DR-04

# MATERIALS PROCESSING IN SPACE TASKS

**Contract No. NAS8-38079**

## WBS Task 5.4--Generic Tasks--Final Report

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## Executive Summary

This task encompassed a wide range of activities related to materials processing in space. For example, all aspects of the space station's flight and ground-based systems design were assessed for the Office of Advanced Concepts and Technology (OACT) Space Processing Division Office. Activities for that organization also included the consolidation of space processing payload requirements for the space station and the development of an OACT payload operations plan. Similar duties were performed for the MSFC Payload Project Office. The SPACECOM database was used to conduct preliminary design studies for microgravity payload carriers and to conduct assessments of materials processing technology. Concepts for the Advanced Protein Crystal Growth Facility (APCGF) were developed. Materials processing vent products were analyzed and a furnace facility filter concept was developed using those studies. A preliminary design for a space station aluminum payload rack was developed. Analysis was conducted to characterize the acceleration environment on-board the space shuttle. Equipment for two fluid experiment apparatus was designed and manufactured for the Space Science Laboratory. The Fluids and Materials Experiments (FAME) data base was expanded. Also, Mir payload integration, technology transfer, and spacelab-to-space station transition studies were conducted.

## Final Report

### Commercial Space Processing Payload Planning

Six task directives were received that required payload planning and design assessment activity for the Space Processing Division of the Office of Advanced Concepts and Technology (OACT). The primary emphasis was on payloads for and the design of the space station. All aspects of the space station flight and ground-based elements were addressed. The first step in the performance of these tasks was the consolidation of payload requirements so that the station program could use them to develop system requirements. After that initial step, the particular system design was assessed for it's ability to meet OACT requirements. There were several iterations in this process as the space station design went through many redesign activities. Major flight hardware systems that were addressed included; the payload data system, power system, fluid services, vacuum services, laboratory support equipment, and the thermal control system. Major operational aspects that were addressed included; payload command and control, payload integration, mission planning, crew training, and payload data distribution. The primary accomplishments of these directives were: the consolidation of laboratory support equipment requirements; direct participation in utilization studies to develop space station requirements; the establishment of payload data system requirements and critique of the payload data system design, participation in all major space station design reviews such as the Work Package-1 Preliminary Design Review and the Level II Man-Tended Capability Preliminary Design Review; the establishment of logistics requirements particularly with regard to early and late access; the development of a

database to capture space station payload requirements; the establishment of space station microgravity requirements, maintenance of the OACT space station payload traffic model; the development of a baseline OACT Space Processing Division payload operations plan; the review of payload support documentation such as the "Payload Accommodations Handbook"; critique of the payload integration process; submittal of payload requirements for space station strategic planning; and the development of OACT Expedite the Processing of Experiments to Space Station (EXPRESS) rack payload requirements and critique of the EXPRESS rack design. Over 250 documents such as preliminary operations plans, Review Item Discrepancy (RID) packages, trip reports, and traffic models were developed and delivered to MSFC in support of these activities.

Microgravity Data Center Support

After the SPACECOM data base was completed it was made a part of the Microgravity Data Center at MSFC. There it was used as a tool to support commercial development planning and to conduct overall assessments of the commercial space processing activities. This service was used to provide design requirements and to identify candidate payloads for carriers such as COMET and Spacehab. It was used to develop reports on all existing protein crystal growth flight hardware and on semiconductor crystal growth furnaces. NASA organizations that utilized this service included the; the Space Science Laboratory and Payload Project Office at MSFC, and the Space Processing Division of OACT. Non-NASA organizations that utilized this service included; McDonnell Douglas Corp, Wyle Laboratories, Westinghouse Inc., the University of Alabama at Huntsville, Teledyne Brown Engineering, Instrumentation Technology Associates, Essex Corp., the University of Toronto, the University of Alabama at Birmingham and the Aerotherm Corp. Requests for analysis and data packages were running an average of three per month by the end of the contract. This subtask also included field trips to demonstrate SPACECOM and the development of documents to highlight its capabilities. One task directive was received to support this area.

A minor activity of this subtask was the development of a Filemaker Pro data base that captured accelerometer package characteristics. It was called the International Flight Accelerometer Data Base (IFADB) and the last version was delivered to MSFC in September 1993.

Fluid and Materials Experiments Data Base

Under a subcontract to Teledyne Brown Engineering (TBE), Wyle Laboratories expanded and updated the Fluid and Materials Experiments (FAME) data base, for the Space Science Laboratory at MSFC. Five task directives were received in support of this area. FLAME contains brief summaries of pier reviewed scientific papers that address microgravity fluid and materials experiments. The latest version of FAME was completed and is now available on the Internet via Mosaic at the NASA HQ Home Page.

Small Expendable Deployer System (SEDS)

Limited design support was provided to the SEDS program. This included a thermal analysis of the overall design and preparation of drawings for the cabling assembly. These items were delivered to MSFC in May 1990. The SEDS concept was being considered as a candidate technology for deorbiting materials processing payloads. One task directive was received to support this area.

Post-Flight Reporting on Flight Experiments

A Filermaker Pro data base was developed to capture highlights of the results of OACT Space Processing Division payloads. That data base was delivered to MSFC in October 1993. One task directive was received to support this area.

Mir Space Station Payload Integration Study

A study was conducted to determine the top-level payload interface requirements and procedures for the Russian Mir space station. That study was documented in a report entitled, "Payload Integration on Mir: Microgravity Payload Case Studies and Relevant Documentation". That report was delivered to MSFC in May 1994. One task directive was received to support this area.

Technology Transfer Marketing Analysis

A top-level summary report of the benefits and deficiencies of NASA's technology transfer program was developed after surveying five commercial organizations. This report includes descriptions of how the transferred data was used and what, if any, new products have been developed as a result. The report was delivered to MSFC in June 1994. One task directive was received to support this area.

Payload Project Office Space Processing Payload Planning

Payload planning and design assessment activity was conducted for the Payload Project Office at MSFC. Emphasis was placed on the Advanced Protein Crystal Growth Facility (APCGF), the Microgravity Science Glovebox, and the Space Station Furnace Facility (SSFF) with regard to their utilization of the space station. All aspects of the space station ground-based and flight-based systems were reviewed. In order to merge the requirements of the APCGF and SSFF with other MSAD payloads their requirements were input and regularly updated in the Microgravity Science Applications Management System (MSAMS) data base which was resident at LaRC. In addition, this activity also required the direct support to the Microgravity Requirements Integration Group (RIG) and the Materials Processing Glovebox RIG. Engineering support was provided for the compilation of requirements that were generated by that group. Fourteen task directives were received to support this area.

Major space station activities included the following: the review of design documentation for Work Package-1 and-2 Preliminary Design Reviews; assessment of the Payload Integration Center (PIC) concept; analysis of the LSE design and the generation of PPO payload requirements for this facility; review of payload data system concepts; the assessment of space station design changes on MSAD

payloads; provision of payload requirements to and assessment of the EXPRESS rack program; and provision of APCGF, SSFF and Material Science Glovebox resource requirements to the space station strategic payload planning process.

A major activity for the Payload Project Office was the development of payload operations plans for MSFC facilities. The primary activities in that development were the following: First, a technical summary of the integration, training and operations requirements, including costing data, was provided in December 1991 and regular updates were provided thereafter. This activity eventually lead to the creation of MSFC's User Operations Facility (UOF) concept. The first full report on the UOF concept was delivered in August 1992, and was updated in October 1992. A UOF implementation plan was developed and delivered in January 1993. Major inputs were made to the development of the UOF Project Implementation Plan which was completed by MSFC in April 1993. In 1993 the UOF was conceived to be part of a larger MSFC facility to be called the Microgravity Development Complex (MDC). An "Operations Overview" plan for the MDC was developed and delivered to MSFC in October 1993. In addition to these activities, contributions were made towards MSFC's plan to develop a UOF Testbed to be used during future Spacelab missions.

The other major area within this subtask was support for the integration of the Materials Science Glovebox on the USML-1 Spacelab mission. This included the assessment of; crew procedures, Experiment Integration Agreements (EIA), and data system requirements. After the successful completion of the mission, support was provided for the dissemination of mission data and the documentation of mission results.

One minor activity was the design and fabrication of mounting brackets for a payload aluminum rack mockup that was assembled at MSFC. The brackets were delivered in May 1994.

Advanced Protein Crystal Growth Facility (APCGF)

Design concepts for an APCGF were developed. This included the development of hardware and science requirements for this facility. The development of these requirements evolved over the length of the contract as major changes to the space station design and schedule impacted APCGF development. The following were the major deliverables to MSFC: a "Safety Issues Report"--delivered November 1990; a "Science Capabilities Document" and an "Engineering Capabilities Document"--delivered December 1990, updates were provided in January 1991 and March 1991; a Breadboarding Plan including parts list--delivered February 1991, a "Development Task Plan"--delivered April 1991; Bench Model Design costing data and Experiment Module Concepts--delivered June 1991; a "Science Requirements Package" and costing estimate--delivered January 1992; Conceptual Design Review package including updated "Hardware Capabilities Document"--delivered April 1992; ROM program cost estimate for a minimal APCG space station program--delivered May 1992; summary and responses to Design Review comments--delivered July 1992. Due to space station program changes, development of the APCGF concept was conducted at a very low level for the next 12 months. Development activity picked-up again in late 1993 with the requirement to assess the Biotechnology Facility

(BTF) and the EXPRESS rack as carriers for the APCG apparatus. The results of that study were delivered in report form to MSFC in June 1994. Seven task directives were received in this area.

Spacelab-to-Space Station Payload Transition Study

A report on the engineering requirements, including cost and schedule, associated with converting the Crystal Growth Furnace (CGF) and the Protein Crystal Growth (PCG) from a Spacelab to a Space Station design was developed. This document was delivered in December 1990. After the basic document was delivered, a series of follow-up meetings was supported to address specific issues associated with this concept. Inputs were made as required to MSAD. Also in this area, a computer routine was developed to be used as a crew training tool. The APCG was used as the representative payload for this development. That program was delivered to MSFC in November 1992. Four task directives were received in this area.

Aluminum Rack Assessment

An aluminum payload rack concept was developed as an alternative to the space station composite rack. The final report included the results of a top level structural analysis, top-level preliminary design drawings, and an assessment of the verification requirements between the aluminum and composite racks. The final report was delivered to MSFC in March 1992. A follow-up executive briefing was provided in July 1992. A set of revised preliminary drawings of the rack-to-space station attach fittings were delivered in January 1993. The revisions were driven by changes to the the space station side of the interface. Two task directives were received in this area.

SSFF Interrack Demonstration Unit

TBE assisted MSFC in developing its SSFF laboratory in Building 4649 by assembling the Inter-Rack Demonstration Unit (IRDU) at that facility. The IRDU had previously been developed for the SSFF program. The IRDU was successfully moved to MSFC and was demonstrated to NASA personnel in October 1992. Three task directives were received in this area.

Vent Gas Analysis for Spacelab Experiments

Samples of materials processing experiment vent gas residue were collected from the vent system for Spacelab missions USML-1, SL-J, and SL-D2. This was done to determine the quantities and species of the vented materials from materials processing facilities. TBE collected the samples and developed the final reports, the sample analysis were conducted by Technical Micronics Control, Inc (TMC). Separate reports were generated for each mission. There delivery dates were; USML---delivered January 1993, SL-J--delivered February 1993, SL-D2--delivered June 1994. The SL-D2 results were delayed because it was discovered that the primary SL-D2 furnace facility contained its own filtration system. This required the collection of additional samples for analysis. Six task directives were received in this area.

Vent Gas Filter Development Study

A Crystal Growth Furnace vent gas filter concept was developed. This concept was proposed for use on the USML-2 Spacelab mission. The design was primarily based on the results of the vent gas analysis which was described in the previous paragraph. Breadboard versions of this filter were developed and tested during late 1993. Test results, design, and costing data were provided to MSFC in December 1993 at an informal design review. Two task directives were received in this area.

Fluid Experiment System/Vapor Crystal Growth System (FES/VCGS)

A preliminary payload integration and safety review report was generated using archived FES/VCGS data. This was a low level effort and the report was delivered in the first quarter of 1990. One task directive was received in this area.

Geophysical Fluid Flow Cell (GFFC) Verification Plan

Technical assistance was provided to the Payload Experiment Developer (PED) for the development of the GFFC Verification Plan. The Verification Plan was delivered to MSFC in November 1990. One task directive was received in this area.

Microgravity Measurement

Several products were developed in support of NASA's Microgravity Measurement Group (MGMG). The major items were to conduct analysis and to assess accelerometer data that was collected from several STS missions, primarily using the Space Acceleration Measuring System (SAMS). The following are a list of acceleration analysis reports and there delivery dates; STS-40 Early Summary Report--delivered November 1990, STS-32 Early Summary Report--delivered June 1991, STS-40 Early Summary Report--delivered October 1991, STS-43 Early Summary Report--delivered January 1992, STS-40 and STS-43 Sensor Report--delivered February 1992, STS-42 (IML-1) Early Summary Report--delivered August 1992, STS-47 (SL-J) Acceleration Summary Report and the STS-42 Sensor Report--delivered April 1993, STS-50 (USML-1) Sensor Report--delivered June 1993, and the STS-52 Summary and Sensor Report--delivered August 1993.

A small subtask was to to compile and assess data on the state-of-the-art in microgravity accelerometer calibration technology. That assessment was delivered in May 1990.

A Ground Acceleration Measurement System was built and used to test acceleration levels generated by such items as Spacelab refrigerators. The unit was completed in April 1991. It was used to assess Life Sciences Laboratory Experiment (LSLE) equipment and Fluid Experiment System vibration generation characteristics. That assessment was delivered in the first quarter of 1993.

Measurements were taken on-board the KC-135 to establish its background acceleration environment. After processing this data, a report of the results was delivered to MSFC in the first quarter of 1993.

There were eighteen task directives in support of this area.

Spherical Polymer Dye Laser Materials

A "Rotating Bottle Latex Reactor" was fabricated from designs provided by the MSFC Space Sciences Laboratory. This was a ground-based device to test concepts for a next-generation latex sphere development facility. The fabricated items were delivered to SSL in the second half of 1992. There was one task directive in support of this area.

Bubble Suppression in Microgravity

Design and fabrication support was provided to the SSL in the development of test hardware test concepts for limiting bubble generation in fluid science experiments. The device was to be tested on the KC-135. The hardware was delivered in February 1994. There was one task directive in support of this area.

## Cost Estimates

The costing data for this task is contained in the reports for the individual subtasks where it was required. This included the concepts for the APCGF, UOF, and CGF filter projects.