LDEF ARCHIVAL SYSTEM PLAN

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INTRODUCTION

The Long Duration Exposure Facility (LDEF) has provided the first significant opportunity to extensively study the space environment and its effects upon spacecraft systems and materials. The long-term value of the data obtained from LDEF, which is applicable to a wide range of areas including space environment definition, space environmental effects and spacecraft design, will depend upon the system developed to archive and retrieve the data. Therefore, in addition to the large effort undertaken to analyze LDEF data, a substantial effort is also necessary in order to retain and disseminate LDEF resources for future research and design. W. J. Schafer Associates, Inc., has a task subcontract to develop the LDEF archival system.

The LDEF resources include data, hardware, photographic records and publications which cover the 20-year history of LDEF from concept design through data analysis. Chronologically, pre-launch resources include documentation of facility and experiment development, testing, integration and operation. Post-retrieval resources are the observations, testing, analysis and publications since the January 1990 retrieval of LDEF. A third set of resources is the experiment and facility hardware and specimens, including more than 10,000 test specimens flown on LDEF and subsequently divided and distributed among investigators at numerous laboratories. Many valuable science and technology investigations have been undertaken with LDEF experiments and hardware, and many more investigations are being identified in areas not yet explored.

LDEF data applications encompass primarily low-Earth orbit spacecraft and structures. The nearly six-year space exposure of LDEF has provided data to evaluate materials, systems and living specimens exposed to radiation, meteoroids, debris and other constituents of the low-Earth environment. Structural, mechanical, electrical, optical and thermal systems were studied, and materials with applications in all aspects of space systems were exposed to the space environment.

The objectives of the LDEF archival system are to maintain the existing LDEF hardware, data, analysis, publications and photographs as a long term resource, and to provide a quick and simple mechanism by which LDEF resources can be identified, located and applied.

BACKGROUND

Other systems exist within NASA and in the broader areas of space and planetary sciences which have goals similar to those of the LDEF archives. In particular, the goals of these systems are to preserve and disseminate data in order to further space and planetary understanding. An evaluation of these systems is useful in developing the LDEF archival system, and in addition, cooperative efforts can benefit both existing and new data archival systems. In this section, some of these data systems are discussed.

NASA's National Space Science Data Center (NSSDC) was established 26 years ago as an active repository for space and Earth science data obtained through space and ground observations. The NSSDC is the primary archive for many NASA missions and it provides data to the broad research communities beyond the principal investigators in the fields of atmospheric, terrestrial and ocean sciences, astronomy, planetary sciences, astrophysics, and ionospheric, magnetospheric and solar-terrestrial physics.[1] The NSSDC is part of the Space Science Data Operations Office of the Space Sciences Directorate at the NASA Goddard Space Flight Center (GSFC).

In 1978, the NSSDC developed a centralized data base system for its holdings, and eventually it developed a Master Directory for computerized searching and identification. In recent years, however, the quantity and complexity of space and Earth science data has grown such that the NSSDC has moved toward a more decentralized organization consisting of independent archives at different locations, although still accessed through one master directory.

The NSSDC maintains both on-line and off-line data resources. The data center includes approximately 4,000 data sets from over 1,000 space flight experiments which flew on several hundred spacecraft.[1,2] Also included are rocket data, ground data and models. The NSSDC handles primarily reduced science data records and not engineering data. The data systems and centers accessible through the NSSDC include the Pilot Land Data System, the Crustal Dynamics Data Information System, the near Earth solar wind magnetic field and plasma data set, the Astronomical Data Center, the Planetary Data System and the Astrophysics Data System. The NSSDC is accessible electronically or through personal communication; the NSSDC manages the Space Physics Analysis Network (SPAN).

Another NASA system, EnviroNET, contains space environment tabular data, graphs, text and models which can be accessed in a user-friendly fashion. As described in another paper in this conference publication, EnviroNET is an on-line data base of technical information on space environmentally-induced interactions.[3] A pointer or node for EnviroNET is in the Master Directory of the NSSDC.

Another of NASA's programs which is concerned with large volumes of data is the Earth Observing System (EOS). The EOS program will include a number of archive centers, some of which will be closely related to the Global Change Data Center at the Goddard Space Flight Center. As the EOS program develops, it will necessitate significant attention toward science data handling and archival for efficient use.

NASA's lunar sample, Antarctic meteorite and cosmic dust collections are curated at the Johnson Space Center (JSC), and analysis results and detailed inventories are maintained there. Each collection has an associated detailed data base in order to locate and distribute information, and they are accessible via SPAN or INTERNET. These curatorial systems facilitate the acquisition, analysis and documentation of test specimens.

What does not appear within NASA's existing data systems is a comprehensive system to address the space environment and its effects upon spacecraft and their operation. NASA maintained a focused space environmental effects program only during the first decade of the Agency's history. This was the Environmental Factors Branch of the Space Vehicles Division of the Office of Advanced Research and Technology. Products of this program include many of the design criteria documents and the bases for natural meteoroid models used today. Due to budget restrictions and shorter-term priorities, the Environmental Factors Branch no longer existed beyond 1970. Over the past 20 years, NASA has given attention to the subject of the space environment and its effects through different programs, which has led to the current situation of separate efforts to study parts of the space environment without a cohesive strategy for the long term. Recently, however,

NASA Headquarters has shown growing interest in a coordinated space environmental effects program.

DEVELOPMENT APPROACH

The LDEF archives are being established with the view that they should evolve into a cohesive space environments and space environmental effects data system. Archives of related data from future space flight experiments, laboratory experiments, spacecraft development testing and analytical studies should be added to the LDEF archives to form the space environments and space environmental effects data system, a simple view of which is shown in Figure 1.

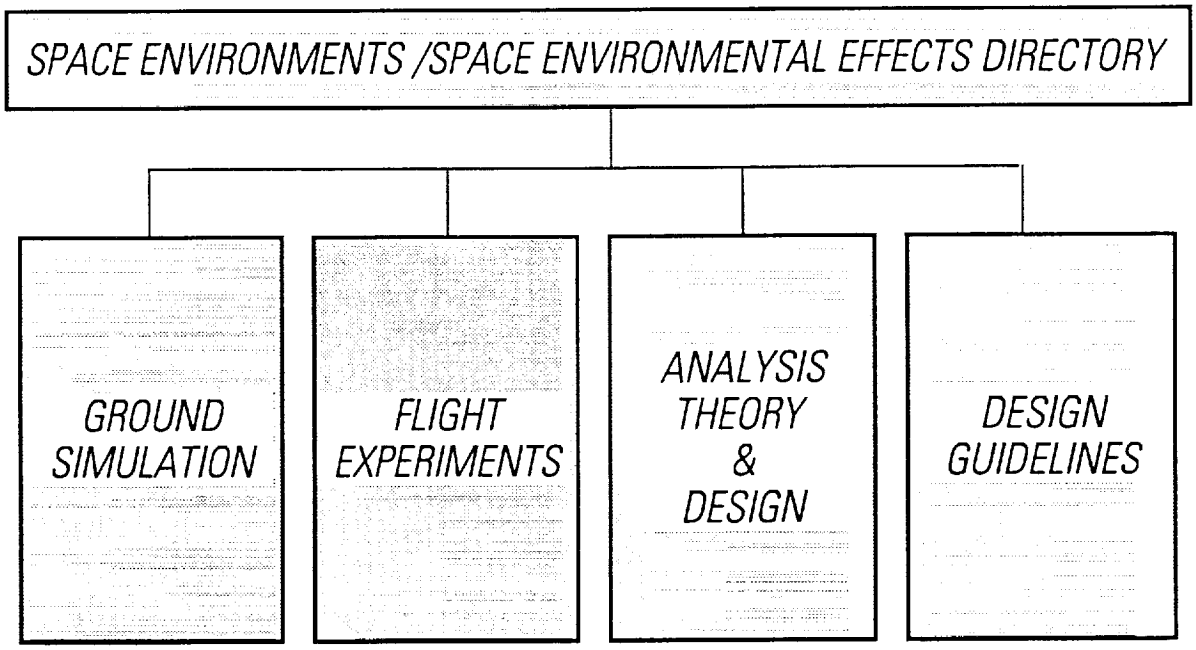

Figure 1. Space environments and space environmental effects data system.

The LDEF archives are meant to encompass the many aspects of the LDEF program which have occurred over the past 20 years. A chronological representation of these activities is shown in Figure 2. The design and fabrication of the LDEF structure occurred at Langley Research Center (LaRC) between 1974 and the launch of LDEF in 1984. During this same period, experiments were developed and fabricated at investigators' laboratories after their selection to fly on LDEF. Operations were coordinated between Langley Research Center, and Kennedy and Johnson Space Centers. By 1984, all facility and experiment elements of LDEF had been integrated and the facility was placed in orbit.

Following the retrieval of LDEF from orbit in 1990, the individual elements were again dispersed back to the principal investigators' laboratories, as well as to other laboratories that conducted special investigations. The facility structure was maintained at the Cape Canaveral Air Force Station (CCAFS) by Kennedy Space Center (KSC) personnel, and some facility elements were the subjects of special investigations at other laboratories. In July 1992, the facility structure was returned via barge to Langley Research Center.

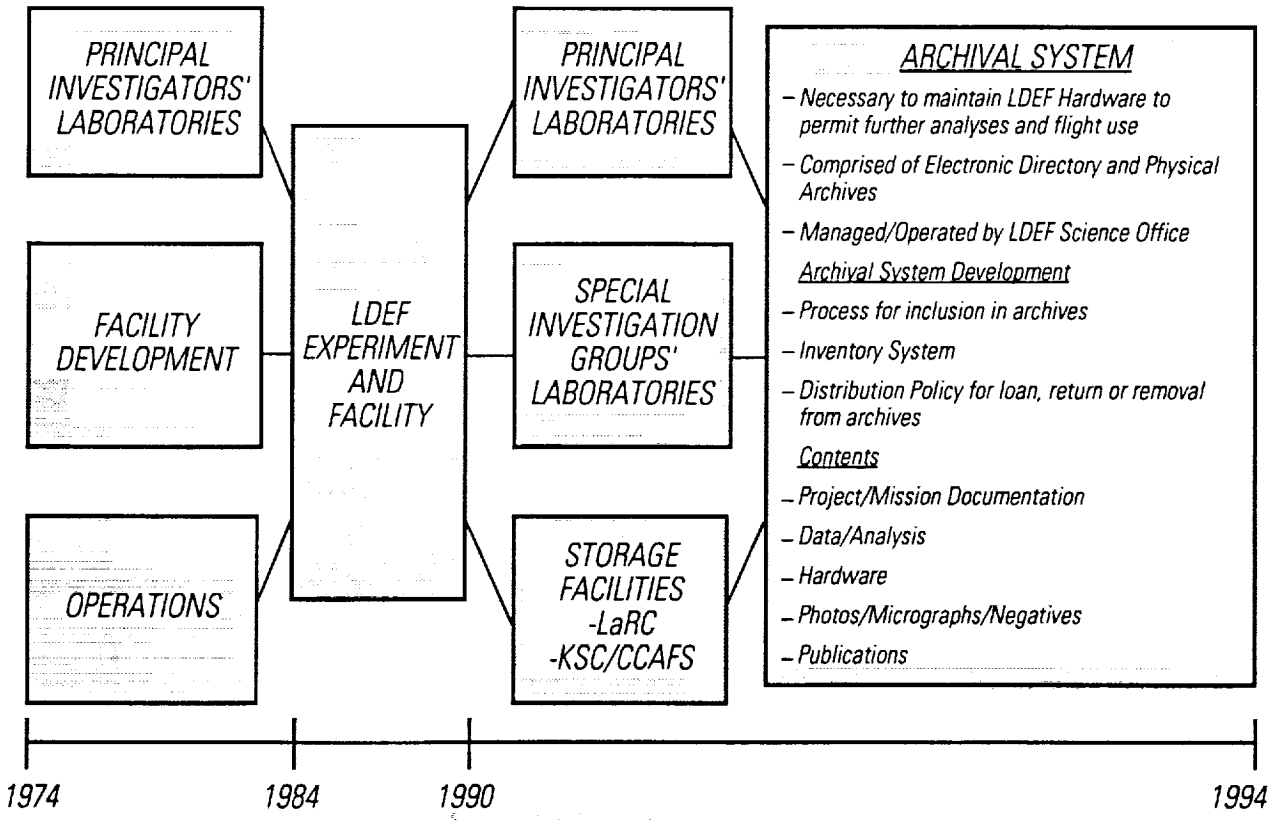

Figure 2. LDEF chronological development.

The first step in developing the LDEF data bases and archives has been the development of a number of data bases for the analysis and cataloging of LDEF data by individual organizations. Some of these individual data bases were created initially for internal purposes while others were designed for distribution to interested researchers. They have been created on different media including electronic disks, magnetic tapes, optical disks, photographs and paper journals. The principal goal of the LDEF archival effort is to develop a centrally-accessible archive system that contains these individual data bases, the large quantity of data that has not been placed in any data base, and the hardware, photographs and publications. Every effort will be made to not duplicate or homogenize what is in existence, but instead to develop a comprehensive system, link the existing parts together, provide access to these parts and identify missing portions. The LDEF archival system relies upon a directory for organization and access.

ARCHIVAL SYSTEM DESCRIPTION

The archival system contains the following elements, as shown in Figure 3:

I. LDEF ARCHIVE DIRECTORY
II. PROJECT / MISSION DOCUMENTATION ARCHIVE
III. DATA / ANALYSIS ARCHIVE
IV. HARDWARE ARCHIVE
V. PHOTOGRAPHS ARCHIVE
VI. PUBLICATIONS ARCHIVE

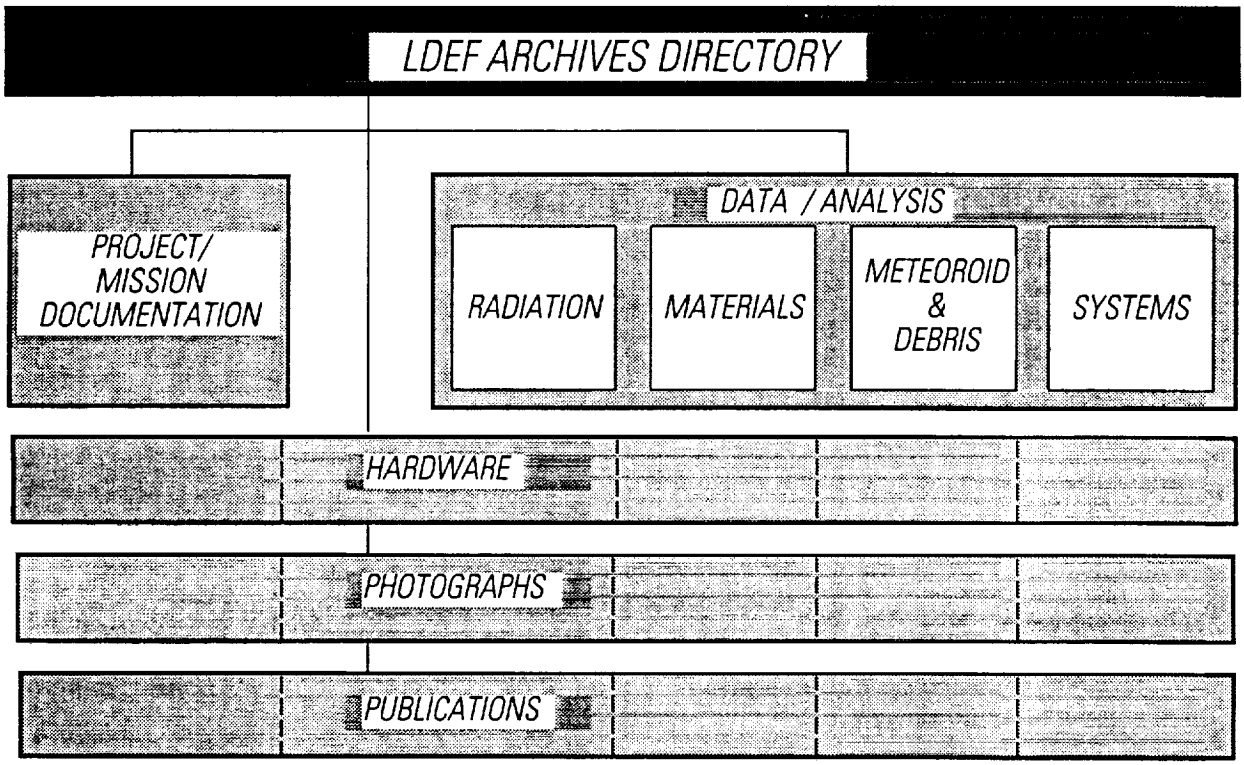

Figure 3. LDEF archival system.

The LDEF archives are categorized into five distinct archives. The project / mission documentation archive is organized chronologically. The data / analysis archive is categorical. The hardware and photographic archives are organized by location on the surface of LDEF and by experiment number. The publications will be kept alphabetically according to author. Two key identifiers, LDEF experiment number and bay / row location, will be associated with all items archived wherever applicable. These are the most commonly used references for LDEF information.

The materials to be placed in the archives are currently located throughout the LDEF community while research is being conducted. The project / mission documentation is primarily at Langley Research Center. The data / analysis archive contains many dispersed segments, and it is the most widely distributed body of information due to the participation of the large number of researchers. The hardware and test specimens are likewise widely held. A large collection of NASA photographs are being catalogued at Langley Research Center, while sizeable collections are maintained at other NASA centers and with principal investigators. A library of publications at Langley Research Center is being established, and a large collection of LDEF-related publications has been indexed. The remainder of this section describes the five archives within the LDEF archive system.

I. LDEF ARCHIVE DIRECTORY

This is an electronic directory intended to do a combination of the following: 1) identify if LDEF information is available on the subject of interest; 2) provide requested information directly; 3) identify additional databases, LDEF or other, that should be searched; 4) identify reports or data records; 5) identify related photographs; and, 6) refer to individual points of contact. It will contain the following elements:

A. Project / Mission Documentation Directory
B. Data / Analysis Directory
C. Hardware Directory
D. Photographs Directory
E. Publications Directory

The extent to which the directory either provides information directly or refers the user to other contacts or data bases for information will depend upon issues such as the current means of access for the data and the availability of other data bases. The driving factor behind the archive design is simplicity of data access.

The following are a few examples of what the directory is expected to do. The directory should identify the systems and materials which flew as parts of LDEF experiments, their locations, quantities and space environment exposures. It will also identify the purpose for the system or material, and whether it was part of the structure or part of an experiment. It is planned to summarize related research and results to date. For specific data, the directory is anticipated to refer the user to other existing data bases in the areas of interest. For instance, a user may be directed to the LDEF Materials Data Base on the Materials and Processes Technical Information System (MAPTIS) at the Marshall Space Flight Center for materials data, or to the LDEF Meteroid and Debris Data Base at the Johnson Space Center for specific information on crater locations, diameters, origins or chemistry.

II. PROJECT / MISSION DOCUMENTATION ARCHIVE

This chronological archive contains documentation generated over a period that has lasted 20 years to date. It includes drawings, technical plans, management plans, safety analysis records including flammability and hazard analysis, stress corrosion, electromagnetic interaction, and structural failures testing for static deflection and dynamic vibrational modes. This archive includes documentation on the Announcement of Opportunity process to acquire experiments and the memoranda between NASA and other organizations inside and outside of the U.S. It also will include the data recorded during flight operations involving Johnson and Kennedy Space Centers. It has the following elements:

A. General
B. Concept Development and Design Philosophy
C. Facility Design and Development
D. Acquisition and Project Tasks in Experiment Development
E. Experiment Development Organization Tasks
F. Experiment / LDEF Integration Engineering
G. LDEF / Space Transportation System (STS) Integration Engineering
H. Integration Operations
I. Launch
J. Sixty-Nine Months in Orbit
K. Retrieval
L. Post-Retrieval Deintegration Operations

III. DATA / ANALYSIS ARCHIVE

The data/analysis archive, the largest of the archives, is structured parallel to the four LDEF special investigation groups since data are currently being collected and maintained separately by these groups. This archive is intended to be the long-term location for the diverse data and models in the areas of ionizing radiation, meteoroid and debris, systems and materials currently kept by principal

investigators and special investigation groups. Each specific LDEF data set or model will be either contained or referenced in this archive.

In addition to the categorization of information according to special investigation group area, a subcategorization is that of space environment data and models, and space environmental effects data and models. The radiation and meteoroid and debris data reflect the environment as well as environmental effects, while the systems and materials data are focused upon environmental effects primarily.

Figure 4 is an simple illustration of the categorization of the data and analysis archive.

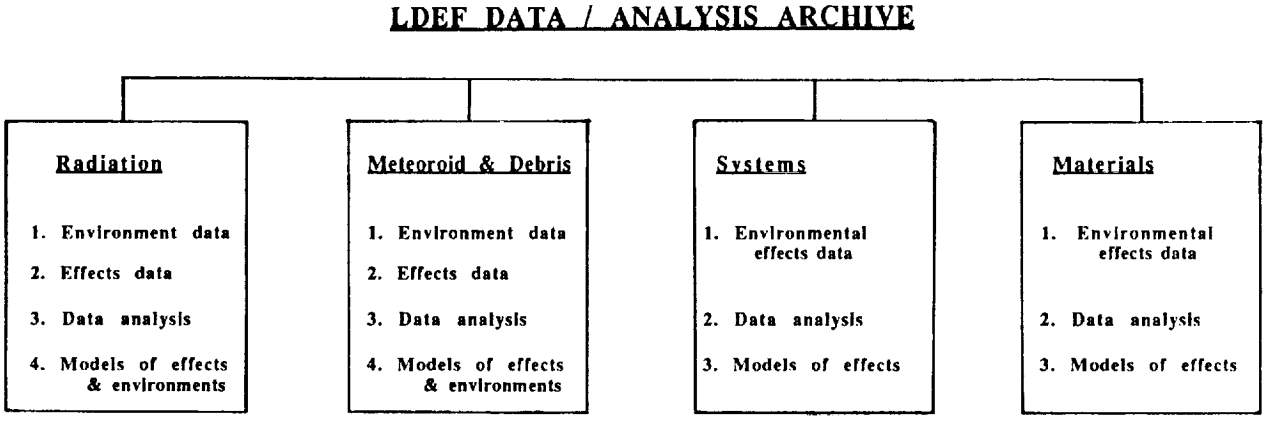

Figure 4. Data / analysis archive structure.

IV. HARDWARE ARCHIVE

A detailed and complete hardware archive has two primary benefits: it provides traceability of hardware pieces, and, it enables further research to be performed with the hardware. All experiment and facility hardware are organized according to bay / row coordinates mapped on the surface of LDEF, and additionally by location within tray. Experiment hardware and samples will also carry the associated experiment number. Subdivision of tray elements will employ the parent / daughter concept similar to some other NASA archival systems. For example, an assigned number of A02E01 would indicate bay A, row 2, experiment hardware item 01. A later specimen may have the number A02E04,1, to indicate that this is experiment hardware item 04, and that it came from a subdivision of hardware item 01. Drawings and experiment development documentation will be referenced, and the processing histories from deintegration through current location are being included.

An initial post-retrieval inventory of LDEF experiment and facility hardware has been developed by W. J. Schafer Associates based on information and documentation collected to date. Several inventory entries are shown in Figure 5. The approach used in the development of this hardware inventory system considered an individual experiment as one entity until its elements were divided and distributed, at which point the individual elements were tracked. Figure 5 details the shipment of a coating specimen mounting plate used in LDEF experiment S0010, Exposure of Spacecraft Coatings, by NASA Langley Research Center. In the nomenclature of this data base, 'Distribution 01,' the last common post-retrieval location for LDEF experiment and facility hardware was the Spacecraft Assembly and Encapsulation Facility II (SAEF-II) building at the NASA Kennedy

Space Center. Between February and May 1990, after the inspection, radiation and photographic surveys of LDEF in SAEF-II, the LDEF experiment trays and facility hardware were deintegrated and distributed. The S0010 coating specimen mounting plate was shipped via an air-ride van to Wayne Slemp, the experiment principal investigator, March 21, 1990. This is recorded as 'Distribution 02'. On April 7, 1990, this item was transferred to Don Humes, also at LaRC, for meteoroid and debris study. The item remains at this 'Distribution 03' location, LaRC building 1200, room 131. This data base system, created with the 4th Dimension program version 2.0 (© 1989 ACIUS, Inc.), is being used in constructing an all-inclusive inventory of LDEF hardware.

Experiment Number :	S0010
Hardware Item :	Coating specimen mounting plate
Item Division :	None

Distribution 0 2 From NASA Kennedy Space Center

Location :

NASA Langley Research Center

Contact:

Mr. Wayne S. Slemp
NASA Langley Research Center
36 Marvin Road
Mail Stop 183
Hampton VA 23665-5225 USA
Telephone : 804-864-1334
Telefax : 804-864-3800

Investigator : PI
Date : 3/21/90

Documentation / Comments
Air-ride van/climate controlled 70-72 degrees F.

Distribution 0 3 From NASA Langley Research Center

Location :

NASA Langley Research Center

Contact:

Mr. Donald H. Humes
NASA Langley Research Center
18 Ames Road
Mail Stop 493
Hampton VA 23665-5225 USA
Telephone : 804-864-1484
Telefax : 804-864-3800

Investigator : M&D
Date : 4/7/90

Documentation / Comments
Building 1200, Room 131. This is current location.

Figure 5. LDEF hardware archive entry.

V. PHOTOGRAPHS ARCHIVE

More than 20,000 individual photographs of LDEF, LDEF experiments, samples and research efforts are currently in the collections of LaRC, KSC, JSC, MSFC and principal investigators. These are being assembled by the LDEF Science Office in a central location and catalogued according to mission chronology, location on LDEF, and subject of interest. Individual photographic surveys were taken during the STS-32 retrieval flight, Edwards Air Force Base operations, and Kennedy Space Center operations including those at the Demating, Orbital Processing, Operations and Checkout Facilities and the Spacecraft Assembly and Encapsulation Facility II. The SAEF-II photographic records are extensive and cover the initial visual inspection period, deintegration of experiments, facility and systems, and the operations to place LDEF in storage. During deintegration, each experiment tray was the subject of a detailed photographic survey.

The LDEF archives will contain each photograph, a negative, a description of the photograph and documentation. The electronic directory will contain the photographic index, and it is intended to enable searches based on a broad set of interests, for instance, M&D craters, silver teflon, a specific polymer, or a crystal growth system. Figure 6 is an example of the photographic records currently being assembled by Lockheed Engineering and Science Corporation under contract to Langley Research Center.

from the **LDEF RETRIEVAL FLIGHT PHOTO SURVEY**

TRAY #	JSC negative # LaRC negative # Experiment # (s) and title abbreviation(s) Photograph details
TRAY B2	S32-78-16 L90-10,427 S0001: SPACE DEBRIS IMPACT Green/pink cast due to preflight anodization - appears in preflight condition
TRAY C2	S32-89-029 L90-10,498 AO015: BIOSTACK AO187: CHEMICAL & ISOTOPIC MEASUREMENTS OF MICROMETEOROIDS M0006: SPACE ENVIRONMENT EFFECTS Biostack canisters have light brown discoloration; AO187 thin foils ruptured and curled
TRAY D2	S32-89-031 L90-10,495 AO189: QUARTZ CRYSTAL OSCILLATORS AO172: SOLAR RADIATION ON GLASSES S0001: SPACE DEBRIS IMPACT Mounting plates for AO189 & AO172 have dark brown discoloration; S0001 appears in preflight condition - row 3 scuff plate appears discolored (darker) than preflight
TRAY E2	S32-89-018 L90-10,496 AO178: ULTRAHEAVY COSMIC RAY NUCLEI Silvered teflon thermal cover appears specular - cover taut and tiedown points evident
TRAY F2	S32-89-023 L90-10,497 P0004-1: SEEDS IN SPACE P0004-2: SPACE EXPOSED EXPERIMENT DEVELOPED FOR STUDENTS Silvered teflon thermal cover possibly shows evidence of diffuse area

Figure 6. Photographic archive records.

VI. PUBLICATIONS ARCHIVE

The LDEF archives will contain a copy of all LDEF-related publications available. These include publications from professional journals, NASA publications, other government publications, books and other sources. A publications library is growing through the identification and indexing of publications as they become available. The directory will catalog all publications according to author, experiment number and bay / row location, and searches will be possible based on areas of interest.

IMPLEMENTATION OF PLAN

The archival system is currently in the development stage. Project documentation archives are being organized. Data / analysis archives remain in the early development stage, although the special investigation groups have developed to varied extents their own archives of data and analysis. The directory for the retrieved hardware has been established and will continue to be expanded as hardware is circulated and subdivided. Retrieval and deintegration photograph archives have been established, and the contents are being indexed. The publications archive is also being assembled. A number of focused data bases and systems have been prepared through special investigation groups and principal investigators, and these will be either indexed or folded into the LDEF archives. The interaction and relation to existing data systems and data centers are being studied.

A number of these existing data bases were discussed at the LDEF Second Post-Retrieval Symposium, 2-7 June, 1992, and the written papers associated with these presentations are included in this Conference Publication. These presentations were on the materials data base activities, meteoroid and debris data bases, and principal investigator data bases. A session was held on materials data base activities, with presentations by the staff of the Materials and Processes Technical Information System (MAPTIS) on the LDEF Materials Data Base,[4] and by Boeing Aerospace and Defense Group researchers on a set of independent data bases on topics including optical experiments and thermal control materials developed for use on MacIntosh and IBM-compatible computers.[5] The Meteoroid and Debris special investigation group presented details of their data base, which includes five separate data tables with detailed crater data, allocation histories and other information, and it is accessible electronically via several networks.[6] The Aerospace Corporation has developed a data base of observations of LDEF experiment M0003, and this contains an extensive set of photographs and recorded observations made during the post-retrieval period.[7] Related topics discussed at the symposium included the development of handbooks on space environments and effects upon specific systems.

Individual principal investigators and special investigation groups have access to the hardware and samples in their possession until they no longer have use for them, at which time they should be returned to the LDEF Science Office. Acquisition of archived hardware elements will be handled through a review process to evaluate requests, to ensure that the maximum benefits are obtained from hardware and that the hardware are not consumed before all research opportunities are exhausted. For elements other than hardware, the LDEF archival system will meet any reasonable request for archived materials. The archive directory will be the main point of entry or contact for those seeking information on space environmental effects and LDEF.

For the archives to be utilized to the fullest extent, the space research community beyond the LDEF researchers should be made aware of the archives, their contents and applications and their accessibility. The LDEF Science Office plans to publicize its holdings to this broader community.

CONCLUDING REMARKS

The data obtained from LDEF analyses are a valuable resource, this value will be lost if not maintained for future access. Similarly, the hardware must be retained for future study and reference as part of the validation of the data obtained. Advancement of research depends upon the ease of accessibility of archived resources. Scientific conclusions are only of value if the facts upon which they are based can be traced and explained.

The LDEF archives are planned as an active and accessible library, and not a remote storage facility. The LDEF archives should be available to all who could use them. Efforts will be made to provide access to LDEF resources for educational and museum purposes when the investigators' science and technology research has been completed. As with all space flight hardware, the Smithsonian Institution has the right of first refusal if NASA decides to relinquish its possession.

The LDEF archival system is intended to form the basis of a comprehensive space environment and space environmental effects archive, and it is expected to be used by space environment and environmental effects researchers and spacecraft designers. Data from existing and future space flight experiments will be more effectively utilized with such an archival system in existence. This involves more than simple storage; it involves maintaining an active library with sufficient materials and resources.

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