Charge of
the Containerless Experimentation
in Microgravity
Workshop

Pasadena Hilton
Pasadena, California
January 17-19, 1990

Mark C. Lee
NASA Headquarters
1. Elimination/Reduction of Surface Contamination
   - Adequate Earth-based technology

2. Reduction of dynamic nucleation
   - Paucity of reliable data
Objectives

- To delineate scientific justification for the U.S. Containerless Experimentation Program in Microgravity for the next decade and beyond

- To guide NASA to define the next generation of containerless experimentation instruments in microgravity
Pre-Workshop Panel Meeting

Held at Caltech on August 16, 1989

Chairman: Professor John Perepezko

Members:
- Prof. R. Bayuzick, Vanderbilt University
- Prof. H. Brody, University of Pittsburgh
- Dr. A. Cezairliyan, NIST
- Dr. D. Elleman, JPL
- Dr. E. Ethridge, MSFC
- Dr. R. Hauge, Rice University
- Dr. W. Hofmeister, Vanderbilt University
- Prof. W. Johnson, Caltech
- Dr. M. Lee, NASA Headquarters
- Dr. P. Nordine, CPI
- Dr. E. Trinh, JPL
- Prof. T. Wang, Vanderbilt University
- Dr. M. Weinberg, University of Arizona
Objectives of Pre-Workshop Panel Meeting

1. To recommend to full workshop pertinent science and technology areas for discussion
2. To organize and structure full workshop
3. To take ownership of the full workshop
Recommendations for Discussion from Pre-Workshop Panel

1. Fluid dynamics (surface tension/thermocapillary at T < 200 °C)
2. Thermophysical properties (diffusion at extremely high temperatures, viscosity and surface tension)
3. Benchmark materials
4. Very high temperature chemistry for nonconducting materials
5. Quiescent undercooled melt nucleation study
6. Exploratory growth of protein and other novel crystals
7. Diffusional interactions of gas-particle dispersion
8. Development/verification of processing modeling
Ten Suggested Questions to be Addressed by the Workshop and Splinter Sessions

1. Is the removal of surface contamination alone enough to justify containerless experimentation in microgravity?

2. If not, then what are the other primary scientific justifications for performing containerless experimentation in microgravity?

3. What is the sensible way to acquire data for the purpose of verifying science justifications not currently available?

4. What should future containerless flight instruments look like if they are developed to meet those scientific justifications?

5. Does NASA need to develop a next generation electromagnetic manipulator?
Ten Suggested Questions (continued)

6. Does NASA need a high temperature acoustic program?

7. Is there any advantage to electrostatic positioning for space applications? Is it useful for melt undercooling study? Is it useful for low temperature protein crystallization applications?

8. Is there any need for a heavy-ion beam positioning scheme in space?

9. Can containerless manipulator capability be better achieved through a hybrid system such as acoustic-electromagnetic or acoustic-electrostatic?

10. How much investment is reasonable for the NASA containerless program? What percentage of the budget is adequate to cover high risk and, if successful, high yield areas?
The Process

- MCPF
  - Science Capability Definition
- Pre-Workshop Panel
- Full Workshop
- Guidance to NASA Research Announcement Appendices
- JPL/NASA NRA
- SRD
- MCPF
- PI Selection
- STS SSF
Multiuser Hardware
"The Double NRA Approach"

NRA Selections
PI Funding

- minimum 2 years
- definition studies with approved proposals

Advantages: Multiuser HW better defined in 2nd announcement
- All Science community has an equal chance for flight opportunities

Release 2nd NRA

ISSUE: Time Required for Double NRA
- MCPF: √
- Materials Science: X
- Fluids: √
- Combustion: √
- Fundamental Science: TBD
- PCG: √
### NRA and AO Phasing

<table>
<thead>
<tr>
<th>Category</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
<th>94</th>
<th>95</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Combustion</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>2. PCG</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>3. Containerless</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>4. Materials Science</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>5. Fluids</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>6. Biotechnology</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>7. Fundamental Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pending</td>
</tr>
</tbody>
</table>

Containerless Experimentation in Microgravity
Products of Workshop

1. Information to guide JPL/NASA in putting together a Containerless NRA to be released in FY90

2. Information to guide JPL/NASA in defining a Modular Containerless Processing Facility (MCPF) for Space Station Freedom
The Challenge

Containerless experimentation in microgravity must be based on sound scientific justification. As NASA and this nation's investment in this area increases, it is even more critical to do so. Without strong scientific justification, it is increasingly difficult for NASA to maintain the current level of effort needed for the Space Station era in the face of mounting criticism voiced by the scientific community at large.

The challenge of this workshop is to provide this scientific justification, and to guide NASA in developing the next generation of flight instruments.
Status and Outlook of the
Microgravity Science and Applications Program at NASA

Presentation to
Containerless Experimentation in Microgravity Workshop

Larry Spencer
January 17, 1990
NASA Microgravity Program Goals

- Develop comprehensive research program in fundamental sciences, materials science, and biotechnology
- Develop understanding of gravity-dependent physical phenomena as basis of reliable predictive capability for processing operations/technological issues in Earth/non-Earth environments
- Foster growth of an interdisciplinary research community
- Encourage international cooperation
- Explore new materials and processes relevant to basic research and commercial applications
- Develop permanently manned, multi-facility national microgravity laboratory in low-Earth orbit
- Promote industrial application of space research
THE APPROACH

NEW IDEAS
- UNIVERSITY RESEARCH
- NASA R&T BASE
- OTHER GOVERNMENT RESEARCH
- INDUSTRIAL RESEARCH

CONCEPT FEASIBILITY

DETAILED LABORATORY INVESTIGATION

"0"g EFFECTS CONFIRMATION

KEY SPACE EXPERIMENTS

COMMERCIALIZATION OPPORTUNITIES
MICROGRAVITY SCIENCE AND APPLICATIONS
EXPERIMENT CAPABILITY

FREE FALL FACILITIES
DROP TOWER
DROP TUBE
UP TO 4.5 SEC.

AIRCRAFT
UP TO 60 SEC.

SOUNDING ROCKETS
UP TO 6 MIN.

ORBITER MIDDECK
UP TO 14 DAYS

SHUTTLE-SPACELAB
UP TO 14 DAYS

SPACE STATION
CONTINUOUS

ORIGINAL PAGE IS
OF POOR QUALITY
Microgravity Science and Applications Program

Fundamental Science
- Fluid Physics
- Combustion Science
- Critical Phenomena
- Relativity Theory

Materials Science
- Electronic Materials
- Metals and Alloys
- Glasses and Ceramics

Biotechnology
- Cell Physiology
- Cell Differentiation
- Protein Crystal Growth
- Biological Separations
<table>
<thead>
<tr>
<th>Release Date</th>
<th>Proposals Due</th>
<th>Announcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Nov 89</td>
<td>31 Dec 89</td>
<td>ESA AO for Materials and Fluid Science Experiments: IML-2</td>
</tr>
<tr>
<td>26 Dec 89</td>
<td>26 Mar 90</td>
<td>NASA NRA for Microgravity Combustion Science: Research and Flight Opportunities</td>
</tr>
<tr>
<td>FY90 *</td>
<td>TBD</td>
<td>Protein Crystal Growth Announcement</td>
</tr>
<tr>
<td>FY90 *</td>
<td>TBD</td>
<td>Solidification Research Announcement</td>
</tr>
<tr>
<td>FY90 - 91 *</td>
<td>TBD</td>
<td>Containerless Research Announcement</td>
</tr>
<tr>
<td>FY91 *</td>
<td>TBD</td>
<td>Fluids Research Announcement</td>
</tr>
<tr>
<td>FY91 *</td>
<td>TBD</td>
<td>Foreign Hardware IML-3 Announcement</td>
</tr>
<tr>
<td>FY92 *</td>
<td>TBD</td>
<td>Fundamental Phenomenal/Critical Point Research Announcement</td>
</tr>
</tbody>
</table>

* Dates identified are tentative pending budget availability
<table>
<thead>
<tr>
<th>EXPMT No.</th>
<th>LOC</th>
<th>EXPMT / FACILITY TITLE</th>
<th>ACRONYM</th>
<th>HQ CODE</th>
<th>SPONSOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td>FLUIDS EXPERIMENT SYSTEM</td>
<td>FES</td>
<td>EN</td>
<td>MSFC</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>VAPOR CRYSTAL GROWTH SYSTEM</td>
<td>VCGS</td>
<td>EN</td>
<td>MSFC</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>MERCURIC IODIDE CRYSTAL GROWTH</td>
<td>MICG</td>
<td>EN</td>
<td>CNES</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>CRITICAL POINT FACILITY</td>
<td>CPF</td>
<td>EN</td>
<td>ESTEC</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>ORGANIC CRYSTAL GROWTH FACILITY</td>
<td>CCGF</td>
<td>EN</td>
<td>NASA</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>SPACE ACCELERATION MEASUREMENTS SYSTEM</td>
<td>SAMS</td>
<td>EN</td>
<td>LrRC</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>MICROGRAVITY VESTIBULAR INVESTIGATIONS</td>
<td>MVI</td>
<td>EB</td>
<td>JSC</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>RADIATION MONITORING CONTAINER/DOSEMETER</td>
<td>RMCD</td>
<td>EB</td>
<td>NASA</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>MENTAL WORKLOAD AND PERFORMANCE EVAL.</td>
<td>MWPE</td>
<td>EB</td>
<td>JSC</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>BIOSTACK</td>
<td>BSK</td>
<td>EB</td>
<td>DLR</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td>IMAX</td>
<td>MC</td>
<td>JSC</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>GRAVITATIONAL PLANT PHYSIOLOGY FACILITY</td>
<td>GPPF</td>
<td>EB</td>
<td>APG</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>BIORACK SYSTEMS</td>
<td>BR</td>
<td>EB</td>
<td>ESA/ESTEC</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>PROTEIN CRYSTAL GROWTH</td>
<td>PEG</td>
<td>EN</td>
<td>MSFC</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>CRYOSTAT</td>
<td>CRY</td>
<td>EN</td>
<td>DLR</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>SPACE PHYSIOLOGY EXPERIMENTS</td>
<td>SPE</td>
<td>EB</td>
<td>CSA</td>
</tr>
</tbody>
</table>
# First United States Microgravity Payload (USMP-1)

## Payload Complement

<table>
<thead>
<tr>
<th>No.</th>
<th>Experiment/Facility Title</th>
<th>NASA HQs Sponsor</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lambda Point Experiment</td>
<td>Code EN</td>
<td>JPL</td>
</tr>
<tr>
<td>2</td>
<td>MEPHISTO</td>
<td>CNES</td>
<td>CNES</td>
</tr>
<tr>
<td>3</td>
<td>Advanced Automated Directional Solidification Furnace (AADSF)</td>
<td>Code EN</td>
<td>MSFC</td>
</tr>
<tr>
<td>4</td>
<td>Space Acceleration Measurement System (SAMS)</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
</tbody>
</table>
# Baseline Payload Complement

<table>
<thead>
<tr>
<th>No.</th>
<th>Experiment/Facility Title</th>
<th>NASA HQs Sponsor</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crystal Growth Furnace (CGF)</td>
<td>Code EN</td>
<td>MSFC</td>
</tr>
<tr>
<td>2</td>
<td>Crystals, Monomers, Deposition and Separation Facility (CMDSF)</td>
<td>Code C</td>
<td>UAH CCDS</td>
</tr>
<tr>
<td>3</td>
<td>Drop Physics Module (DPM)</td>
<td>Code EN</td>
<td>JPL</td>
</tr>
<tr>
<td>4</td>
<td>Surface Tension Driven Convection Experiment (STDCE)</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
<tr>
<td>5</td>
<td>Glovebox (GBX)</td>
<td>Code EN</td>
<td>TBD</td>
</tr>
<tr>
<td>6</td>
<td>Space Acceleration Measurement System (SAMS)</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
<tr>
<td>7</td>
<td>Solid Surface Combustion Experiment (SSCE)</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
<tr>
<td>8</td>
<td>Zeolite Crystal Growth (ZCG)</td>
<td>Code C</td>
<td>Battelle CCDS</td>
</tr>
<tr>
<td>9</td>
<td>Protein Crystal Growth (PCG) (3 R/IM's)</td>
<td>Code C</td>
<td>MSFC</td>
</tr>
<tr>
<td>10</td>
<td>Generic Bioprocessing Apparatus</td>
<td>Code C</td>
<td>Bioreserve</td>
</tr>
<tr>
<td>11</td>
<td>Solution Crystal Growth (SCG)</td>
<td>Code C</td>
<td>Battelle CCDS</td>
</tr>
<tr>
<td>12</td>
<td>Astroculture (ASC)</td>
<td>Code C</td>
<td>Wisconsin CCDS</td>
</tr>
</tbody>
</table>
## Payload Complement

<table>
<thead>
<tr>
<th>No.</th>
<th>Experiment/Facility Title</th>
<th>NASA HQs Sponsor</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Critical Fluid Light Scattering Experiment</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
<tr>
<td>2</td>
<td>Isothermal Dendritic Growth Experiment</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
<tr>
<td>3</td>
<td>MEPHISTO</td>
<td>CNES</td>
<td>CNES</td>
</tr>
<tr>
<td>4</td>
<td>Advanced Automated Directional Solidification Furnace (AADSF)</td>
<td>Code EN</td>
<td>MSFC</td>
</tr>
<tr>
<td>5</td>
<td>Space Acceleration Measurement System (SAMS)</td>
<td>Code EN</td>
<td>LeRC</td>
</tr>
<tr>
<td>EXPMT</td>
<td>OV LOC</td>
<td>EXPERIMENT / FACILITY TITLE</td>
<td>ACRONYM</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>-------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIORACK (W/O CLR/FZR)</td>
<td>BR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AQUATIC ANIMAL ENVIRONMENTAL UNIT</td>
<td>AAEU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PERFORMANCE WORKSTATION</td>
<td>PWS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VESTIBULAR &amp; SENSORI MOTOR EXPERIMENT</td>
<td>VSE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SLOW ROTATING CENTRIFUGE WITH MICROSCOPE</td>
<td>NIZEMI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>REAL-TIME RADIATION MONITORING DEVICE</td>
<td>RFMD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BACK PAIN IN ASTRONAUTS</td>
<td>BPA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BIOTACK</td>
<td>BSK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VIBRATION ISOLATION BOX EXPERIMENT SYSTEM</td>
<td>VIBES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ELECTROMAGNETIC CONTAINERLESS PROCESSING FAC.</td>
<td>TEMPUS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BUBBLE, DROP &amp; PARTICLE UNIT</td>
<td>BDPU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>APPLIED RESEARCH ON SEPARATION METHODS USING</td>
<td>RAMSES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPACE ELECTROPHORESIS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FREE FLOW ELECTROPHORESIS &amp; THERMO ELECTRIC INCUB.</td>
<td>FFEU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QUASI STEADY ACCELERATION MEASUREMENT</td>
<td>OSAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ADVANCED GRADIENT HEATING FACILITY</td>
<td>AGHIF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LARGE ISOORTHAL FURNACE</td>
<td>LIF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CANADIAN MINI-SLED</td>
<td>CMS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LOWER BODY NEGATIVE PRESSURE DEVICE</td>
<td>LBNPD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DOUBLE RACK ADAPTOR PLATE</td>
<td>DRAP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EDOMP EXERCISER</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPACE ACCELERATION MEASUREMENT SYSTEM</td>
<td>SAMS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SLEEP MONITORING EXPERIMENT</td>
<td>SME</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ADVANCED PROTEIN CRYSTALIZATION FACILITY</td>
<td>APCR</td>
</tr>
</tbody>
</table>
1989 Highlights
Advanced Programs

• Space Station:
  - Joint Science Utilization Study Support
  - May 1989: Modular Combustion Facility Assessment Workshop
  - June 1989: Space Station Furnace Facility One Year Conceptual Design Study awarded to Teledyne Brown Engineering
  - August 1989: Deployment dates for multi-user facilities rephased
  - November 1989: Request out to all MSAD investigators to provide model experiment scenarios for Space Station
  - December 1989: Microgravity Requirement addressed at combined Level I/Level II Space Station Control Board meeting at Reston, Virginia

• Human Exploration Initiative
  - Preliminary Program Plan developed for Microgravity Science and Applications in response to call for 90-day NASA report to Vice-President Quayle
Six multi-user experimental facilities planned for Space Station Freedom

- Advanced Protein Crystal Growth Facility
- Space Station Furnace Facility
- Modular Containerless Processing Facility
- Fluid Physics/Dynamics Facility
- Modular Combustion Facility
- Biotechnology Facility
Microgravity Science and Applications
Evolution Strategy

- Initial Strategy: Deploy six facilities prior to SSF Assembly Complete

- Current Strategy: Rephased developments in order to resolve issues with:
  - Phasing of Space Station
  - Budget and schedule incompatibilities
  - Technical capability constraints

- Rephasing allows MSA Program time to:
  - Enhance research base
  - Strengthen project management base
  - Gain more on-orbit experience
### Human Exploration Initiative

**Basic approach**

**1990's**
- Space Station Freedom
- Lunar Orbiter

**2001 - 2010**
- Lunar Outpost
- Mars Robots

**Beyond 2010**
- Mars Exploration
- Lunar Operations

- Long-range exploration goal is Mars
- Moon is justified on its merits, as well as a stepping stone toward Mars
- 90-day study will develop a baseline option and analyze impact of variations on milestones and program scope
- Baseline and options will be approved by NASA Administrator
Human Exploration Initiative
MSAD Program Strategy

**MSAD's Role in the Human Exploration Initiative**

- Determine influence of gravity and other extraterrestrial environments on fundamental processes/phenomena. Emphasis on:
  - Processes/phenomena significantly altered or affected by gravity variations and other unique attributes of the extraterrestrial environment
  - Processes/phenomena whose understanding under extraterrestrial conditions will benefit planned HEI activities

- Support basic research activities which can clearly benefit from exploiting the unique attributes of the lunar environment
Initiative Research Areas

- Fluid Dynamics and Transport Phenomena
  - Multiphase flow
  - Phase change heat transfer
  - Fluids management

- Mechanics of Granular Media
  - Soil mechanics
  - Rheology

- Combustion
  - Fire safety
  - Power

- Materials Processing
  - Resource utilization/chemical processes
  - Materials manufacturing
• Aggressive hardware development program to take advantage of a number of opportunities
  – Shuttle
  – Space Station
  – Free Flyers
  – Human Exploration Initiative

• Increased emphasis on Research Announcements
  – Ground-Based Program
  – Flight Program

• Planned program augmentations
  – Ground-Based Program
  – Fundamental Science (Flight Program)
  – Sounding Rocket Opportunities