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THE TRANSITION OF GROUND-BASED SPACE ENVIRONMENTAL EFFECTS TESTING TO THE SPACE ENVIRONMENT

by

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Introduction

The goal of the Space Flight Program at the Center for the Commercial Development of Space—Materials for Space Structures located at Case Western Reserve University is to provide environmentally stable structural materials to support the continued humanization and commercialization of the space frontier. Information on environmental stability will be obtained through space exposure, evaluation, documentation and subsequent return to the supplier of the candidate material for internal investigation. This program provides engineering and scientific service to space systems development firms and also exposes CCDS-developed candidate materials to space environments representative of in-flight conditions.

The maintenance of a technological edge in space for the National Aeronautics and Space Administration suggests the immediate search for space materials that maintain their structural integrity and remain environmentally stable. The materials being considered for long-lived space structures are complex, high strength/weight ratio composites. In order for these new candidate materials to qualify for use in space structures, they must undergo strenuous testing to determine their reliability and stability when subjected to the space environment. Ultraviolet radiation, atomic oxygen, debris/micrometeoroids, charged particle radiation, and thermal fatigue all influence the design of space structural materials as shown in Figure 1.[1-3] The investigation of these environmental interactions is key to the purpose of this Center, one of the sixteen Centers established and sponsored by NASA.

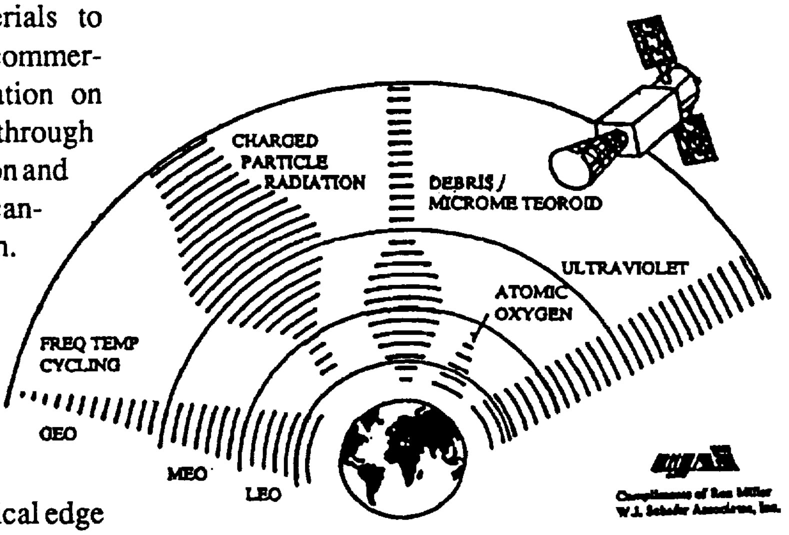

Figure 1

Space Flight Program

Materials produced by CCDS projects will be verified for space environment stability by testing on future space flights beginning in April 1991 and continuing through 2005. Currently, no terrestrial capability exists that precisely reproduces the environment in which these materials must function. This Space Flight Program concentrates on using existing and planned

Space Transportation Systems to facilitate exposure of materials while, at the same time, reducing costs. The Space Flight Program intends to build on the completed experiments of Long Duration Exposure Facility (LDEF) and Evaluation of Oxygen Interactions with Materials (EOIM) through the development of materials exposure fixtures which will provide for *in-situ* data generation. Thus, the search for the information necessary to ascertain which materials will be suitable for space applications stretches into the next century. These advanced materials investigations will allow the development of special application engineered materials.

The Space Flight Program at this CCDS consists of three distinct phases. Phase I focuses on program planning and program development under the auspices of active Center sponsors from Industry, Academia and Government. The Phase I flight requests consist of essentially three passive payloads currently scheduled in 1991. Data from these flight related activities will be used to:

1. Expand the existing space materials data base
2. Establish a service related endeavor with functional/operational parameters
3. Verify standards for materials degradation
4. Calibrate and perform functional checks of required special nondestructive test equipment

The flight projects identified by the Center under Phase I development are termed Limited Duration space environment Candidate Materials Exposure (LDCE) experiments.

As the CCDS flight activities grow, the need for *in-situ* data generation also grows. Phase II flights address this need. During Phase II, the CCDS will expand the number of tests conducted to expose materials to the space environment, and undertake the analysis of those test results. Four extended duration payloads will be flown during Phase II under three distinct modes. One scheduled via the STS carries the designation CMSE/E, and one representing an expansion of CMSE/E is designated CMSE-1; one scheduled on Wake Shield carries the designation MATLAB-1; and one scheduled on the Office of Commercial Programs free flyer "COMET" is designated MATLAB-2. Data from these flights will be used to:

1. Expand the technology base for increased operations
2. Refine sensor performance

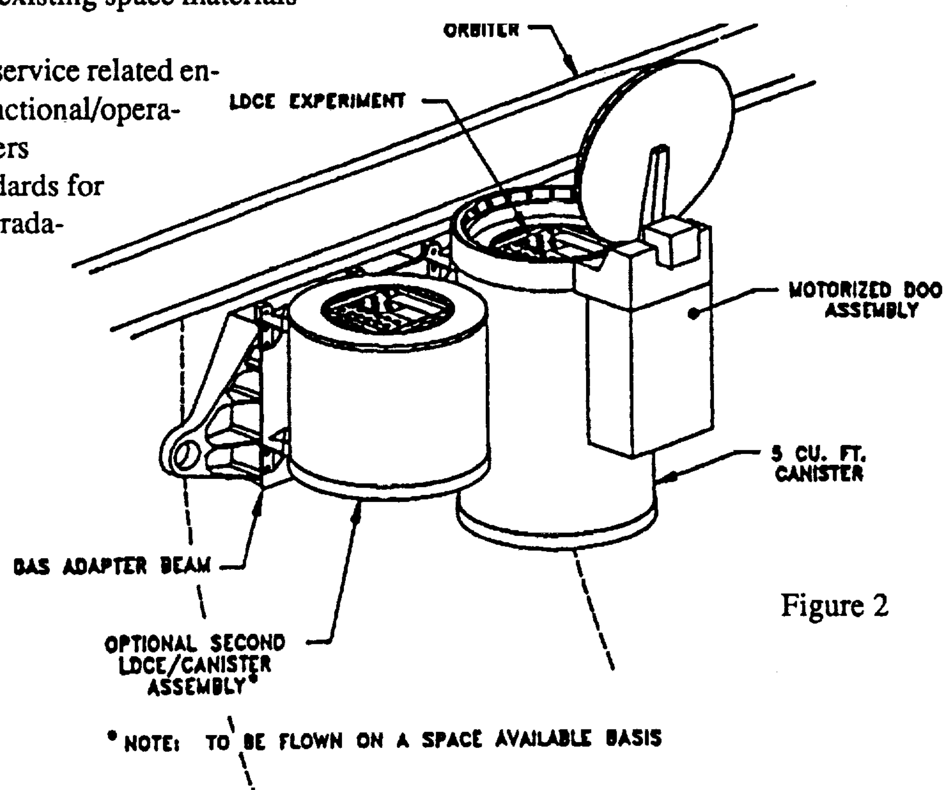

Figure 2

3. Evolve advanced materials with smart structure integration modules for space or terrestrial use

The three Phase II flights are scheduled to begin in December 1991 and to end in 1993.

This CCDS plans additional, long duration exposure facilities during Phase III of this program. These payloads contain experiments designed to be conducted in space on existing or planned structures/platforms. This phase also includes the use of the planned Space Station as a materials exposure and evaluation facility. Flight requests submitted to the NASA Office of Commercial Programs for Phase III were deferred pending successful integration during Phase I. However, the CCDS will continue to concentrate on project definition and industrial sponsorship.

Space Flight Payloads

PHASE I Limited Duration space environment Candidate materials Exposure (LDCE)

The three LDCE payloads utilize a complex autonomous payload (CAP) container with a motorized door assembly (MDA) mounted in the Orbiter (Figure 2)[4]. The LDCE payload fixture is a 19.65 inch diameter disc with a 15.34 inch diameter midsection to which the candidate materials are attached and exposed when the MDA is opened (Figure 3). This configuration meets the immediate requirements of this Center and current industry backlog. The interim objective is to perform atomic oxygen durability verifications using this passive fixture arrangement. Preflight and post-flight sample surface analysis in addition to carefully controlled sample mass determinations will provide insight to the atomic oxygen influence on surface recession or growth.

Passive materials exposure experiments constitute the LDCE-1, LDCE-2 and LDCE-3 payloads and consequently have a very limited operation scenario. The intended operation steps to support these experiments are:

1. Step one, Attitude requirement - The payload bay faces forward so an ambient atomic oxygen beam is presented to the material surface areas. The exposure surfaces are perpendicular to the Orbiters operational velocity vector (-Zvv).

2. Step two, MDA operation - Once the Orbiter orientation is obtained, the MDA is opened for LDCE-1 and LDCE-3. LDCE-2 is mounted without a MDA.

3. Step three, Materials exposure - The ambient atomic oxygen interaction is required for 40 hours.

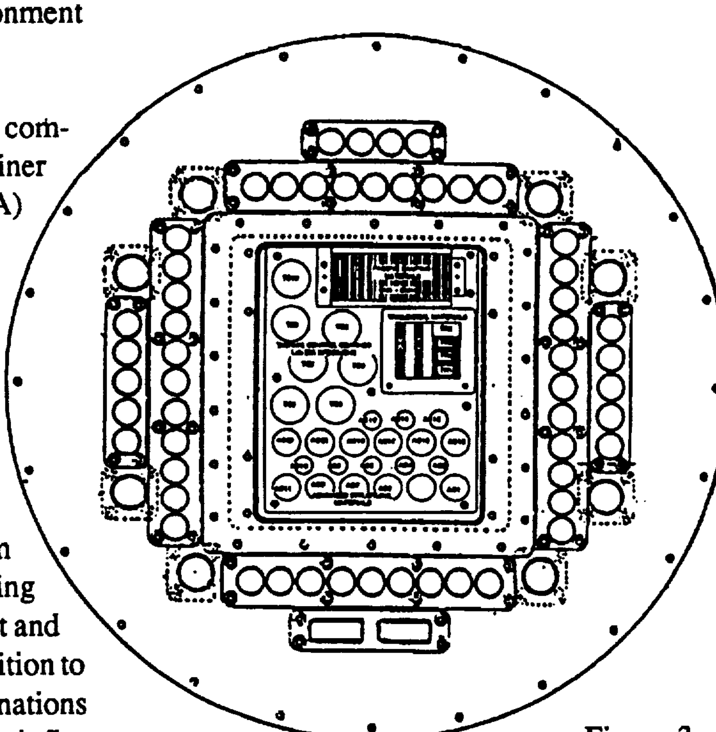

Figure 3

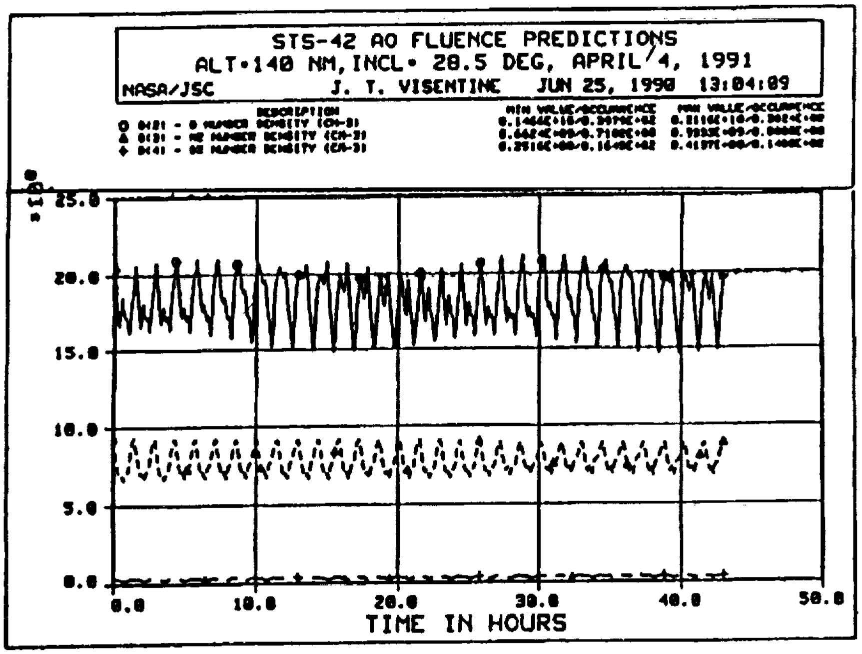

Figure 4

4. Step four, MDA operation - Before repositioning the Orbiter, the MDA is closed.

NASA will supply an Orbiter altitude between 120-180 n. miles and an Orbiter orientation [payload bay facing forward (-Zvv)] for ground simulation experiments.

One such ground simulation study involves the calculation of the total atomic oxygen fluence the samples received. The Johnson Space Flight Center computed the atomic oxygen species predicted from STS-42 flight geometry using the MSIS86 atomic oxygen fluence calculation program (Figure 4)[5]. The STS-42 flight sequence scheduled for April 1991 tentatively carries the LDCE-1 and LDCE-2 payloads. Several well characterized passive atomic oxygen fluence dosimeters are included in each of the LDCE series experiments.

Following the determination of post flight exposure from the Mission Elapsed Time documentation, an update of MS1S86 fluence calculation will further define this elusive variable. This active participation and coordination with various NASA installations further enhances the materials data base generated by Center research.

PHASE II Increasing Space Activities

Candidate Materials Sample Exposure (CMSE) - CMSE/E

From a materials' perspective, the flight of EOIM-III in December 1991 will provide benchmark data for LEO environment operations. NASA centers (JSC, GSFC, MSFC, LaRC, JPL and LeRC) and selected Space Station contractors have contributed experiments toward EOIM-III success. One experiment in particular, an ion-neutral mass spectrometer, will have significant influence on quantifying LEO species. The CMSE/E payload incorporates active/passive samples for a proposed baseline correlation with experiments being performed on EOIM-III. The active box incorporated in CMSE/E and correlated with advanced EOIM-III hardware becomes an integral portion of all Phase II experiments for this Center (CMSE and MATLAB payloads). The active box transmits data accumulated from sample changes due to strain, temperature, resistance, photo-intensity and frequency. Fixtures and active box configurations are compatible with the LDCE series hardware by making CMSE/E a cost effective, upgraded follow-on configuration. This design allows for baseline data correlation, determination of coupled environmental factors, and *in-situ* sensor module evaluation and calibration. The CMSE/E payload will aid in the understanding of the mechanisms and processes of atomic oxygen.

CMSE-1

Capitalizing on the success of LDCE and CMSE/E, CMSE-1 utilizes the same calibrated box (or boxes) but increases the number of samples in the payload. A CMSE Experiment Support Assembly (Figure 5), remote from the CAP, will expose additional active/passive samples. The Shuttle manipulator arm lifts the Experiment Support Assembly from the cargo bay and orients the assembly for the LEO exposure.

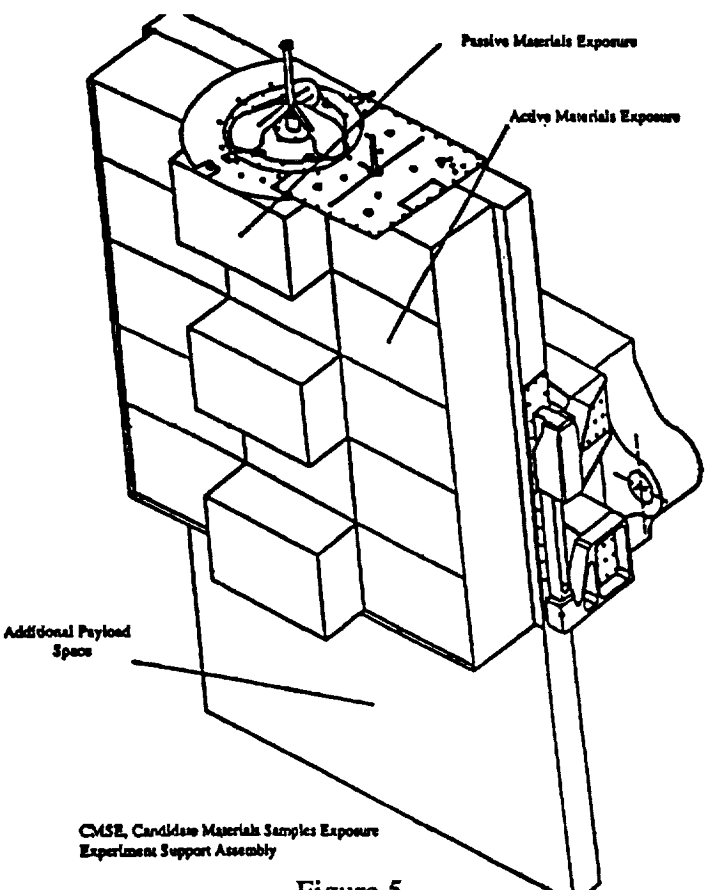

Figure 5

MatLab-1 and MatLab-2

The MatLab payloads augment the CMSE/E and CMSE-1 experiments through changes in LEO positioning. The proven hardware of the MatLab-1 fixture will be located on the forward, high pressure side (atomic oxygen ram) of Wake Shield. Additional plasma diagnostics experiments incorporated into Wake Shield hardware will enhance data reliability and provide further insight into the LEO environment.

MatLab-2 will occupy space on the NASA Commercial Programs "COMET" payload. This "free flyer" will extend the payload exposure duration for additional LEO characterization.

PHASE III Future Projects - Space Station Freedom

Long Duration Space Environment exposure (LDSE)

The LDSE proposal utilizes portions of the space station as an orbiting platform for long term space materials exposure. This payload is scheduled as part of the Space Station Freedom and will support long term materials exposure for several decades beginning in 1996. The payload will incorporate several exposure surfaces capable of supporting numerous materials samples in locations which will render maximum exposure to targeted LEO environments. This flight project will require frequent on-site servicing by the Space Transportation System(STS) to start six months after the placement of the first fixture and once every six months thereafter.

Space Materials Evaluation Facility (SMEF)

The SMEF proposal will be a working part of the Space Station in the year 2000. The facility is dedicated to the processing, preparation and on-site materials analysis of space environment exposed materials. SMEF will have the capacity to monitor materials environmental control measures, perform materials properties experiments on microgravity processed materials and conduct failure analyses in support of Space Station servicing requirements. Housed in a SpaceHab Space Station Support Module, SMEF is planned as a full service, lightweight and compact materials science laboratory. The evolution of Space Station clearly supports establishing this service oriented development effort.

Future Projects - Space Exploration

Lunar Surface Candidate materials Exposure (LSCE)

This flight project includes the placement of an active materials exposure fixture on the lunar surface and the return of a structurally complex element of a previous lunar mission in the year 2010. The planned active materials exposure fixture will telecommunicate materials stability data to the SMEF or Earth.

Deep Space Candidate materials Exposure (DSCE)

This DSCE project will be required to support the future humanization of space by 1996. This flight test project is planned to evolve as flights of opportunity. The flight materials instrumentation package involved with this project will monitor and report materials stability in unknown environments.

Summary

Current flight payloads identified in Phase I and Phase II of the Space Flight Program are summarized in Figure 6. The graph indicates available space on appropriate exposure experiments. The Center actively seeks co-sponsorship proposals from firms or agencies actively participating in "leading edge" materials technologies. Through this mechanism, the concept of "commercial" participation expands.

Advanced space structural materials require exposure testing in the space environment. The NASA-CCDS — Materials for Space Structures at Case Western Reserve University has identified this necessity and has proposed a Space Flight Program to affect a gradual, ordered, cost-effective way for Industry, Academia and Government to access space for materials evaluation. Low-cost participation in the space environment will commercialize the endeavor and allow a cost-effective way for Industry, Academia and Government to access space for materials evaluation. The Space Flight Program will aid the commercial transition from the decade of the 1990's into the 21st Century.

Early Phase Schedule

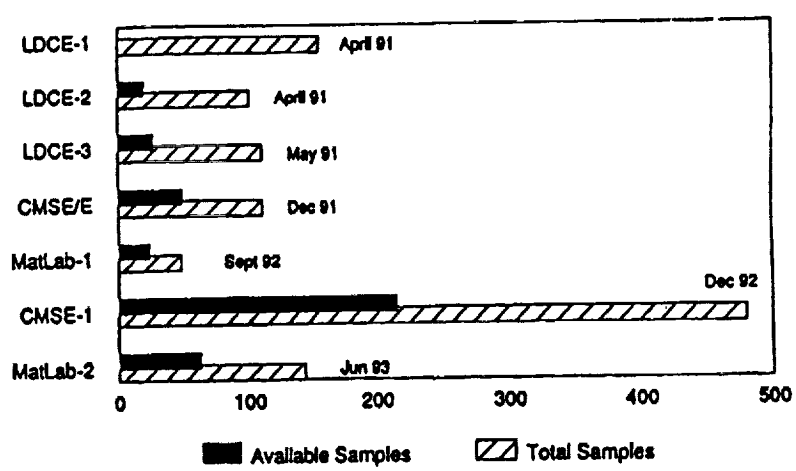

Figure 6

Information as of June 1, 1990

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4. Stepp, Robert, Customer Support Manager-Hitchhiker Project, Goddard Space Flight Center, 1989.

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