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## ABSTRACT

The Long Duration Exposure Facility (LDEF) will provide unique, needed, and affordable opportunities for large numbers of researchers in diverse fields to work in space, and, it is expected that LDEF experimenters will identify new ways to make space work for man.

The LDEF is essentially a free-flying cylindrical rack which is transported to and from space via the shuttle and on which many experiments, each contained in standard trays, are mounted.

This paper focuses on the types of experiments planned for the first LDEF mission to illustrate the benefits from the LDEF/shuttle activity. The paper also briefly describes the LDEF and its mode of operation.

## INTRODUCTION

The new dimension brought to space research by the shuttle is dramatically illustrated when the gleaming black and white craft lands and rolls to a stop. The shuttle can transport with ease payloads not only to space but from space and the LDEF has been tailored to utilize this capability.

Specifically, the LDEF has been designed to provide on each mission a large number of economical opportunities for science and technology experiments which require modest electrical power and data processing while in space and which benefit from postflight laboratory investigations with the retrieved experiment hardware. In fact, many of the experiments developed for the first LDEF/STS mission are completely passive, depending entirely on postflight laboratory investigations for the experiment results.

The LDEF, like the shuttle, is reusable and repeat missions are planned--each with a new complement of experiments. The first LDEF mission is currently scheduled for early 1984 and subsequent missions are envisioned, possibly every 18 months.

## DESCRIPTION OF LDEF

The LDEF, shown in figure 1, is composed of a simple structure, a viscous magnetic damper system, and an experiment initiate system. The 8000-pound facility is approximately 14 feet in diameter, 30 feet in length and can accommodate 86 trays with experiment hardware around the periphery and on each end. The 86 trays and experiment hardware can weigh up to 13,000 pounds. The facility provides no central power or data handling. The experiments are totally self contained in their tray or trays.

The LDEF is delivered to orbit by the shuttle. On orbit, the shuttle remote manipulator system (RMS) removes the LDEF from the shuttle payload bay and places it in the gravity-gradient stabilized attitude (cylindrical axis Earth pointing). After a time in orbit which is set by experiment requirements, the LDEF is retrieved on a subsequent shuttle flight. The shuttle RMS is again used during the retrieval to capture the LDEF and return it to the payload bay.

The only active LDEF system is a simple battery powered electronic system which provides a start signal to experiments when the LDEF is deployed and a stop signal when the LDEF is captured for retrieval.

Standard trays (figure 3), an experiment power and data system (EPDS), and an experiment exposure control canister (EECC) have been developed and are obtainable for experiments. Typical trays for mounting hardware to the periphery of the facility are 34 inches wide by 50 inches long. Trays for mounting hardware on the end frames are smaller (34 inches square). The depth of the trays vary as required by experiments. The EPDS can be hardwire programmed by the user to sequence his experiment and to process and store data. Power is provided by lithium batteries. The EECC, developed to provide controlled exposure periods for experiment hardware during the mission, is basically a sealable drawer which is opened and closed at preset times by a worm drive.

The LDEF operation illustrated in figure 2 focuses on experimenters in the user community who conceive, build, and mount their respective experiments in the LDEF trays. To reduce cost, the experimenter is free to establish the reliability, quality control, and testing necessary to ensure the proper operation of his experiment. The LDEF Project is primarily concerned with the safety of flying the experiment and ensuring that it does not adversely effect other experiments.

After experimenters fabricate their experiments, the trays are shipped to the Kennedy Space Center (KSC) for integration on LDEF and the shuttle launch. After the LDEF is returned from space, the experiment trays are removed and shipped to the respective experimenters for postflight inspection and analysis.

The ability to perform postflight laboratory measurements, in addition to substantially reducing experiment complexity and cost, increases the data return from most experiments.

FIRST-MISSION EXPERIMENTS

Forty seven science and technology experiments are being developed for the first LDEF mission. These experiments involve several hundred investigators from 11 U. S. Government laboratories, 10 private industries, 10 universities, and 8 countries. Eight of these experiments are described in the following sections to illustrate the range of the 47 investigations and the scope of the expected results. Four of the eight involve scientific studies of interstellar gas, micrometeoroids, cosmic rays, and crystal growth in zero gravity and four involve technology studies of the space environmental effects on solar cells, composite materials, thermal coatings, fiber optics, and electronic instruments.

Interstellar Gas Experiment. This experiment will collect and isotopically analyze interstellar gas atoms to better understand nucleosynthesis and the dynamics of the interstellar wind inside the heliosphere and the isotopic composition of the interstellar medium outside the heliosphere. The experiment is being developed by the NASA Johnson Space Center and the University of Bern.

The observed regularities in the abundance of elements and their isotopes upon which the theories of the early nuclear processes in our galaxy rests have been observed primarily from measurements of material in our solar system (meteorites, the Earth, and the sun and solar wind). This sample, however, represents only a tiny fraction of the material of the universe and even a small sample of extra-solar-system material will give a significant new insight into the various nuclear processes which have occurred and are ongoing in our galaxy.

The experiment will collect in metal foils interstellar gas atoms at several locations around the Earth's orbit. The hardware, mounted in four trays, acts as a set of simple "cameras" with high-purity copper beryllium-collecting foils serving as the "film." The hardware mounts and thermally controls the foils, establishes the viewing angles and viewing directions, provides baffling to reject ambient neutral particles, provides a voltage grid to reject ionospheric-charged particles, sequences and controls foil exposure times, and protects the foils from contamination during the deployment and retrieval of the LDEF.

Once returned to Earth the entrapped atoms will be analyzed by mass spectroscopy to determine the relative abundance of the different isotopes of the noble gases Helium and Neon. An attempt will also be made to detect Argon.

The Chemistry of Micrometeoroids. This experiment, developed jointly by the NASA Johnson Space Center, Washington University, Max Plank Institute, and the Technical University of Munich, will obtain a chemical and isotopic analysis of a statistically significant number of micrometeoroids. Micrometeoroids having masses as low as $10^{-16}$ grams are largely excluded from models of the early solar system evolution because their composition is unknown. Their orbital parameters and total flux are, however, somewhat established and the majority are believed to be derived from comets. Because of their probable cometary origin, micrometeoroids may offer a unique opportunity to study early solar system processes that occurred at large distances from the sun ($\gtrsim$20AU) reflecting pressure and temperature conditions in the solar nebula and offering insight into the formation of comets themselves.

This experiment will collect micrometeoroid residue in and around impact craters. The residue will be analyzed via a large array of state of the art, microanalytical tools after retrieval of the targets. Two collector target configurations are mounted in three LDEF trays. High-purity gold sheets will serve as targets in one configuration. These gold targets are contained in a clamshell housing which will be closed during launch and retrieval to protect the target surfaces from contamination. The second collection target configuration consists of high purity germanium targets with very thin metallized plastic foils stretched above them. The foils are expected to trap micrometeoroidic material that is ejected from the crater during the impact process.

A High Resolution Study of the Ultra-Heavy Cosmic Ray Nuclei. Cosmic rays constitute a unique sample of material from distant parts of our galaxy that still bear the imprint of the source region and they can provide a great deal of information about the evolution of matter in the Universe and the solar system.

The main objective of this experiment by the Dublin Institute for Advanced Studies and the European Space Agency/ESTEC is to study the charge spectra of ultra-heavy cosmic ray nuclei from Zinc (Z = 30) to Uranium (Z = 92) and beyond and specifically the relative abundances in the region $Z \geq 65$, which is thought to be dominated by r-process nucleosynthesis. Other objectives include the study of the cosmic ray transition spectrum and a search for postulated long-lived super-heavy nuclei ($Z \geq 110$). The predicted half-lives for super-heavy nuclei are short compared to the age of the Earth but long compared to the age of cosmic rays and the detection of such nuclei can have far-reaching consequences for nuclear structure theory.

The experiment uses thin polymer sheets to detect impacting cosmic rays. These sheets are chemically etched after recovery from space to reveal tracks which indicate the passage, the charge, the velocity, and the atomic number of encountered cosmic rays.

The detector sheets with sheets of lead which serve as energy degraders are stacked and mounted in pressurized aluminum cylinders. Three cylinders are in each of 16 trays for the first mission.

Growth of Crystals from Solution in Low Gravity. The primary objective of this experiment, which is being jointly developed by Rockwell International Science Center and the Technical University of Denmark, is to develop a new method for growing single crystals of PbS, $CaCO_3$, TTF-TCNQ, and TSF-TCNQ in low gravity. PbS is a semi-conductor and $CaCO_3$ has useful optical properties and both have many applications if they can be synthesized as large, highly-perfect single crystals. The TTF-TCNQ and TSF-TCNQ crystals have one-dimensional electrical conductivity which is strongly dependent on crystal perfection.

Crystals grown in low gravity are expected to be larger and more perfect, and, this experiment is expected to yield crystals which are superior to any heretofore obtained. The crystals produced will be studied after recovery to establish their physical properties and to investigate future applications. A second objective of the experiment is to better understand mechanisms of crystal growth.

The experiment utilizes specially-designed reactors having three or more compartments separated by valves which keep the reactant solutions and solvent separated until in orbit. After stabilizing in space, the valves open to initiate the diffusion and growth processes. An array of reactors are mounted in one 12-inch deep tray on the Earth-facing end of the LDEF. The reactors will be regulated to a constant temperature ($\sim 35^{\circ}C$). This type of crystal growth requires a low-g level ($<10^{-4}g$) for weeks or months and the LDEF flights are the only space flights planned which can satisfy this requirement.

Advanced Photovoltaic Experiment. This experiment is being developed by the NASA Lewis Research Center with 15 other organizations participating and supplying test samples. The experiment involves three specific investigations, namely: (1) to provide information on the performance and endurance of advanced and conventional solar cells; (2) to improve reference standards for laboratory photovoltaic measurements; and (3) to measure the energy distribution in the solar spectrum.

The experiment approaches for the three investigations are as follows:

(1) To expose advanced and conventional solar cells in the space environment and periodically to measure their power output.

(2) Various reference cells including some previously measured on balloon, aircraft, or rocket flights will be measured before flight and throughout the flight to determine their outputs. Upon return, these cells with known output in space will serve as laboratory standards for accurate determination of space output from other cells and arrays. The flight of previously-calibrated cells will permit verification of the accuracy of the various calibration techniques.

(3) A series of optical bandpass filters coupled to solar cell detectors will be used to determine the energy in sixteen spectral regions between 0.3 and 1.1 micrometers. The total energy in the spectrum above 0.5 micrometers and below 0.5 micrometers will be measured using a dichroic $45^{\circ}$ mirror. These measurements will be used to assess the accuracy of laboratory instruments such as the filter wheel solar simulator. Finally, the total energy in the solar spectrum will be determined with an absolute radiometer detector.

The experiment will occupy a 12-inch deep peripheral tray and use a standard EPDS for data recording and power. Data will be recorded once each day when a maximum sun angle less than $20^{\circ}$ is reached (as determined by a two-axis sun angle sensor which detects the maximum cosine angle for the data period).

The Effect of Space Environment Exposure on the Properties of Polymer-Matrix Composite Materials. This University of Toronto experiment will determine the effect of space exposure on the mechanical properties of selected commercial polymer-matrix composite materials which include graphite, boron, S-glass and PRD-49. The mechanical properties to be investigated are orthotropic coefficients of thermal expansion, impact resistance, crack propagation, and fracture toughness. In addition, the effect of laminate thickness on property changes will also be investigated.

The use of polymer-matrix composites in spacecraft is increasing and yet the long-term exposure effects on the mechanical properties of these materials in space are not known. Although laboratory simulations using thermal-vacuum chambers have been employed, the correlation between these results and actual in-situ space behavior has not been established.

The experiment approach is as follows:

(1) Manufacture five groups of test articles comprised of laminated cylindrical tubes and flat plates from a given batch of material.

(2) One group from each material will be evaluated under ambient laboratory conditions to determine the orthotropic elastic constants, the cubic polynomial-failure parameters, the impact resistance, the crack propagation and fracture touchness, and the coefficients of thermal expansion.

(3) Repeat (2) with second group of specimens subjected to thermal-vacuum exposure in a laboratory facility, including the effects of ultraviolet and electron-beam radiation.

(4) Repeat (2) with third group of specimens subjected to actual space environment onboard the LDEF.

(5) Repeat (2) using two "control batches" to assess effects of storage environment, qualifying tests and aging on LDEF flight articles.

The experiment, will occupy one-half of a 3-inch deep peripheral tray and is divided into three sections. Each section will consist of a layered arrangement of both tubular and flat specimens. Aluminum end fittings, which function as test fixtures following space exposure, are bonded to each of the test specimens.

Thermal Control Surfaces Experiment. This NASA Marshall Space Flight Center experiment will determine the effects of the near-Earth space environment on spacecraft thermal control surfaces. No optical measurements of thermal control surfaces have been made in space. Temperature measurements of thermally isolated samples have been made and used to calculate solar absorptance and thermal emittance. Spectral reflectance measurements of samples in space are, however, required to establish environmental effects and to identify damage mechanisms.

The experiment will measure in flight the hemispherical reflectance as a function of wavelength and the temperature as a function of time of samples which are mounted in a calorimeter. In addition, the experiment will expose 24 passive samples in the same environment for postflight laboratory measurements.

The samples for in-flight measurements are mounted on a carousel which will rotate the samples under a protective cover for launch and retrieval. The carousel will also rotate the specimen approximately 20 times during the mission under appropriate instruments for spectral measurements. The experiment has radiometers to measure the radiant energy impinging on the samples.

Fiber Optic Data Transmission Experiment. The objectives of this Jet Propulsion Laboratory experiment are: (1) to qualify design approaches for selected components for spacecraft fiber-optic transmission links, and (2) to evaluate the effects of the space radiation environment in terms of both permanent degradation and transient (noise) effects.

Fiber links are inherently insensitive to electromagnetic interference; fibers are roughly two orders of magnitude smaller and lighter than their copper wire equivalent; and, it is anticipated that a fiber link will become cheaper than copper. The same fiber components, once installed, can handle a wide range of signal bandwidths from telephone rates up to tens of megabits. Early verification of fiber-optic technology in space, as will be done with this experiment, will have broad interest.

The experiment will test four fiber links by transmitting a sequence of bits and measuring both the type and quantity of errors in the received data. The operation will be repeated once each 48 hours. The experiment is mounted in a 6-inch deep peripheral tray. A controller, the heart of the system, switches power on and off, selects the fiber links to be tested, generates the test data stream to be sent down each link, and, checks the returning data stream for errors which if detected are accumulated and read out to an EPDS tape recorder. The test circuits which interface the controller with each fiber link consist of an LED transmitting device and photodiode detector and preamp package. The experiment also will expose four fibers which are not connected to electronic measurement circuitry. These fibers will be subjected to postflight measurement to establish the induced attenuation integrated over the flight duration.

Passive Exposure of Earth Radiation Budget (ERB) Experiment Components. This experiment, being developed by The Eppley Laboratory, Inc., will expose ERB components to the space environment they must operate in and, with subsequent retrieval and postexposure recalibration, establish the effects of the exposure. ERB instruments require accuracies in solar and Earth-flux radiation measurements in the order of fractional percentages. In order to assure that these instruments are indeed measuring real variation and not responding to changes induced by the space environment, it is critical that they be subjected to calibrations after space exposure.

This experiment will expose three ERB Earth-flux radiometers in one-fourth of a 3-inch tray on the Earth end of LDEF and one solar-flux radiometer in one-sixth of a 3-inch peripheral tray. Prior to the flight and after retrieval these radiometers will undergo complete radiometric and spectrophotometric examinations and calibrations. Specific components within the radiometers which may be adversely effected by exposure in space and which will be examined in detail include thermopiles, cavity elements, filters, and windows.

## CONCLUSIONS

With the number and diversity of experiments to fly on the first LDEF mission it is difficult to summarize the expected benefits. The interstellar gas, micrometeoroid, and cosmic ray experiments described illustrate scientific experiments that can be performed on LDEF to obtain a better understanding of the origin and evolution of the universe, our solar system, and the Earth. They contribute to the satisfaction of man's basic curiosity about his surroundings, and if we recall that many phenomena, nuclear reactions for example, were first discovered through astronautical observations, we can recognize that these basic science experiments may also benefit man in more tangible ways.

The crystal growth experiment described is an example of a more applied science LDEF experiment. Superior crystals may result allowing a better understanding of their unique properties and possible applications in new devices. The study of these crystals may also contribute, through a better understanding of crystal growth, to the discovery of ways to manufacture them on Earth.

The technology experiments described are critical elements in broader research programs to develop enabling technology for future space missions. They are experiments that, prior to shuttle and LDEF, could not for economic reasons be performed in space. The basic benefits expected from flying these technology experiments relate to three factors. First, with flight data the risk of using a new technology in space is greatly reduced; second, with flight data a new technology will be used sooner; and third some new technology can only be developed in space.

The low-cost feature of LDEF permits more high risk but also potentially high return exploratory experiments to be flown. The low-cost LDEF experiments also lend themselves to student involvement. Both are critical factors in learning to fully exploit space with the new shuttle transportation capability. One must also keep in mind when evaluating the benefits that might result from an experiment that in many instances the discovery of an unexpected and possibly now inconceivable result will become the most significant benefit.

If interested in more information regarding LDEF, please contact the author:

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Figure 1.- Long Duration Exposure Facility on Ground Transporter

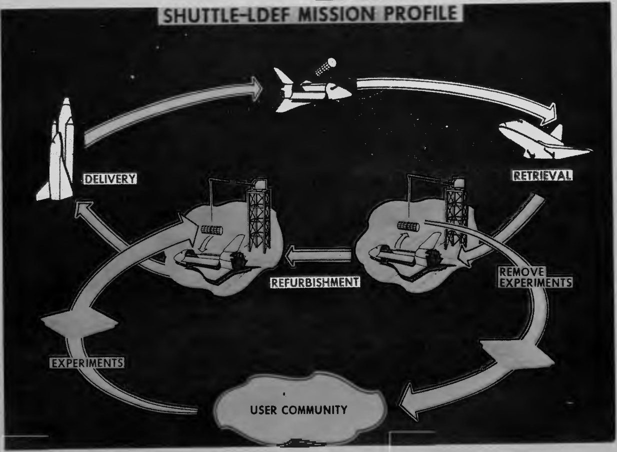


Figure 2.- Long Duration Exposure Facility Mission Profile