate Technology, 18 Holly Lane, Darien, CT 06820, [203]655-8390

United Catalysts, Inc., Box 32370, Louisville, KY 40232
Type: alkylation, custom, dealkylation, dehydrogenation, deoxidation, desulfurization, hydrogenation, organic synthesis, oxidation, palladium, platinum, polymerization, reforming, supports
Walter L. Chemerys, Marketing Manager, [502]637-9751

UOP Process Division, 20 UOP Plaza, Des Plaines, IL 60016
Robert A. Lengemann, Vice President for Science and Technology, [312]391-2370
Jack Allen Hunter, Director, Business Development Products Group, RFD Box 3322, Long Grove, IL 60047, [312]391-2348

Upjohn Company, Polymer Chemicals Division, Box 685, LaPorte, TX 77571
Type: urethane
Peter J. Manno, Manager of Market Research, [713]479-1541

Whittaker Corporation, Ram Chemicals Division, 210 E. Alondra Blvd., Gardena, CA 90248
Type: organic synthesis, polymerization

Witco Chemical Corporation, Organics Division, 520 Madison Avenue, New York, NY 10022
Witco Chemical Corporation, Pearsall Chemical Division, 2519 Fairway Park Drive, Box 437, Houston, TX 77001
Witco Chemical Corporation, Peroxygen Division, 850 Morton Avenue, Richmond, CA 94804
Type: acid, alkylation, custom, hydrogenation, organic synthesis, oxidation, polymerization, polyolefin, urethane, vinyl
B. R. Bluestein, Director of Corporate Research and Development, 100 Bauer Drive, Oakland, NJ 07436, [201]337-5812

APPENDIX B

ALTERNATE OR SECOND CHOICE COMPANIES SELECTED FOR CATALYST EXPERIMENTATION IN SPACE

(a priority listing)

Chemical Industry

Allied Corporation
Stauffer Chemical Company

Petroleum Industry

Chevron Chemical Company
Sun Company
Phillips Petroleum Company
Standard Oil Company (Ohio)

Catalyst Manufacturers

Strem Chemicals, Inc.
Johnson Mathey, Inc.
Katalco Corporation
Syn Met, Inc.
Platina Laboratories, Inc.
Kaiser Chemicals, Inc.
Dart Industries, Inc., Catalyst Resources, Inc.
Armak Company, Noury Chemical Corporation
MacKenzie Chemical Works, Inc.
Aluminum Company of America
Teledyne McCormick Selph

SLIDE SEQUENCE

1. Our Purpose
2. NASA Policy
3. Quotes from House and Senate
4. Quote from Reagan's State of the Union Address
5. First Efforts
6. Next Steps Toward Commercialization
7. Materials Processing in Space
8. Materials Science Experiments
9. Buoyancy and Sedimentation
10. Picture of 9. (paraffin and sodium acetate)
11. Picture of 9. (oil and water)
12. Picture of 9. (metal foam)
13. Thermal Convection
14. Picture of 13.
15. Hydrostatic Pressure
16. Picture of 15.
17. Need for Container
18. Picture of 17.
19. Opportunity for the Chemical/Petrochemical Industry
20. Why Catalysts? (a NASA view)
21. Why Space? (a catalyst manufacturer's view)
22. Potential Outcomes
23. Nature of the Space Environment
24. Catalyst Preparation Methods Influenced by Gravity - Method
25. Catalyst Preparation Methods Influenced by Gravity - Microgravity Effect
26. Picture of Latex Spheres
27. NASA's Current Capability
28. Picture of the Shuttle
29. Getaway Special
30. Features of the Getaway Special
31. Middeck Locker
32. Features of the Middeck Locker
33. Fluids Experiment Apparatus
34. FEA Float Zone Configuration
35. FEA Exterior
36. FEA Optional Subsystems
37. Spacelab
38. Features of the Spacelab
39. Pallet in Bay
40. Long Duration Capsule
41. Space Station
42. NASA's Hardware Currently Available
43. Current Capabilities
44. NASA's Laboratory Facilities
45. Flight Experiment Hardware
46. Experiment Systems Catalogue
47. Program Options - NASA
48. Program Options - Technical Exchange Agreements
49. Technical Exchange Agreements
50. Program Options - Guest Investigator
51. Program Options - Joint Endeavor
52. Joint Endeavor
53. Program Options - Industry
54. Program Options
55. Scheduling Low Gravity Experiments
56. Shuttle Flights Scheduled
57. NASA Center
58. The Challenge

O U R P U R P O S E

TO DETERMINE WHETHER NASA'S CURRENT CAPABILITIES TO PUT PACKAGES INTO SPACE AND BRING THEM BACK TO EARTH CAN BE USED TO BENEFIT CATALYST TECHNOLOGY

Slide 2

N A S A   P O L I C Y

Broadly

To implement President Reagan's National Space Policy of July 4, 1982 that a major objective of the United States is:

> *"to develop a climate conducive to expanded private sector investment and involvement in civil space activities."*

More narrowly

To explore with industry segments, selected on some rational basis, the potential benefits of that industry's using the space capabilities already developed or soon to be available.

"We should establish a policy which would encourage commercialization of space technology to the maximum extent feasible."

U.S. House of Representatives
Committee on Science and Technology
April 15, 1983 Report

"The committee is fully supportive of efforts by the private sector to invest and seek commercial opportunities in space."

U.S. Senate
Committee on Commerce, Science,
and Transportation
May 16, 1983 Report

Slide 4

O U R   C H A R T E R

".....we've pushed civilization forward with our advances in science and technology. .... Our program in space.....is a tribute to American teamwork and experience. Our finest minds in government, industry, and academia have all pulled together..... Our great goal is to build on America's pioneer spirit and develop our next frontier: space."

from President Reagan's State of the Union address on January 25, 1984

F I R S T   E F F O R T S

The communications industry has undergone revolutionary change as a result of satellites

- NASA began efforts in house
- Rockets were the launch vehicles
- Commercial interests became involved and now are the controlling interests
- Space shuttle had added capability and rockets are being phased out
- Rated highly successful

Slide 6

N E X T S T E P S T O W A R D C O M M E R C I A L I Z A T I O N

(a picture of
the shuttle)

Space shuttle is
a proven vehicle

Therefore space has
become available

Who can use it to
advantage?

MATERIALS PROCESSING IN SPACE
(MPS)

A pervasive area to investigate

Everything we use is made of a material or a combination of materials

There is a long history of improving material performance by changing its properties

Such improvement is at the base of our high standard of living

Therefore it is worthy of exploration

M A T E R I A L S   S C I E N C E   E X P E R I M E N T S

Over 24 different types of experiments have been conducted

A total of over 70 experiments have been completed

All have shared one common environmental factor – low or microgravity

Specific manifestations of gravity are –

- buoyancy and sedimentation
- thermal convection
- hrdrostatic pressure
- need for container

BUOYANCY AND SEDIMENTATION

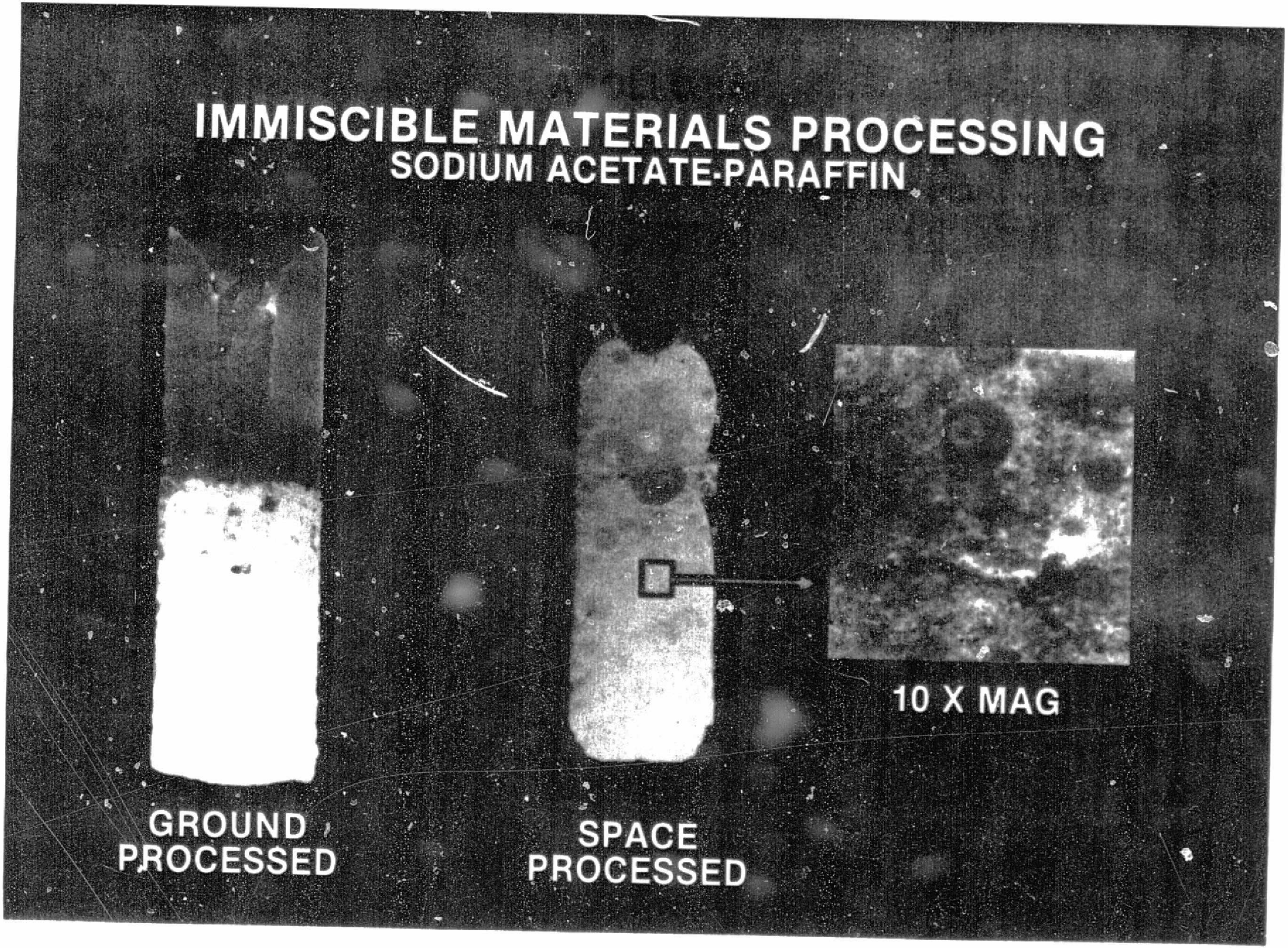
Development of immiscible alloys

Preparation of emulsions

Preparation of unique foams

Tailoring of polymer chain formation

Chemical fining of glass



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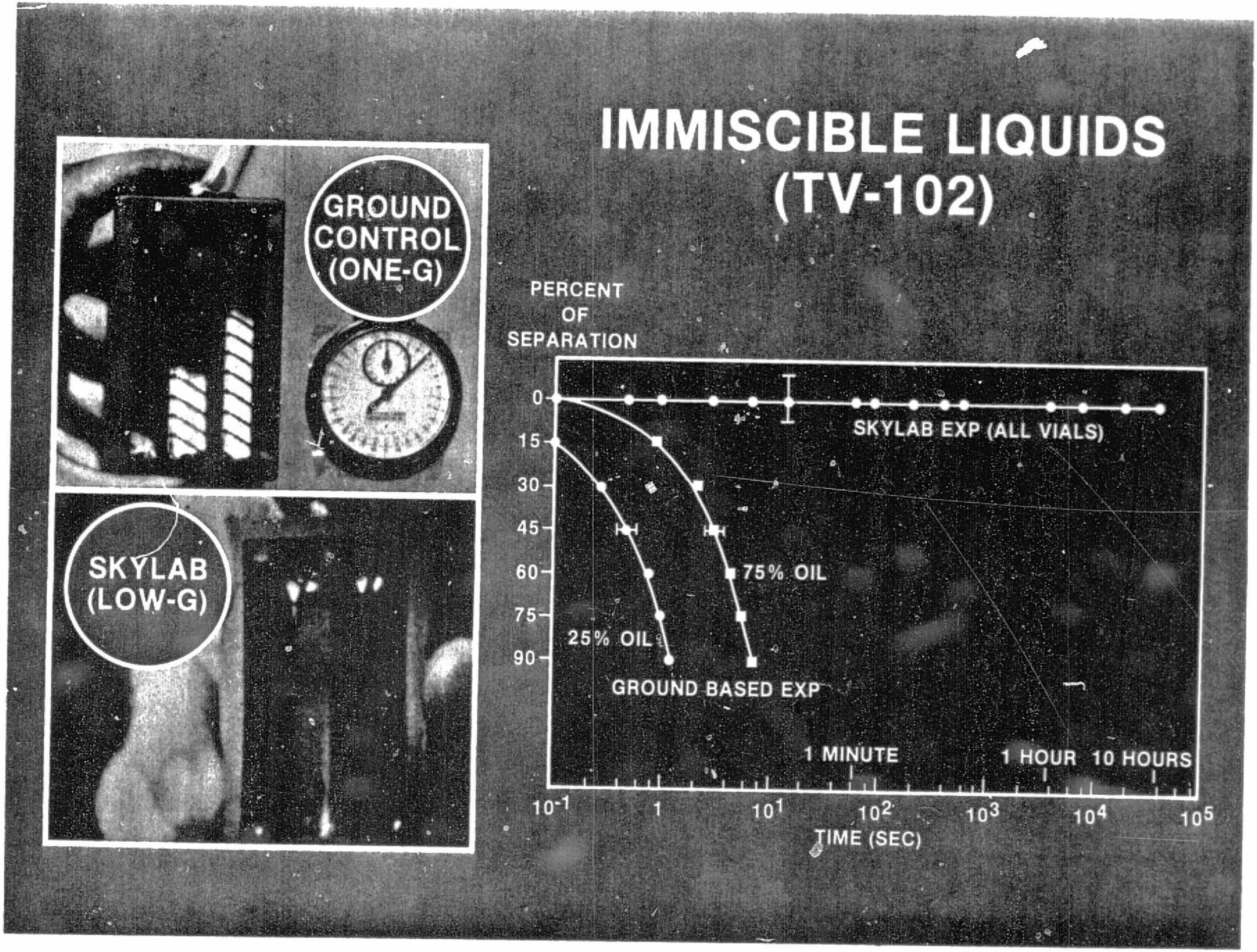

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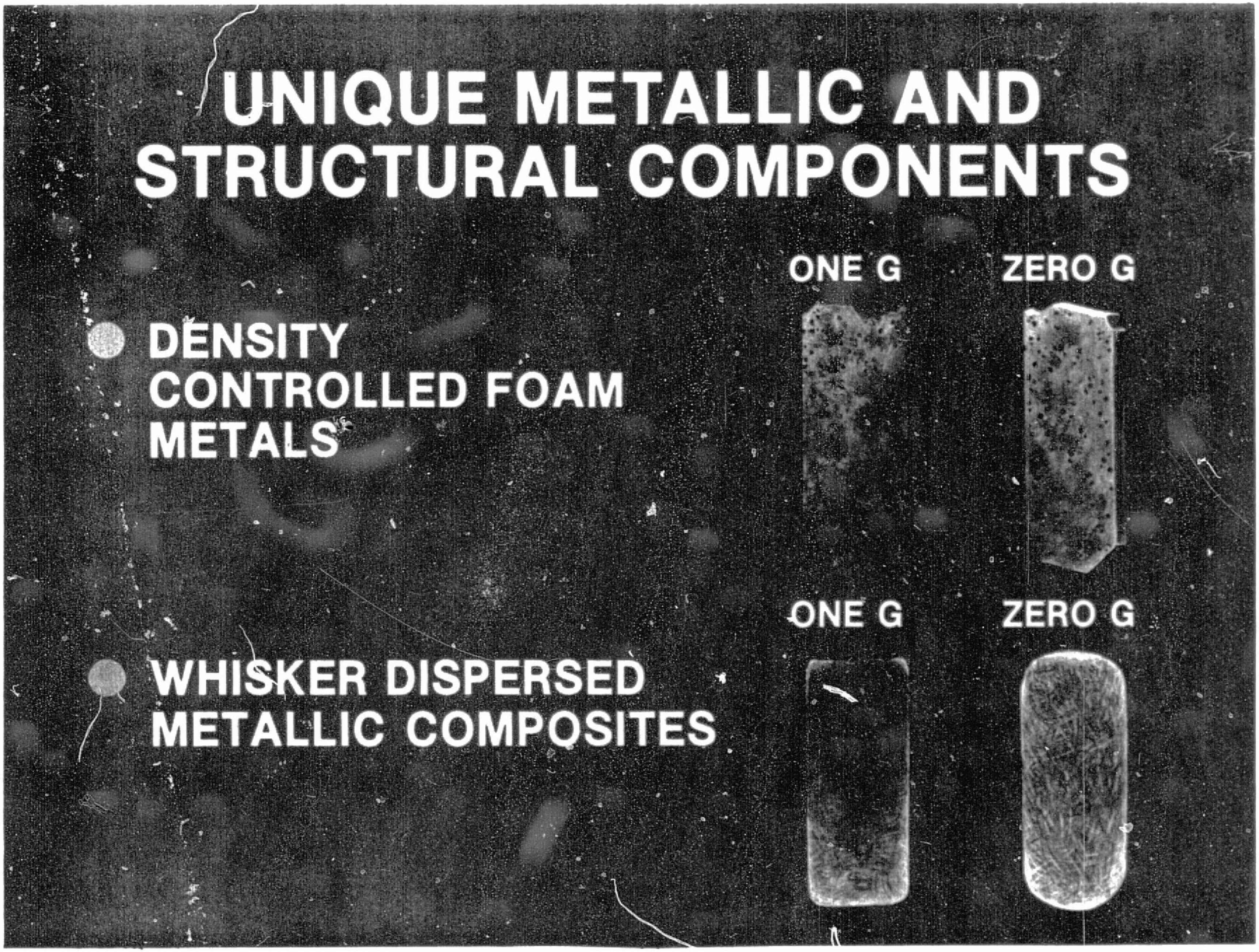
Slide 12



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THERMAL CONVECTION

Distribution of dopant in solid state crystals

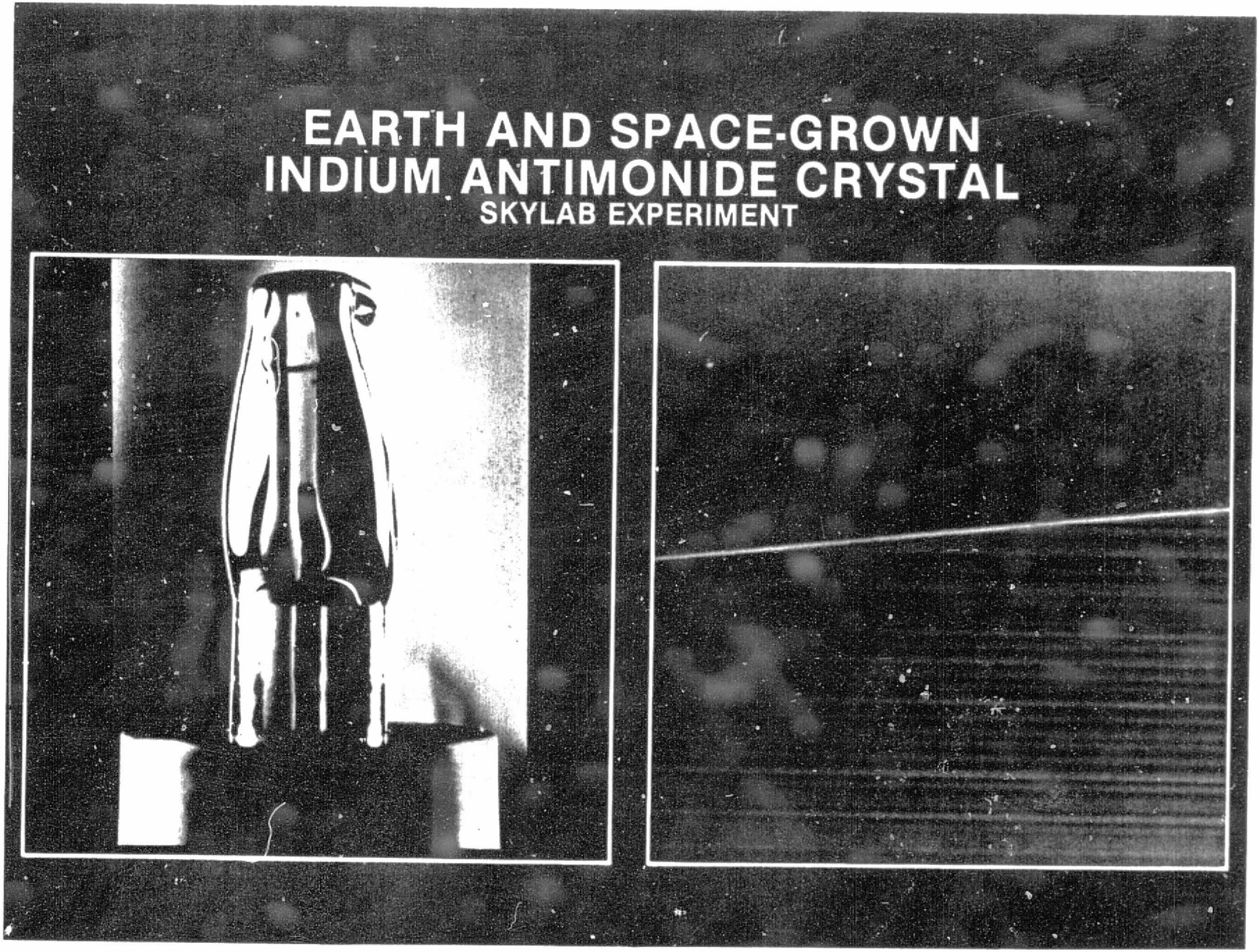
Uniformity of crystal growth

Control of interface kinetics

Elimination of mixing in electroseparation

Investigation of segregation in castings

Slide 14



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Slide 15

H Y D R O S T A T I C   P R E S S U R E

Surface tension will predominate

Surface energy is minimized

Major influence on -

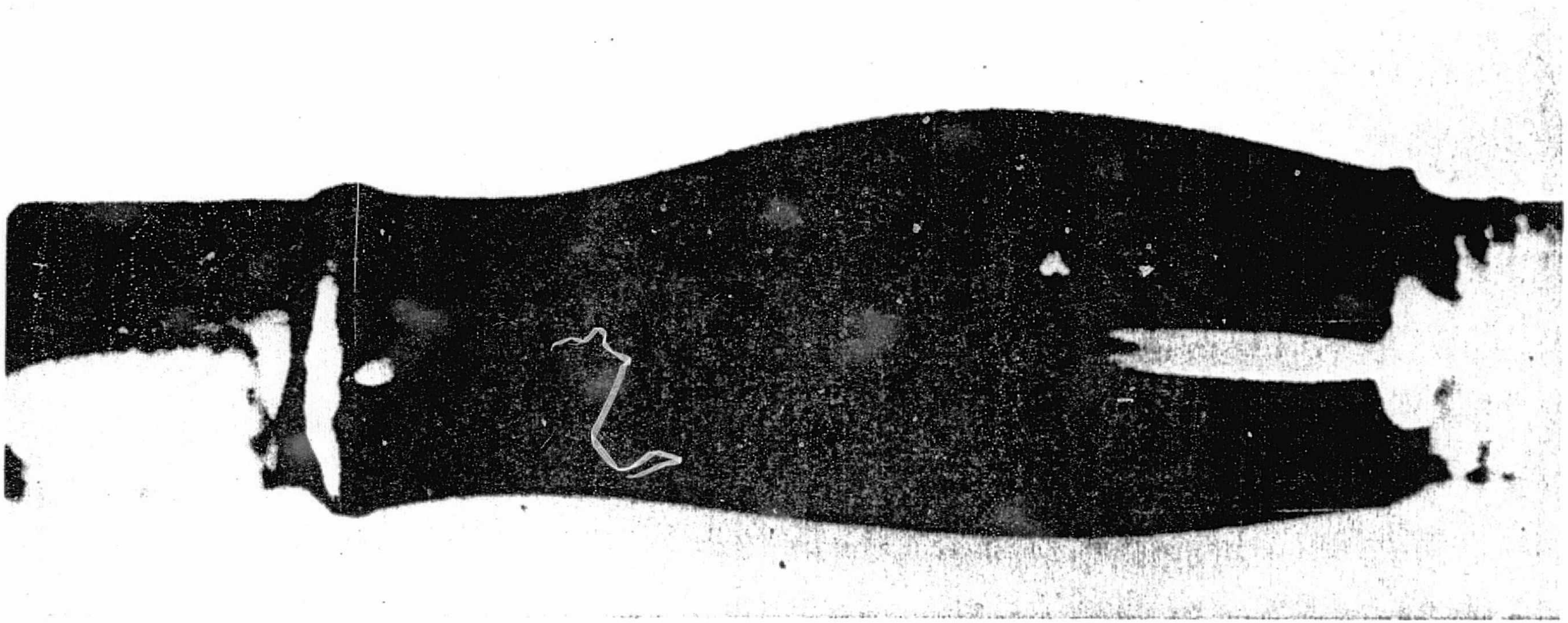
wetting

spreading

coalescence

Slide 16

FLOAT ZONES



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Slide 17

N E E D   F O R   C O N T A I N E R

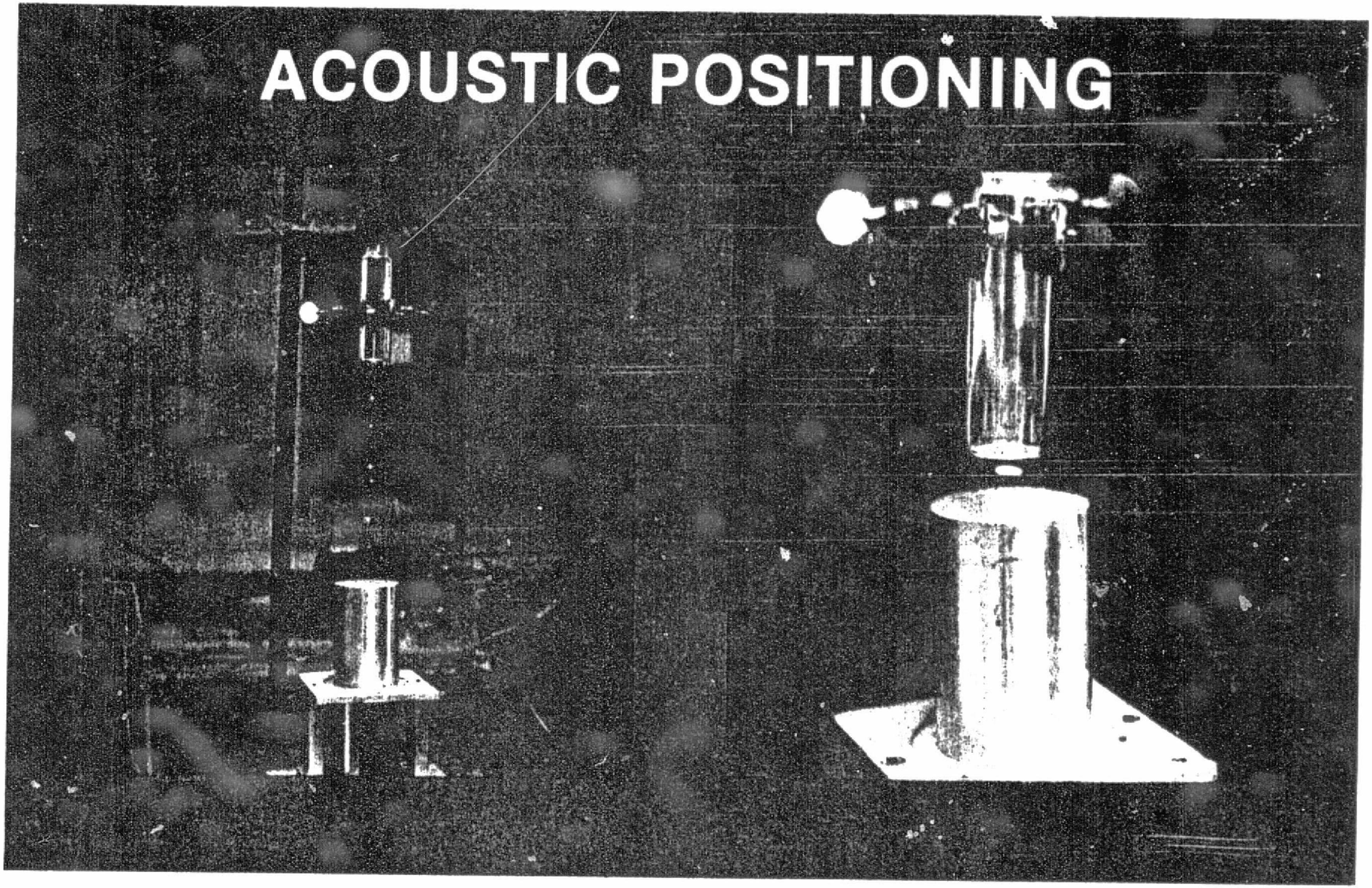
Elimination of nucleation

contamination

chemical attack

strain

Slide 18



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O P P O R T U N I T Y   F O R   T H E

C H E M I C A L / P E T R O C H E M I C A L   I N D U S T R Y

C * A * T * A * L * S * T * S

Plating

Coatings

W H Y   C A T A L Y S T S ?

(a NASA view)

First: An existing commercial business segment

Second: The manufactured product (the catalyst) is highly leveraged in many cases

Third: The field is unexplored - there are no theories or hypotheses

Fourth: There exists vastly improved analytical tools to measure progress and afford intelligent direction of study

W H Y   S P A C E ?

(a catalyst manufacturer's view)

A catalyst with improved performance can

* give a higher yield of desired product
* give higher conversion per pass
* reduce or eliminate by-products
* reduce loss of effectiveness from poisons
* lower operating temperature
* lower operating pressure
* increase reaction rate
* lengthen life of the catalyst

POTENTIAL OUTCOMES

Something in the critical design of the catalyst may be learned by synthesis in space and subsequent analysis in earth laboratories, which may be translatable to earth synthesis

OR

Such significant improvement in the performance of the catalyst may be realized that it will be economically viable to manufacture the catalyst in space for earth use

NATURE OF SPACE ENVIRONMENT

Microgravity	10^{-4} to 10^{-6} g
Vacuum	10^{-6} to 10^{-8} Torr
[in the wake	10^{-10} to 10^{-17} Torr]
Radiation	undiluted solar and cosmic rays
	cosmic protons at 10 billion electron volts

CATALYST PREPARATION METHODS INFLUENCED BY GRAVITY

Method

Coating surfaces

Plating

Impregnation

Crystal formation

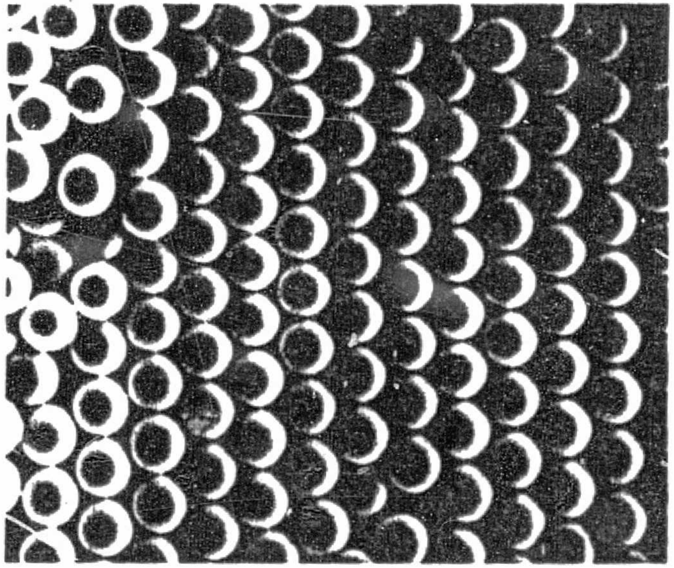
Alloy synthesis

CATALYST PREPARATION METHODS INFLUENCED BY GRAVITY

Method	Microgravity Effect
Coating surfaces	More uniform distribution
Plating	Thinner, more uniform caoting
Impregnation	Control of degree of penetration
Crystal formation	More Perfect - fewer imperfections Higher surface-to-volume ratio
Alloy synthesis	Realize previously unattainable compositions

MONODISPERSE LATEX SPHERES

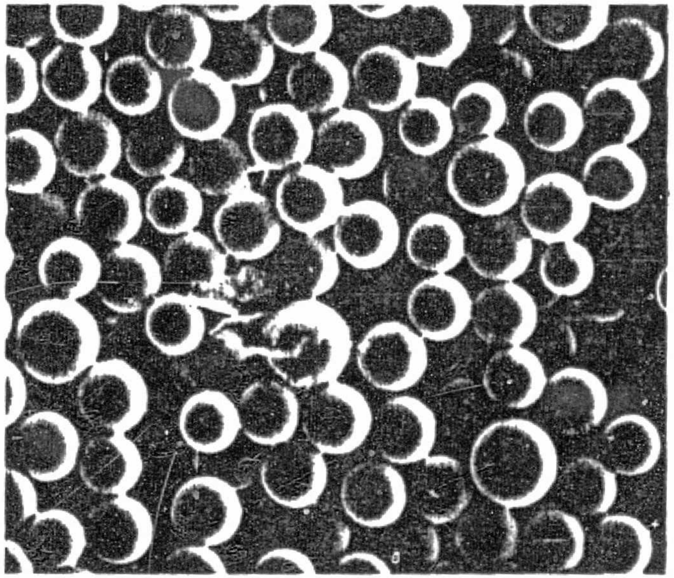
SPACE



17.8 μm DIAMETER

1.2% STANDARD DEVIATION

GROUND



17.7 DIAMETER

5.4% STANDARD DEVIATION

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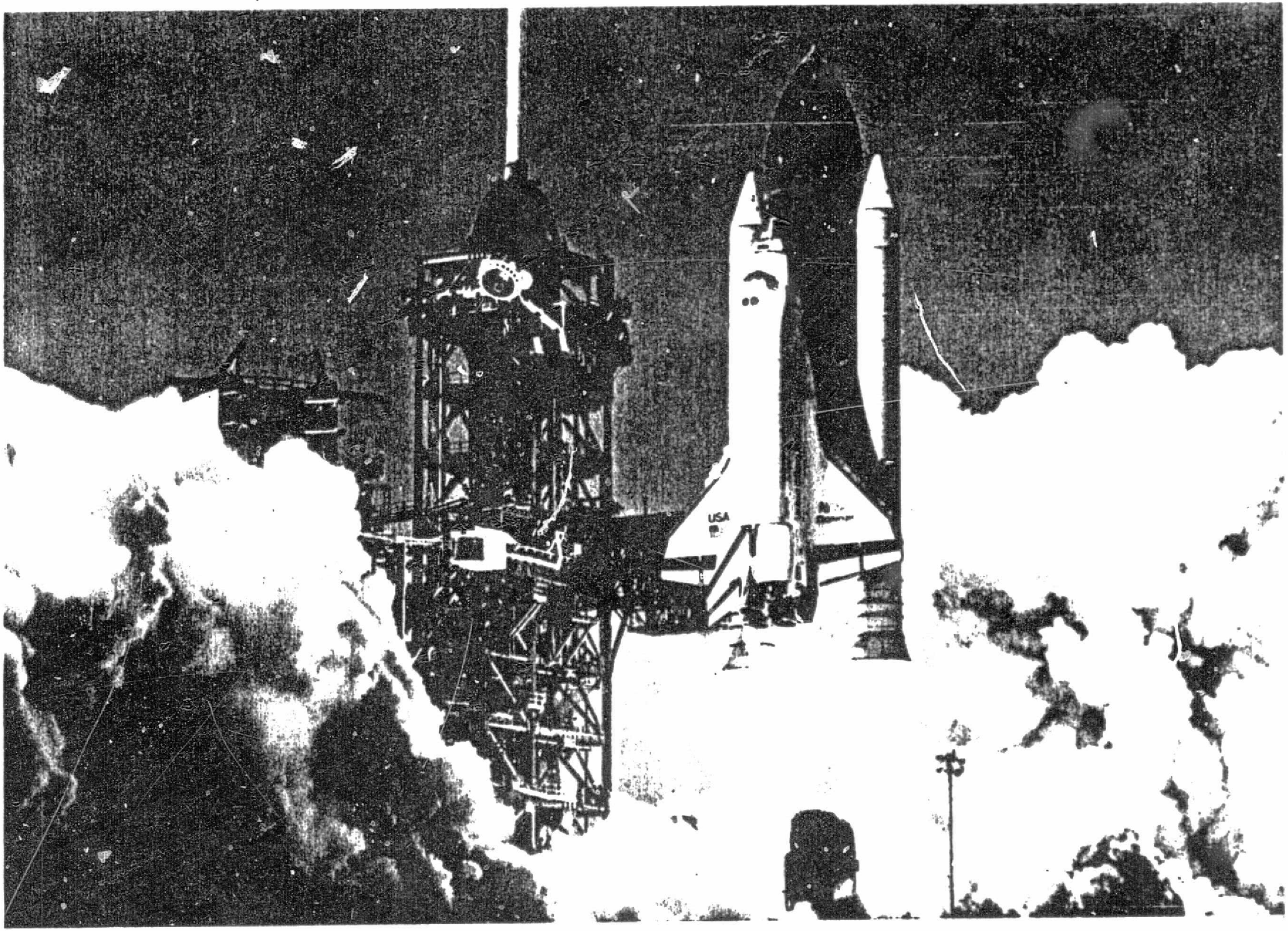

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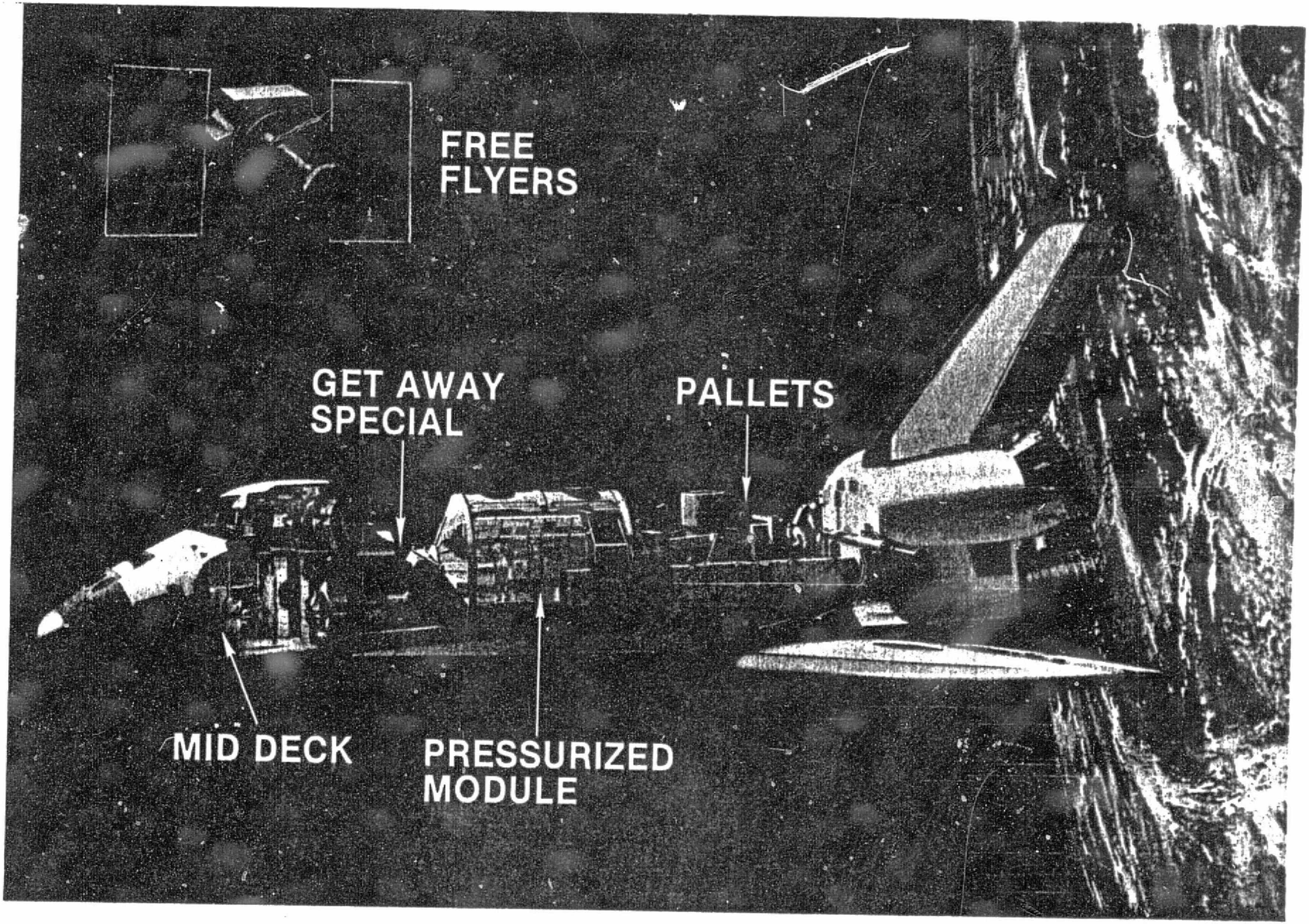
Slide 28



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GETAWAY SPECIAL

(picture)

[slide available from Rockwell]

Slide 30

F E A T U R E S   O F   T H E   G E T A W A Y   S P E C I A L

Most Economical

Easiest scheduling

Minumum external controls: ON and OFF

Self contained: power sufficient

Multiples possible

M I D D E C K   L O C K E R

(picture)

[slide available from Rockwell]

F E A T U R E S   O F   T H E   M I D D E C K   L O C K E R

Size: 8" x 16" x 20"

Modest electric power supplied

Mission specialist will turn
a switch and read a meter

Can store, move, combine, stir

Real time earth linkage of
performance data

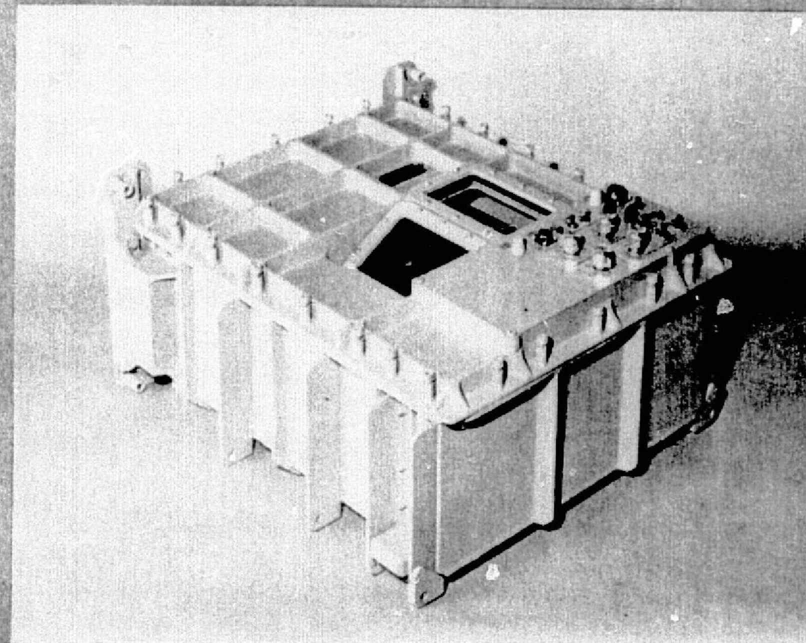
FEA CONCEPT

FUNDAMENTAL SPACE PROCESSING RESEARCH

MODULAR ZERO GRAVITY CHEMISTRY/PHYSICS LABORATORY

PURPOSES

- BASIC PROCESS/PRODUCT RESEARCH
- GENERAL LIQUID CHEMISTRY
- CRYSTAL GROWTH
- FLUID MECHANICS
- THERMODYNAMICS
- CELL CULTURING



OPERATIONAL CHARACTERISTICS

- HEAT/COOL SAMPLES
- MIX GASSES, LIQUIDS, & SOLIDS
- STIR SAMPLES
- CONTAINED SAMPLES
- FLOAT ZONE SAMPLES
- VACUUM AVAILABLE
- MEASURE TEMPERATURE/VISCOSITY
- PHOTOGRAPH (MOVIE) SAMPLE
- RECORD DATA
- ASTRONAUT OPERATED
- SHUTTLE MID DECK

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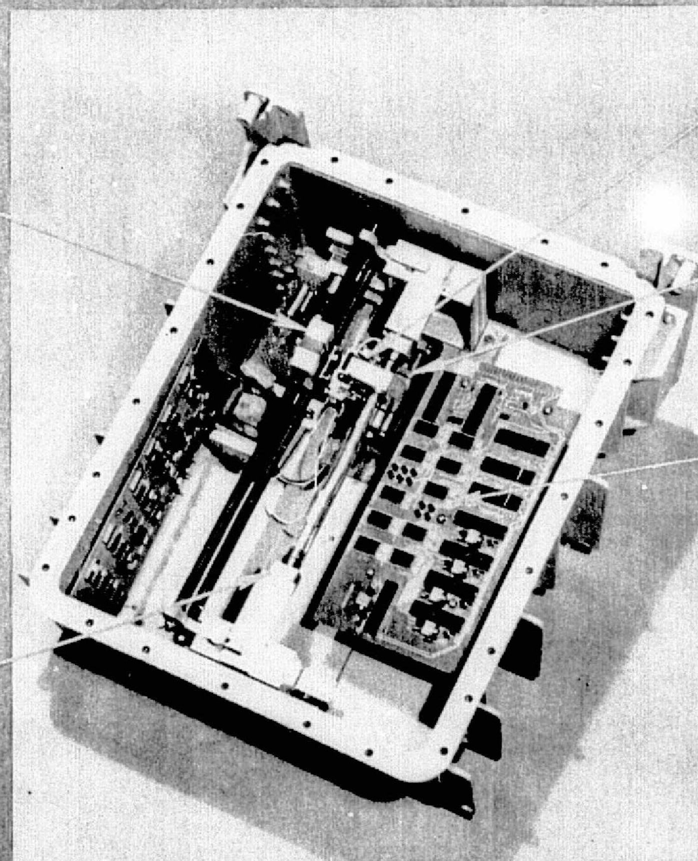
FEA FLOAT ZONE CONFIGURATION



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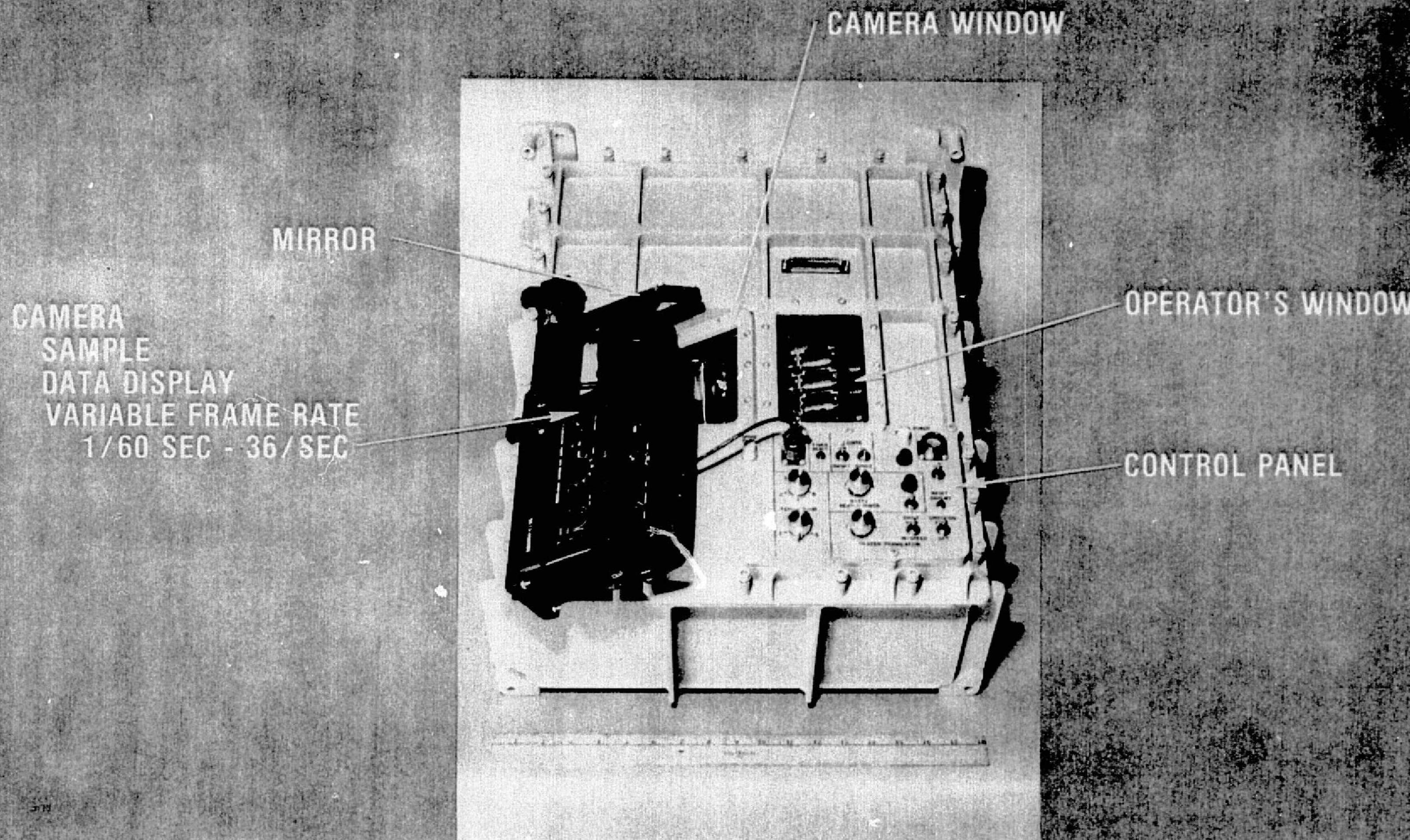
FEA EXTERIOR



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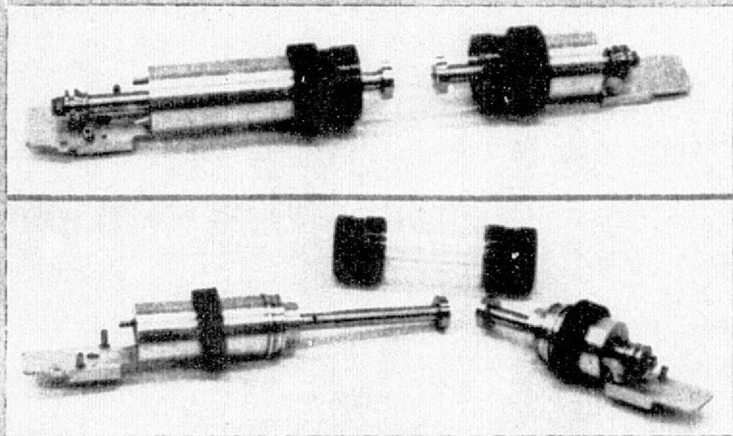
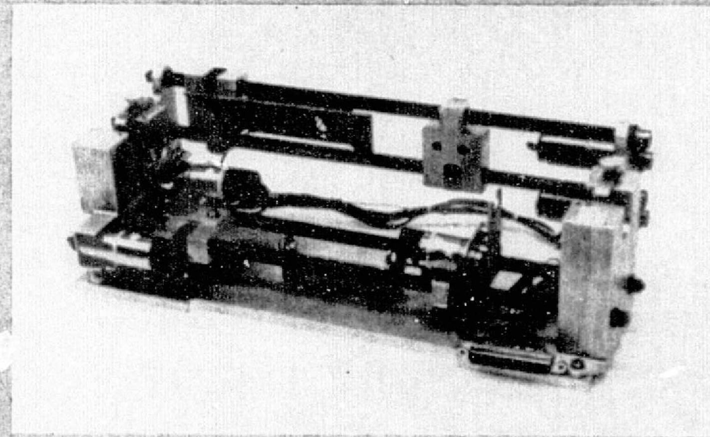
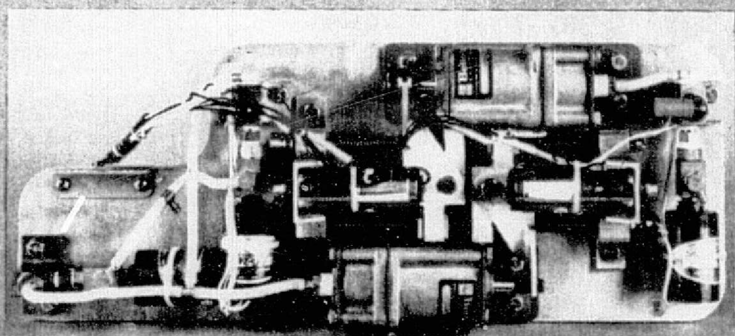
FEA OPTIONAL SUBSYSTEMS



FLUIDS MANIPULATION
EXPERIMENT CONTAINER



EXPERIMENT MANIPULATION
ASSEMBLY



FLUIDS STORAGE &
PUMPING ASSEMBLY

OTHERS

- BULK FLUID CHEMISTRY CHAMBER
- LIVING CELL INCUBATOR
- MULTISAMPLE COLUMN
- CUSTOM HEATER DESIGNS
- SAMPLE CHILL BLOCKS
- SPECIAL INSTRUMENTATION

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SPACELAB

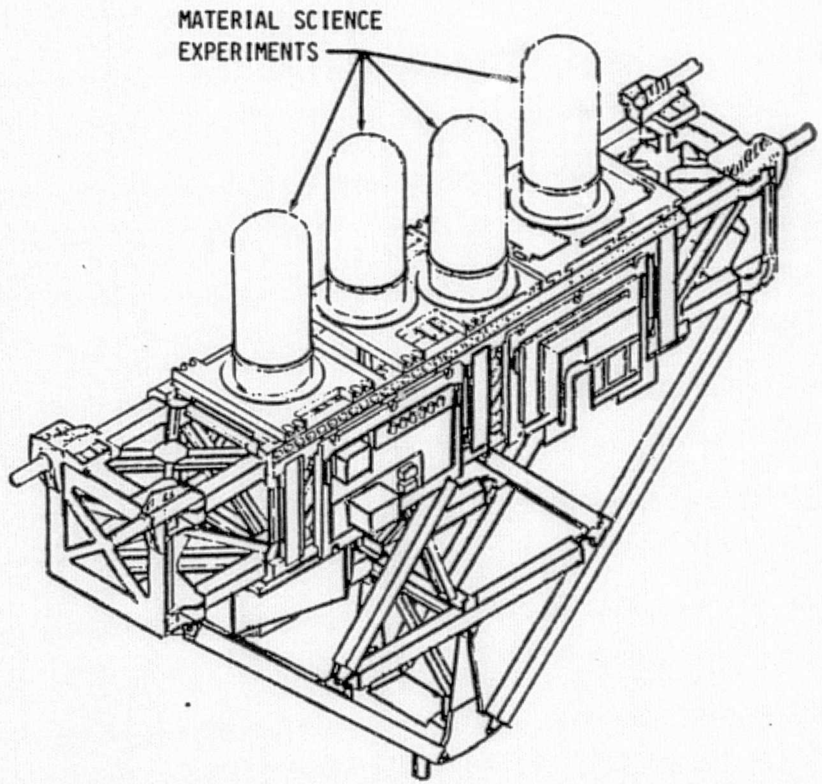
(picture)

[slide available from Rockwell]

F E A T U R E S O F T H E S P A C E L A B

[to be supplied by MSFC]

PALLET IN BAY



Slide 40

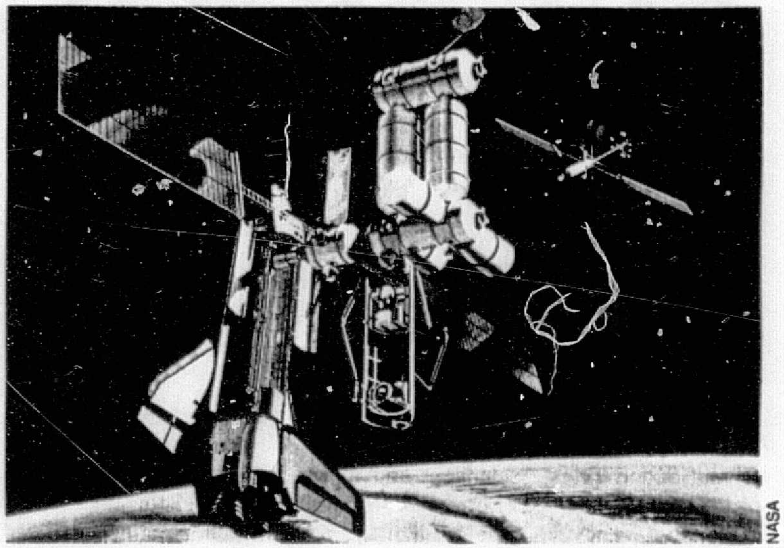
LONG DURATION CAPSULE

(picture)

[slide available from Rockwell]

Slide 41

SPACE STATION



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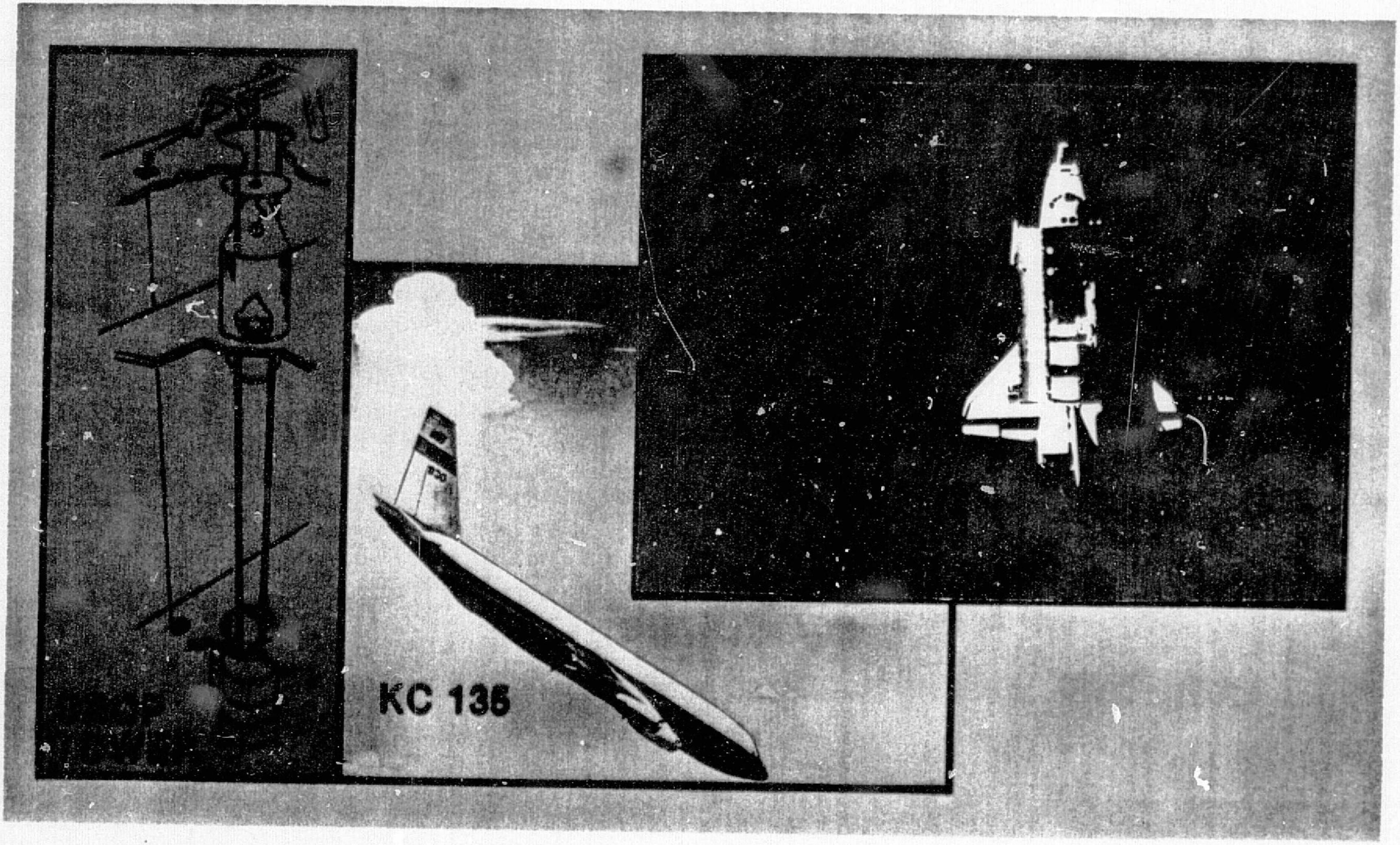
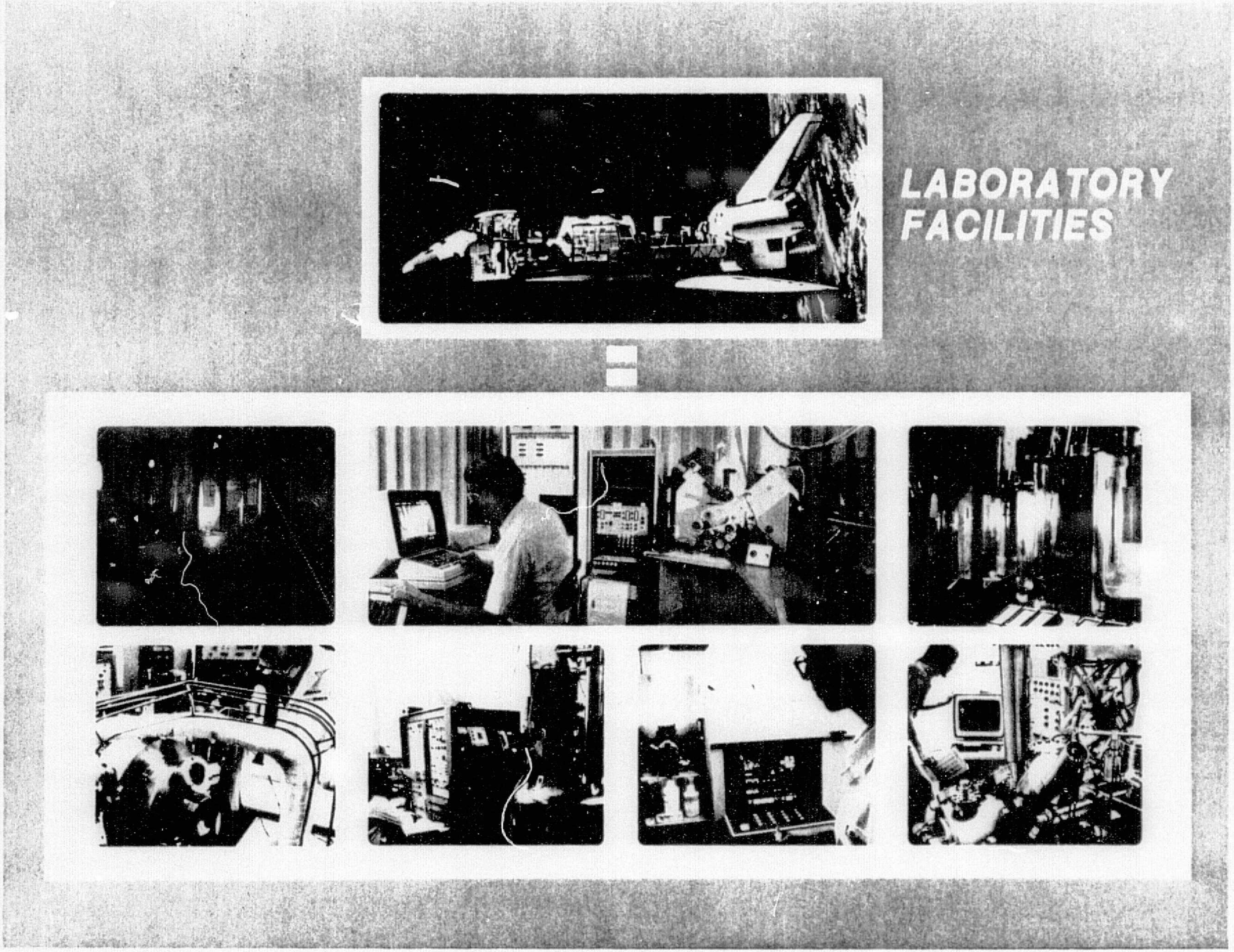
66.

N A S A ' S   H A R D W A R E   C U R R E N T L Y   A V A I L A B L E



CURRENT CAPABILITIES

Facility	Time at Low Gravity	Sample Size
30 meter drop tube	2.6 sec.	0.5 to 1.0 gms.
100 meter drop tube	4.5 sec.	1 to 5 gms.
KC-135 aircraft	15-25 sec.	5 to 10 gms.
F-104 aircraft	30-60 sec.	5 to 10 gms.
Shuttle middeck	1 to 7 days	5 cubic centimeters
Shuttle bay	1 to 7 days	as required



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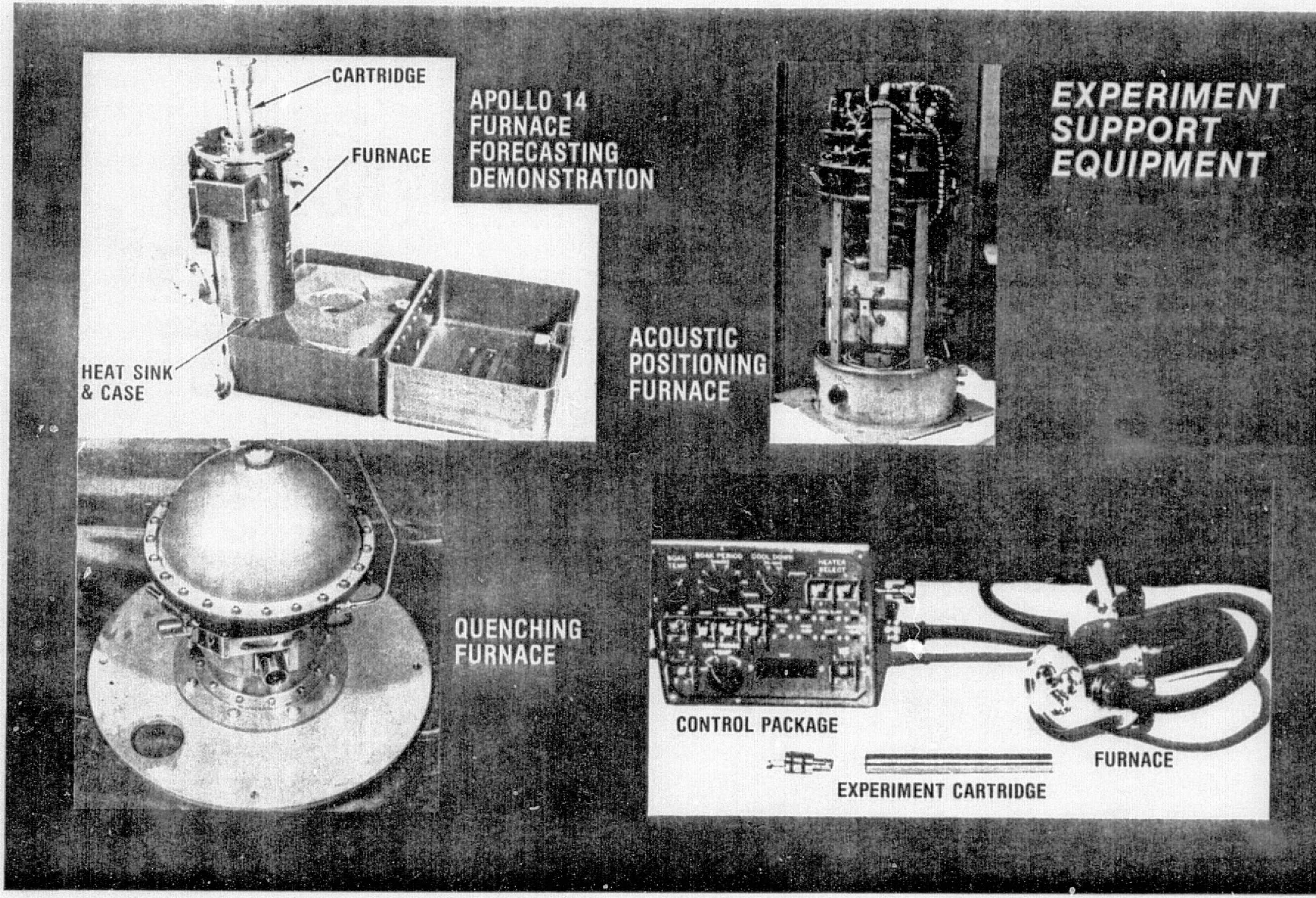

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EXPERIMENT SYSTEMS CATALOGUE

- FLUIDS
- VAPOR CRYSTAL GROWTH
- POLYMER LATEX REACTOR
- CHEMICAL
- CONTINUOUS FLOW ELECTROPHORESIS
- FLOAT ZONE
- ISOELECTRIC FOCUSING
- ELECTROPHORETIC SEPARATION
- ACOUSTIC CONTAINERLESS
- ELECTROMAGNETIC CONTAINERLESS
- ELECTROSTATIC CONTAINERLESS
- ISOTHERMAL FURNACE
- GRADIENT FURNACE
- ELECTROEPITAXIAL CRYSTAL GROWTH
- BIOLOGICAL
- SPACE VACUUM RESEARCH FACILITY
- CASTING FURNACE
- TRANSPARENT FURNACE

P R O G R A M   O P T I O N S

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	N A S A	TECHNICAL EXCHANGE AGREEMENT	GUEST INVESTIGATOR	JOINT ENDEAVOR	INDUSTRY
OBJECTIVE	R & D	R & D	R & D	R & D and COMMERCIAL	COMMERCIAL
FUNDING					
SCIENTIST	NASA	INDUSTRY	INDUSTRY	INDUSTRY	INDUSTRY
EXPERIMENT	NASA	NEGOTIABLE	NASA	INDUSTRY	IMDUSTRY
EQUIPMENT	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
INTEGRATION AND TRANSPORTATION	NASA	NASA	NASA	NASA	INDUSTRY
DATA AND SAMPLES	NASA	SHARED	SHARED	NEGOTIABLE	INDUSTRY
PROPRIETARY RIGHTS	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
KEY FEATURES	DATA AND RIGHTS ARE IN THE PUBLIC DOMAIN	INDUSTRY UTILIZES NASA GROUND-BASED RESEARCH CAPABILITIES	INDUSTRY SCIENTIST WORKS WITH NASA PRINCIPAL INVESTIGATOR	BEST EFFORTS BY INDUSTRY AND NASA	INDUSTRY DOES IT ALL AND GETS IT ALL
		NO EXCHANGE OF FUNDS			

PROGRAM OPTIONS

	NASA	TECHNICAL EXCHANGE AGREEMENT	GUEST INVESTIGATOR	JOINT ENDEAVOR	INDUSTRY
OBJECTIVE	R & D	R & D	R & D	R & D and COMMERCIAL	COMMERCIAL
FUNDING					
SCIENTIST	NASA	INDUSTRY	INDUSTRY	INDUSTRY	INDUSTRY
EXPERIMENT	NASA	NEGOTIABLE	NASA	INDUSTRY	IMDUSTRY
EQUIPMENT	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
INTEGRATION AND TRANSPORTATION	NASA	NASA	NASA	NASA	INDUSTRY
DATA AND SAMPLES	NASA	SHARED	SHARED	NEGOTIABLE	INDUSTRY
PROPRIETARY RIGHTS	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
KEY FEATURES	DATA AND RIGHTS ARE IN THE PUBLIC DOMAIN	INDUSTRY UTILIZES NASA GROUND-BASED RESEARCH CAPABILITIES	INDUSTRY SCIENTIST WORKS WITH NASA PRINCIPAL INVESTIGATOR	BEST EFFORTS BY INDUSTRY AND NASA	INDUSTRY DOES IT ALL AND GETS IT ALL
		NO EXCHANGE OF FUNDS			

TECHNICAL EXCHANGE PROGRAMS

- INCO
  - ELECTROPLATING IN ZERO GRAVITY
  - KC-135 TESTS
- JOHN DEERE
  - CASTING & SOLIDIFICATION PHENOMENA
  - DROP TUBE, KC-135, & F-104 TESTS
  - POSSIBLE SHUTTLE TESTS USING GTI FURNACE
- DU PONT
  - UNIQUE CHEMICAL REACTIONS
  - DROP TUBE TESTS
- OTHERS UNDER DISCUSSION

Rockwell International

PROGRAM OPTIONS

	NASA	TECHNICAL EXCHANGE AGREEMENT	GUEST INVESTIGATOR	JOINT ENDEAVOR	INDUSTRY
OBJECTIVE	R & D	R & D	R & D	R & D and COMMERCIAL	COMMERCIAL
FUNDING					
SCIENTIST	NASA	INDUSTRY	INDUSTRY	INDUSTRY	INDUSTRY
EXPERIMENT	NASA	NEGOTIABLE	NASA	INDUSTRY	IMDUSTRY
EQUIPMENT	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
INTEGRATION AND TRANSPORTATION	NASA	NASA	NASA	NASA	INDUSTRY
DATA AND SAMPLES	NASA	SHARED	SHARED	NEGOTIABLE	INDUSTRY
PROPRIETARY RIGHTS	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
KEY FEATURES	DATA AND RIGHTS ARE IN THE PUBLIC DOMAIN	INDUSTRY UTILIZES NASA GROUND-BASED RESEARCH CAPABILITIES	INDUSTRY SCIENTIST WORKS WITH NASA PRINCIPAL INVESTIGATOR	BEST EFFORTS BY INDUSTRY AND NASA	INDUSTRY DOES IT ALL AND GETS IT ALL
		NO EXCHANGE OF FUNDS			

PROGRAM OPTIONS

	NASA	TECHNICAL EXCHANGE AGREEMENT	GUEST INVESTIGATOR	JOINT ENDEAVOR	INDUSTRY
OBJECTIVE	R & D	R & D	R & D	R & D and COMMERCIAL	COMMERCIAL
FUNDING					
SCIENTIST	NASA	INDUSTRY	INDUSTRY	INDUSTRY	INDUSTRY
EXPERIMENT	NASA	NEGOTIABLE	NASA	INDUSTRY	IMDUSTRY
EQUIPMENT	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
INTEGRATION AND TRANSPORTATION	NASA	NASA	NASA	NASA	INDUSTRY
DATA AND SAMPLES	NASA	SHARED	SHARED	NEGOTIABLE	INDUSTRY
PROPRIETARY RIGHTS	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
KEY FEATURES	DATA AND RIGHTS ARE IN THE PUBLIC DOMAIN	INDUSTRY UTILIZES NASA GROUND-BASED RESEARCH CAPABILITIES	INDUSTRY SCIENTIST WORKS WITH NASA PRINCIPAL INVESTIGATOR	BEST EFFORTS BY INDUSTRY AND NASA	INDUSTRY DOES IT ALL AND GETS IT ALL
		NO EXCHANGE OF FUNDS			

JOINT ENDEAVOR AGREEMENTS

- McDONNELL DOUGLAS
  - CONTINUOUS FLOW ELECTROPHORESIS
  - PHARMACEUTICALS
  - SHUTTLE TESTS
    - 6 IN THE MID-DECK
    - 2 IN THE PAYLOAD BAY
- GTI
  - MULTIPLE CAVITY MODULAR FURNACE
  - UNIQUE ALLOY SAMPLES
  - 4 SHUTTLE TESTS
- MICROGRAVITY RESEARCH ASSOCIATES
  - SPECIAL FURNACE
  - ELECTROEPITAXIAL GROWTH OF GALLIUM ARSENIDE CRYSTALS
- OTHERS UNDER DISCUSSION

Rockwell International

PROGRAM OPTIONS

	NASA	TECHNICAL EXCHANGE AGREEMENT	GUEST INVESTIGATOR	JOINT ENDEAVOR	INDUSTRY
OBJECTIVE	R & D	R & D	R & D	R & D and COMMERCIAL	COMMERCIAL
FUNDING					
SCIENTIST	NASA	INDUSTRY	INDUSTRY	INDUSTRY	INDUSTRY
EXPERIMENT	NASA	NEGOTIABLE	NASA	INDUSTRY	IMDUSTRY
EQUIPMENT	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
INTEGRATION AND TRANSPORTATION	NASA	NASA	NASA	NASA	INDUSTRY
DATA AND SAMPLES	NASA	SHARED	SHARED	NEGOTIABLE	INDUSTRY
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PROGRAM OPTIONS

	NASA	TECHNICAL EXCHANGE AGREEMENT	GUEST INVESTIGATOR	JOINT ENDEAVOR	INDUSTRY
OBJECTIVE	R & D	R & D	R & D	R & D and COMMERCIAL	COMMERCIAL
FUNDING					
SCIENTIST	NASA	INDUSTRY	INDUSTRY	INDUSTRY	INDUSTRY
EXPERIMENT	NASA	NEGOTIABLE	NASA	INDUSTRY	IMDUSTRY
EQUIPMENT	NASA	NEGOTIABLE	NASA	NEGOTIABLE	INDUSTRY
INTEGRATION AND TRANSPORTATION	NASA	NASA	NASA	NASA	INDUSTRY
DATA AND SAMPLES	NASA	SHARED	SHARED	NEGOTIABLE	INDUSTRY
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		NO EXCHANGE OF FUNDS			

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S C H E D U L I N G   L O W   G R A V I T Y   E X P E R I M E N T S

Drop tube and aircraft

6 to 9 months lead time

Shuttle

depends on space availability

for example a Getaway Special which is ready to go
can usually be placed on board within 6 months;
other modules may require 2 years for first flight

Slide 56

S H U T T L E   F L I G H T   S C H E D U L E S

Year	Number of Operational Shuttles	Total Number of Flights
1984	2	10
1985	3	12
1986	4	17
1987	4	23

N A S A   C E N T E R

Commercial Materials Processing in Space

Marshall Space Flight Center

Huntsville, Alabama 35812

Telephone [205]453-3424

THE CHALLENGE

President Reagan said:

"We can follow our dreams to distant stars, living and working in space for peaceful, economic and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade."

from the State of the Union address on January 25, 1984

APPENDIX D

SUPPLEMENTARY INFORMATION TO BE INCLUDED IN THE BROCHURE

PRINCIPLE EFFECTS OF GRAVITY

Convection

The elimination of gravity-driven convection in molten materials can preclude the sometimes undesirable stirring and mixing encountered during the growth of crystals, the casting or solidification of alloys and composites, chemical reactions, or the separation of biological materials . .

Sedimentation and Buoyancy

The elimination of gravity-induced sedimentation and buoyancy can broaden the spectrum of alloys and composites that may be formed by permitting particles of vastly different density to remain in suspension until solidification occurs. Also, the elimination of sedimentation and buoyancy eliminates the need for mechanical stirring. This is important in instances where the stirring may be detrimental to the materials involved

Gravity Induced Deformations

Where hydrostatic pressure controls or limits a process or the force of gravity (weight) causes deformation or fracture of a material, the elimination of gravity can provide opportunities for investigations of unique materials and manufacturing techniques

Containerless Processing

The elimination of the necessity to confine liquids and molten materials within a container can open interesting possibilities. Materials, depending upon their electromagnetic characteristics and the influences of processing in a gaseous environment, may be melted, mixed, manipulated, shaped, and solidified in free suspension by use of acoustic, electromagnetic, or electrostatic fields. Surface tension will hold the materials together in a mass. Another form of containerless processing which can be enhanced by microgravity is the float zone process: since the molten zone will be confined by surface tension, much more latitude may be available for crystal production in space

From NASA Technical Paper 1925
Avenues and Incentives for Commercial Use of a Low-Gravity Environment

NASA TECHNICAL MEMORANDUM

NASA TM-78240

SUMMARIES OF EARLY MATERIALS PROCESSING IN SPACE EXPERIMENTS

By Robert J. Naumann and E. Darby Mason
Space Sciences Laboratory

August 1979

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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VIII. SUMMARY OF WHAT WAS LEARNED

In the area of crystal growth the significant findings are as follows:

1) Control of macrosegregation in melt growth has been demonstrated. It was shown that a steady state diffusion layer can be established over a short growth distance, resulting in a macroscopically uniform dopant distribution over most of the length of the boule. The distribution of dopants in the Witt and Gatos Skylab experiment resembles the classical text book description of diffusion-controlled growth.

2) Elimination of microsegregation due to growth rate fluctuations has been demonstrated. This indicates that it may be feasible to grow some of the higher composition alloy semiconductors such as HgCdTe and PbSnTe from the melt without interfacial breakdown resulting from uncontrolled growth rate fluctuations and under conditions where defects resulting from the growth process may be eliminated.

3) Seeded containerless growth has been demonstrated. Extremely flat surface facets were formed, indicating that the crystalline ordering forces dominated over surface tension forces. Elimination of the container also resulted in a substantial reduction of strain-induced defects.

4) Crystals grown by chemical vapor transport in low-g showed improved growth habit, surface morphology, and lower defect density than those grown on Earth. These differences imply a more uniform growth environment in the absence of gravity-driven convection.

5) Observed growth rates by chemical vapor transport in low-g were substantially higher than expected on the basis of extrapolation of laboratory data from the low pressure regime where convective effects were thought to be insignificant. This indicates a fundamental lack of understanding of the transport mechanisms and their dependence on gravity-driven flows.

6) The ability to produce and maintain extended floating zones was demonstrated. Predicted rotational liquid surface instabilities were confirmed experimentally, and an unexpected nonaxisymmetric instability mode was discovered.

7) There was no evidence of surface tension-driven flows in some of the high-temperature melts that apparently had free surfaces.

In the field of metallurgy, the significant findings are as follows:

1) Welding and brazing can be performed in space. Voids due to trapped gases were effectively prevented. The observed microstructure of weldments in low-g was different from that observed in unit gravity and, in fact, was contrary to what was expected. This is probably due to the absence of sedimentation of the dendrite arms broken off by the flow induced by the e-beam.

2) A number of experiments were designed to produce composites with uniformly dispersed second phases. It was shown that buoyancy effects were effectively eliminated but that close attention must be paid to sample preparation, elimination of gases, and control of solidification rates in order to achieve uniform distributions.

3) Unexpected agglomeration of some immiscible metallic systems occurred during solidification. This indicates that there are strong driving forces for droplet growth or coalescence in the Al-In system, for example, which act in the absence of appreciable buoyancy and are much too fast to be a diffusion effect. One hypothesis at present is that this massive agglomeration is a constitutional effect.

4) Attempts to understand some of the results obtained in the flight experiments have prompted the reexamination of published phase diagrams of several systems. Several refinements were established; e.g., the previously accepted value for the consolute temperature of Pb-Zn was low by 20 K and the eutectic composition of Mn-Bi was found to be 2.6 atomic percent Mn and 97.4 atomic percent Bi.

5) The low-temperature, high coercive strength magnetic phase of MnBi has been studied in detail and a new ordering effect at high magnetic intensities has been discovered. The enhanced magnetic performance of the MnBi samples processed in space is now thought to be the result of finer rod dimensions of the MnBi phase obtained by directionally solidifying an off-eutectic composition that remained uniform in the absence of convective stirring.

In the area of fluid phenomena there appears to be considerable confusing and conflicting data, indicating that there is still much to be learned about the behavior of fluid in a low-gravity environment. The present understanding of these phenomena is summarized as follows:

1) Although a few of the experiments were apparently disturbed by vehicular accelerations, crew activity, or inadvertant crew contact, most of the experiments did not seem to be adversely influenced by the residual g-levels of Skylab and ASTP. There was no evidence of major bulk flows from the random acceleration environment associated with the manned missions, in which the accelerations tend to average to zero.

2) Anomalous wall contact behavior was observed in a number of solidification experiments in which the solid pulled away from the wall

even though the liquid presumably wet the container. In one case the type of dopant atoms present in trace quantities seemed to influence this behavior. Whether such effects result from different wetting behavior in the absence of hydrostatic pressure, the presence of trapped gases, or from volume change phenomena during solidification is not clear.

3) There is still much to be learned about the importance and control of surface tension-driven flows in low-g. The Heat Flow and Convection Experiment flown on Apollo demonstrated unstable surface tension-driven flow in an oil film with a free surface with a destabilizing perpendicular thermal gradient. Surface tension-driven flows resulting from concentration gradients were suggested to explain the observed mixing in the Reed experiment on ASTP, although not conclusively demonstrated. However, there was no evidence of surface tension-driven flows in the crystal growth experiments in which the solid pulled away from the wall.

4) Some anomalous effects were noted in the diffusion experiment of Ukanwa and in the simple Skylab demonstration experiment using a mixture of tea and H_2O. Although the expected diffusion profile was obtained near the center of the sample, this profile was distorted near the walls as though the diffusive transport was retarded.

5) Long-term stability of a fine dispersion of oil and H_2O was demonstrated. This indicates that low-level residual accelerations or other effects do not cause significant agglomeration in an isothermal environment.

6) Free column electrophoresis was successfully demonstrated. Methods for controlling nongravitational flows due to electroosmosis were developed.

In many cases these first experiments were constrained by available resources: development time, flight facilities, power, on-orbit processing time, processing environment, etc. Ambiguities still exist because many of the results were unanticipated and could not be investigated with sufficient detail with the available experiment designs and instrumentation. However, these experiments have provided an extremely valuable first step in the learning process and form an essential background for the next generation of space experiments.

EXPERIMENTS WHICH HAVE BEEN RUN

Crystals

semi conductor materials growth in low gravity
solid solution crystal growth of PbSnTe
float zone experiments in space
solution growth of crystals in low gravity
vapor growth of alloy-type semi conductor crystals
epitaxial growth of single crystal films

Metals

liquid metal diffusion in solubility gap materials
agglomeration in immiscible liquids at low gravity
aligned magnetic composites
dendrite remelting and micro segregation in castings
solidification behavior of Al-In in alloys under low gravity
alloy casting

Fluids

contact and coalescence of viscous and viscoelastic bodies
bubble motion in a thermal gradient under low gravity conditions
liquid mixing experiments
surface tension variations with temperature and impurities
surface tension driven convection phenomena
nucleation and growth of immiscibles

Glass

containerless processing technology
fining of glass in space
containerless preparation of advanced optical glass
thermochemical study of corrosive reactions in oxide materials
glass shell manufacturing in space
dynamics of liquid bubbles

AREAS OF CURRENT RESEARCH

- CRYSTAL GROWTH AND SOLIDIFICATION
  - SOLID SOLUTION IR DETECTORS (HgCdTe, PbSnTe)
  - VAPOR GROWTH (HgI_2, ALLOY TYPE)
  - SOLUTION GROWTH (TGS, GROWTH ENVIRONMENT VS. MORPHOLOGY)
  - FLOAT ZONE (MARANGONI CONVECTION, RADIAL SEGREGATION, INTERFACIAL STABILITY)
- METALLURGICAL MATERIALS AND PROCESSES
  - IMMISCIBLE ALLOYS
  - MAGNETIC COMPOSITES
  - METAL FOAMS
  - HIGH G/R SOLIDIFICATION
  - SOLIDIFICATION AT EXTREME UNDERCOOLING
- COMPOSITES
  - CASTING OF DISPERSION STRENGTHENED ALLOYS
  - SOLID ELECTROLYTES WITH DISPERSED ALUMINA
  - PARTICLE PUSHING BY SOLIDIFICATION INTERFACES
- GLASSES
  - GLASS FINING
  - LASER HOST CLASSES
  - OPTICAL GLASSES WITH UNIQUE PROPERTIES
  - METAL GLASSES
- CHEMICAL PROCESSES
  - MONODISPERSE LATEXES (POLYSTYRENE MICROSPHERES)
  - STABILITY OF FOAMS AND SUSPENSIONS
  - COLLOIDAL INTERACTIONS
  - HIGH TEMPERATURE PROPERTIES OF REACTIVE MATERIALS
  - DIFFUSION CONTROLLED SYNTHESIS
- SEPARATION SCIENCES
  - HIGH VOLUME–HIGH RESOLUTION ELECTROPHORESIS CELL SEPARATION
  - PROTEIN PURIFICATION BY CONTINUOUS FLOW ISOELECTRIC FOCUSSING
- FLUID STUDIES
  - NON–BUOYANCY DRIVEN CONVECTIONS
  - WETTING AND SPREADING STUDIES
  - ROLE OF CONVECTION IN PROCESSES (ELECTROKINETIC SEPARATION, ELECTROPLATING, CORROSION, ETC.)

From NASA Technical Paper 1925
Avenues and Incentives for Commercial Use of a Low-Gravity Environment

CRYSTAL GROWTH

Melt growth is the most widely used technique for production of high technology, single-crystal materials for semiconductor chips used in large scale integrated circuits for communications and computers. The MPS program emphasis is concentrated on achieving chemical homogeneity, hence, maximum electrical performance, in HgCdTe and lead-tin-telluride (PbSnTe) semiconductors. These crystals are among the most sensitive and important infrared sensors and most difficult to grow materials on Earth. The materials bridge the spectrum of growth conditions. In the case of PbSnTe, one component is less dense than the bulk melt, hence the system is subject to solute instabilities. The HgCdTe, on the other hand, has the opposite problem. One component is more dense than the bulk melt. Therefore, it is subject to solidifying interface-shape instabilties. Low-g experiments will determine how such systems can be grown in the absence of gravity.

Float zone growth is a variation of melt growth in which the material can be melted without the deleterious contact with any container wall. Floating zone techniques are widely used to produce crystals such as doped silicon for semiconductors and solar cells. The MPS program emphasis is on establishing uniform growth conditions in commericially important materials such as indium-doped silicon and CdTe which is a semiconductor with a very high theoretical maximum energy conversion efficiency.

Solution growth is an important alternative to melt growth for materials that are unstable at their melting point because the crystals can be processed at much lower temperatures. The MPS program emphasis is directed toward triglycine sulphate (TGS) a room temperature, infrared detector material and gallium-arsenide (GaAs) one of the most important semiconductors for a wide range of applications from microwave devices, to computers, and solid state lasers.

Vapor growth does not compete favorably with other growth techniques on Earth where large crystals are required because gravity disrupts the vapor transport mechanism; it is a useful process for growing "whiskers" or thin noncrystalline films and for materials that do not lend themselves to other convenient techniques. The absence of gravity opens new possibilities for the growth of large, flat, pure crystals by the vapor technique; therefore, the MPS program includes the investigation of HgI_2 nuclear detector crystals and HgCdTe and copper-indium-antimony (CuInSb) solid solution semiconductor crystals.

From NASA Technical Memorandum 82525
Materials Processing in space - Program Tasks

C-2

SOLIDIFICATION OF METALS, ALLOYS, AND COMPOSITES

Directional solidification is a casting process used to produce single crystals and two-phase composite materials wherein the microstructure is aligned in a particular direction such that the mechanical and physical properties differ among various axes, or wherein fine, homogeneous dispersions are achieved. Common example of two(or multi) phase composites might be fiberglass wherein glass filaments are suspended (either unidirectionally or randomly) in a plastic matrix to increase strength and provide anisotropic properties and dispersion hardened stee l wherein small carbide particles are included in the steel matrix to improve strength. The MPS interest in directionally aligned composites is built upon the extraordinary high magnetic coercivity measured in space-grown composites of Mn-Bi/Bi. Additional interest is based on the potential of approaching the theoretical maximum magnetic strength of materials such as samarium-cobalt ($SmCo_5$) which is 10 times higher than currently realized on Earth.

The second aspect of directional solidification finds application in miscibility gap alloys that defy preparation in one-g in bulk quantities because gravity-driven effects cause the materials to segregate upon solidification. If producible, such materials might have such diverse applications as electrical contacts (as replacements for silver and gold) and self-lubricating bearings. Experiments in low-g have successfully produced finely dispersed, homogeneous mixtures of Ga-Bi and Al-In. Other materials, such as Cu-Pb, Cd-Ga, Ag-Ni, Al-In-Sn, Cu-Pb-Al, Cd-Ga-Al, and transparent model materials, are being studied in the MPS to define nongravity segregation phenomena and to establish the techniques to produce these unique materials for property evaluation.

Undercooled solidification is the rapid quenching of molten materials at temperatures well below their freezing points. This process is valuable in the preparation of amorphous (glass or glass-like) materials as well as pure single crystal and metastable phases. The NASA MPS program has developed unique groundbased free fall facilities at MSFC in which extreme undercooling (hundreds of degrees centigrade in excess of existent theory) has been achieved in the production of bulk quantities of pure single crystals and superconducting metastable phases; these materials have not been made in bulk quantities by other methods. The emphasis in undercooled solidification centers on the formation of pure Nb and the superconducting phase Nb_3Ge, which has a high superconducting transition and temperature and offers great promise for electrical transmission and electrical devices.

The MPS program is using the zero-g environment to study the formation and resultant properties of various cast materials (both simple model materials and commercial alloys) to establish process controls and techniques that might be adapted on Earth.

FLUIDS, TRANSPORTS, AND CHEMICAL PROCESSES

Fluid mechanics are critical to nearly all material processes since at some point in the process, the materials exist in either the liquid or gaseous state and are, therefore, subject to gravitational disturbances. The MPS Program has undertaken to analyze tho processes and to develop appropriate theoretical and mathematical models for both the one-g and low-g aspects once such understanding is imperative to understanding the Earth-based property limits and the viability of low-g experimentation. The development of adequate mathematical models (at least for simple materials) is especially important since many, if not most, commercial material processes have been developed empirically over long periods of time and often involve such complex mixtures and combinations of materials that they defy analysis of the reactions and interactions taking place. Low-g offers an opportunity to isolate one of the major variables in understanding these processes.

Chemical processes are being studied to elucidate the effects of gravity in processes where particle size and geometry may affect the chemical reaction kinetics. Currently, the MPS program is investigating the reaction kinetics of polymers to understand and, perhaps, overcome the current commerical size limitations in producing uniform, microscopic particles for applications such as blood cells counter and electron microscopic calibration, calibration of pore sizes in living or other membranes, and for tagging biological materials. Under one-g, as particle size is increased, they tend to aggregate and sediment. An early low-g flight experiment may provide valuable information on chemical process controls applicable to the field of polymer chemistry.

Bioseparation technology is being addressed because Earth-based techniques for producing high purity materials in significant quantities from complex biological mixtures are adversely affected by gravity. In the gravity-free environment of space, separation techniques that are based on electric fields and biological material surface characteristics become highly efficient. Furthermore, such separation techniques are inherently gentle and do not damage or destroy living cells or material. The focus of the MPS program is in developing the technology for separation techniques such as electrophoresis, isoelectric focusing, and phase partitioning.

ULTRAHIGH VACUUM AND CONTAINERLESS TECHNOLOGIES

Levitation technology is being pursued to develop devices for positioning, melting, manipulating, and resolidifying materials in space without the constraint of containers or crucibles. In space, liquid materials will remain in a stable, spherical drop without containers; thus, small restraining forces are sufficient to keep the drop where desired. The processing of materials without the necessity of containers is an exciting and unique capability of the space environment and permits the formation of pure materials without contamination from the container, permits the formation of amorphous (glass) materials that cannot be made on Earth, and permits the measurement of physical properties of molten materials at temperatures that exceed the melting point of crucibles needed on Earth. The MPS program technology is directed toward the development of high temperature acoustic levitators (or positioning devices) for use with materials with electrically conductive materials, in either gaseous or vacuum processing environments, and electrostatic levitators for use with dielectric materials that need to be processed in vacuum environments. Low-g flight experiments have been conducted successfully with both acoustic and electromagnetic devices, and the practical application of this technology to a vast spectrum of both scientific and commerical processes can be realized through the elimination of detrimental gravitational effects.