

**Investigation Title:** Astroculture (ASC)  
**Principal Investigator(s):** Raymond Bula, Ph.D., University of Wisconsin-Madison  
**Additional Investigators:** Weijia Zhou

## **INVESTIGATION OBJECTIVES**

The objective of the ASTROCULTURE™ experiment was to determine if wheat plants, a commercially important crop species, would complete their life cycle in microgravity if grown in a plant chamber that provided a high level of control of the critically important environmental variables.

## **PHASE 1 MISSIONS**

NASA 7

## **OPERATIONAL ACTIVITIES**

Wheat seeds were planted prior to launch. Following the transfer of the astroculture hardware from the Shuttle, STS-89, to the Mir, the experiment was activated. On activation of the ASTROCULTURE™ (ASC-7) flight unit, nutrient solution was transferred from the storage reservoir to the root material for initiating germination of the wheat seeds. During the subsequent growing period of 70 to 80 days, the environmental data recorded by the ASC-7 computer were downlinked to ground controllers. Periodically, video records were to have been made using the on-board camcorder attached to the video camera in the ASC-7 flight unit. After 70 to 80 days, the crew initiated a preprogrammed sequence of environmental changes in the plant chamber that would result in drying the plant material and thereby preserving it until it was returned on STS-91.

## **RESULTS**

The flight unit was activated after STS-89 undocked from the Mir and functioned nominally for approximately 23.5 hours. At that time, a malfunction error was displayed. It was determined that the CPU board of the computer in the flight unit was not functioning.

A replacement board was delivered to Mir and installed without any problem. The flight unit was restarted and functioned nominally for approximately 2 hours and then shut down. After approximately another 2 hours the flight unit restarted. It was decided that this malfunction most likely was due to the internal temperature in the flight unit (not in the plant chamber) was reaching a level that activated the thermal cut-off switch and opened the power circuit to the flight unit. After several such cycles, it was decided to deactivate the flight unit and terminate the experiment.

## **CONCLUSIONS**

No conclusions

## **PUBLICATIONS**

No publications

**Investigation Title:** Commercial Generic Bioprocessing Apparatus (CGBA)  
**Principal Investigator(s):** Louis Stodieck, Ph.D., University of Colorado at Boulder  
**Additional Investigators:** Sportiello, Tran, Korzun, Cape, Todd, Kundrot, Redman, Doyle, Shoham, Marchin, Urban, Hilaire, Guikema, Li, MacCallum, Manfredi, Juergensmeyer, Juergensmeyer, Kacena, Osslund, Villa, Heyanga, Mahady, Wachtel, Stoner, Clawson

## **INVESTIGATION OBJECTIVES**

Improve processes used in terrestrial biotechnology or create new biologically-derived products based on the novel scientific insight gained from observing how microgravity affects various functions of living systems. CGBA investigation categories: protein crystallization, seedling and plant tissue cultures, biomaterials, cell separation, bacterial growth and antibiotic resistance, water purification and biopharmaceutical production.

## **PHASE 1 MISSIONS**

NASA 3, NASA 6

## **OPERATIONAL ACTIVITIES**

The CGBA payload operations were largely automated. Crew operational activities included transfer to and from Mir and regular periodic status checks.

## **RESULTS**

High quality lysozyme crystals exhibiting approximately half the mosaicity (level of disorder) of the ground crystals grown on NASA 3 using 5 techniques and a single very large (~8mm x 8mm) Granulocyte-Colony Stimulating Factor (G-CSF or Neupogen<sup>®</sup>) grown on NASA 6; Oligonucleotide crystals grown in space diffracted to 0.9 Angstrom units compared to the slightly less ordered ground crystal diffraction of 0.95 Angstrom units; Fungal-fighting abilities of plant seedlings maintained in microgravity; iodine resistance of *Pseudomonas* observed in space; aquatic plants, invertebrates and microbes were maintained in a closed system with various morphological and metabolic differences noted in space; No clear pattern of postflight antibiotic resistance noted, but variations between bacteria and antibiotic combinations suggests efflux pump role.

## **CONCLUSIONS**

A wide variety of industry-sponsored research projects were supported by the CGBA payload. All are part of an ongoing program that provides commercial scientists with access to space. Each flight experiment represents a specific step in a process intended to open biotechnology opportunities that derive benefit from the unique environment of space. The Mir Phase 1 Program provided many "lessons learned" which have provided researchers a bridging opportunity to evolve investigations from short-duration Shuttle missions into continuous research carried out on board the ISS.

## **PUBLICATIONS**

Articles appearing in -- Spacebound 97 Proceedings, Microgravity Science and Technology and Current Microbiology

**Investigation Title:** Commercial Protein Crystal Growth (CPCG)  
**Principal Investigator(s):** Lawrence Delucas, Ph.D., University of Alabama at Birmingham  
**Additional Investigators:** Shigeo Aibara, Louis Delbaire, James Knox, Karen Moore, Stephen Quirk, Michail Spangfort, Narayana Sthanam.

## **INVESTIGATION OBJECTIVES**

By conducting technology experiments in space, new insight may be gained concerning industrial needs and technological developments on Earth. This experiment investigated the process of growing protein crystals and biological macromolecules under microgravity conditions to facilitate the analysis of their structure.

## **PHASE 1 MISSIONS**

STS-79, STS-86

## **OPERATIONAL ACTIVITIES**

STS-79 - The Commercial Protein Crystal Growth Experiments flew aboard STS-79 as a sortie mission in the Shuttle middeck. The vapor diffusion protein crystal growth experiments aboard STS-79 involved nine proteins in the third flight of the Commercial Protein Crystal Growth hardware. This hardware consisted of 128 protein crystal growth chambers contained in the Commercial Refrigerator/Incubator Module (CRIM). The experiments were conducted at 22 degrees C. The proteins involved in these experiments were Trypsin Inhibitor, PEP Carboxykinase Complex, Van X, Van A, B, GDP Mannose Mannosyl Hydrolase, Grass Pollen Allergen Ph1 P5, Factor D, and Lysozyme.

STS-86 - The Commercial Protein Crystal Growth Experiment flew aboard STS-86 as a sortie mission in the Shuttle middeck.

## **RESULTS**

STS-79 - In general, the preliminary results indicate that protein crystal growth experiments on STS-79 were quite successful. Analysis of the x-ray diffraction data from these crystals is ongoing.

STS-86 - There was a tremendous difference between the space- and Earth-grown crystals with the microgravity crystals exhibiting vastly superior conformation and optical clarity. They were also very large; being rhombohedra of 1.5 mm on a side in some cases. X-ray diffraction studies are underway.

## **CONCLUSIONS**

STS-79 - In general, the preliminary results indicated that the experiments produced diffraction-sized crystals of five of the nine proteins flown, with crystals of another protein marginal for x-ray diffraction studies. One of the proteins, GDP Mannosyl Mannose Hydrolase, produced crystals with the best macroscopic clarity yet seen for this protein. Additionally, valuable information was obtained about the optimum crystal growth conditions for microgravity experiments.

## **PUBLICATIONS**

None.

**Investigation Title:** Materials in Devices as Superconductors (MiDAS)

**Principal Investigator(s):** Stephanie Wise, NASA/Langley Research Center

**Additional Investigators:**

## **INVESTIGATION OBJECTIVES**

1. To determine the effects of microgravity and space flight on the electrical and magnetic properties of high-temperature superconductivity materials (HTS).

## **PHASE 1 MISSIONS**

NASA 3

## **OPERATIONAL ACTIVITIES**

MiDAS was launched on STS-79 and transferred to the Mir Space Station. It stayed on the Mir for the NASA 3 mission and brought back to the ground on STS-81.

## **RESULTS**

The MIDAS research results show that superconductive thick films can be successfully produced, integrated into durable electronic packages, and operated in a microgravity environment. While aboard the Mir, the specimens exhibited electrical properties that approximate those observed on the ground. Furthermore, the data show that the critical transition temperature ( $T_c$ ) and critical current density ( $J_c$ ) properties did not degrade over time while in space, as evidenced by both the on-orbit and postflight data. Finally, the electrical resistance and current versus voltage characteristics of the thick film specimens when taken at temperatures above the  $T_c$  showed no change during the 90 days of measurements on orbit. These findings demonstrate the survivability of the superconductive films and serve to relieve some of the concerns associated with the incorporation of these new materials into space systems.

## **CONCLUSIONS**

See Results

## **PUBLICATIONS**

No publications

**Investigation Title:** Optizone Liquid Phase Sintering Experiment (OLiPSE) (LPS)

**Principal Investigator(s):** James Smith, Ph.D., University of Alabama at Huntsville

**Additional Investigators:**

## INVESTIGATION OBJECTIVES

1. To study the affect of microgravity on the formation of defects (voids) in sintered products, wetting and alloy formation, and grain sizes and shapes.
2. Analyze the effects of wetting and alloy formation.
3. Study grain sizes and shapes.

## PHASE 1

NASA 2, NASA 6, NASA 7

## OPERATIONAL ACTIVITIES

NASA 2 - (OLiPSE) consisted of 16 sample ampoules, two calibration sample ampoules, and on-orbit support equipment. The samples were processed in the Optizone high temperature furnace available in the Kristall module of the Mir Space Station. The samples were carried aloft on STS-76 and processed between March 30 to April 20,1996. Of the the 16 sample ampoules, 13 ampoules were processed. NASA 6 - During the calibration of Optizone furnace it was learned that it was malfunctioning, so the project was moved to NASA 7.

## RESULTS

NASA 2 - Analysis of the successfully processed samples resulted in data collection for densification, microstructural analysis, pore behavior, grain growth, coordination number, solid volume fraction and dihedral angle. Densification was determined with the water displacement technique. All four samples show positive densification and the densification decreased as the liquid volume increased. Stress intensive regions resulted in a increase liquid volume fraction 10 -20 %. This stress is the driving mechanism to pore filling. However, no pore filling was observed. Pores were uniformly distributed in the microstructure in the 80Fe-20Cu sample. The heavily interconnected grains preclude pore migration and growth. There was little pore coarsening in the 80Fe-20Cu sample. It was observed that grain size decreased as the percent of liquid volume increased. The measured maximum grain size was 1.5 times the mean grain size as predicted from the LSW model under steady state conditions. Wetting of Fe particles by liquid copper results in a reduction of interparticle contact. This reduction corresponds to a decrease in the three-dimensional coordination number with increasing liquid volume fraction. The coordination numbers obtained from the 60Fe-40Cu and 50Fe-50Cu samples are lower than those obtained from the same composition of ECLiPSE samples. The mean dihedral angles show little change along the liquid volume fraction. This indicated an equilibrium dehdral angle around 55 degrees may have been achieved.

NASA 6 - One ampoule was returned on STS-89. Problems with Optizone furnace caused this experiment to be moved from NASA 6 to NASA 7.

NASA 7 - Results from NASA 7 are not available at this time

## CONCLUSIONS

NASA 2 - Though the data set was not complete due to the anomaly previously discussed, shown that the samples processed produced significant scientific results and raised additional questions that the samples processed during NASA 7/Mir 25 should resolve.

## PUBLICATIONS

1. "Optizone Liquid Phase Sintering Experiments (OLiPSE-01) Aboard the Mir Station: Performance and Preliminary Results", with He, Y., Ye, S., Kuruvilla, A., Savin, S., Ivanov, A., Markov, E, Andropov, V.,

Bratukin, U. Putin, G. and Smith, J., Proceedings of the Joint Xth European and VIth Russian Symposium on Physical Sciences in Microgravity, pp 133-135, St. Petersburg Russia, June, 1997.

2. "Preliminary Results From Liquid Phase Sintering Aboard the Russian Mir Station", with He, Y, Ye, S., Kuruvilla, A., and Smith, J. To appear, Proceedings of SpaceBound 97, Montreal Canada, May 11-15, 1997.
3. "High Temperature Liquid Phase Sintering: OLIPSE-01," with He, Y., Ye, S. and Smith, J., Proceedings of the Phase 1 Research Program Interim Results Symposium, Microgravity and Materials Sciences Section, pp 61-74, August 5-7, 1997.
4. He, S. Ye, A. K. Kuruvilla, and J.E. Smith Jr., "*Preliminary Results from Liquid Phase Sintering Studies Aboard Russian Mir Station*", 9<sup>th</sup> International Symposium on Experimental Methods for Microgravity Materials Science, TMS publication (in CD-ROM format), compiled and edited by Dr. Robert A. Schiffman. 1997.