United States General Accounting Office

GAO

Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives

March 1990

SPACE OPERATIONS

NASA Is Not Properly Safeguarding Valuable Data From Past Missions

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GAO

United States
General Accounting Office
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Information Management and
Technology Division

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March 2, 1990

The Honorable Robert A. Roe
Chairman, Committee on Science, Space,
and Technology
House of Representatives

Dear Mr. Chairman:

This report assesses how well NASA is managing, storing, and archiving space science data acquired from its past missions and identifies a number of problems and challenges that NASA faces in ensuring the integrity and utility of massive volumes of valuable scientific data. As agreed with your office, we will issue another report at a later date on whether a mechanism exists for obtaining input from the scientific community on what types of space science data should be preserved and archived.

As arranged with your office, unless you publicly release the contents of this report earlier, we plan no further distribution until 30 days after the date of this letter. At that time, we will send copies to other appropriate congressional committees; the Administrator, NASA; the Administrator, General Services Administration; the Archivist of the United States; and make copies available to other interested parties upon request.

This work was performed under the direction of Samuel W. Bowlin, Director for Defense and Security Information Systems, who can be reached on (202) 275-4649. Other major contributors are listed in appendix VII.

Sincerely yours,

Ralph V. Carlone

Ralph V. Carlone
Assistant Comptroller General

Executive Summary

Purpose

The National Aeronautics and Space Administration (NASA) is responsible for space exploration and the management, archiving, and dissemination of space science data. Since 1958, the agency has spent about $24 billion on its space science program and successfully launched over 260 scientific missions. Data from these missions have expanded our understanding of the earth, its solar system, and the universe. Through these past missions NASA has acquired a massive volume of data stored on an estimated 1 million reels of magnetic tape for immediate and long-term scientific use. The nation's long-term ability to monitor changes in the earth's environment, such as the depletion of ozone and the destruction of tropical rain forests, may depend on data from early missions.

Future missions are expected to produce additional volumes of data unparalleled in NASA's history. Two missions—the Earth Observing System and the Hubble Space Telescope—are expected to generate more data than NASA collected during the past 30 years, and will likely require the use of advanced data storage technologies.

Given the nation's investment in space exploration, the data's long-term value, and the need to safeguard this irreplaceable information, the House Committee on Science, Space and Technology asked GAO to assess how well NASA is protecting the tapes containing this information from loss and deterioration.

Background

Because many of the data from past missions are irreplaceable, they should be managed as a valuable national resource. NASA stores most of these data on magnetic tapes. Federal regulations, established by the National Archives and Records Administration (NARA) and the General Services Administration (GSA), require government agencies to follow specific regulations in the management, maintenance, and storage of magnetic tapes. These regulations were adopted to ensure the long-term preservation of data stored on magnetic tapes, the prompt disposal of unneeded tapes, and the efficient management of storage resources. NARA and GSA are responsible for periodic reviews of NASA's and other federal agencies' data management and archival activities.

Results in Brief

Currently, hundreds of thousands of tapes containing space science data are stored under deplorable conditions. Furthermore, NASA needs to improve its management of tape archiving and storage activities. It has not performed an agencywide inventory of its magnetic tapes and, consequently, does not know what data are retained, or may have been lost.

nor can it easily identify or retrieve tapes being stored in its centers or at universities. Further, NASA has not enforced federal regulations or developed its own standards for minimum acceptable storage, maintenance, security and quality control, and inventory practices.

NASA has several steps underway or planned to address certain aspects of the problems noted. However, without the allocation of adequate resources to improve the tape storage and archival facilities, the continuing deterioration of the magnetic tapes may result in the permanent loss of irreplaceable space science data. Moreover, unless it continues to improve its management of space science data, NASA will be hard-pressed to effectively and efficiently handle the massive volumes of data expected from its future missions.

Principal Findings

NASA Stores Many of Its Tapes Under Substandard Conditions

Eight of the 10 tape storage and processing facilities GAO visited did not comply with at least two of the applicable federal regulations established by NARA. Five of these facilities, which store almost 500,000 of the 1.2 million tapes identified by GAO, did not comply with more than half the combined federal regulations and industry tape management guidelines. These facilities did not have adequate temperature and humidity control, fire protection, water protection, or tape maintenance. In some instances, GAO found tapes stored in hallways, basements, and dusty warehouses not designed for tape storage. For example, in one major facility GAO found nearly 300,000 tapes packed in boxes covered by dust and stacked on shipping pallets.

A general lack of security also poses a serious threat to NASA's computer resources and space science data holdings. Some facilities GAO visited lacked even a rudimentary access control to guard against unauthorized entry into computer rooms and tape storage areas. Only one facility maintained backup tapes of original data so they could be restored if the originals were stolen or accidentally lost or destroyed. Consequently, without a secure environment, hundreds of thousands of magnetic tapes are susceptible to loss.

In contrast, a good storage environment is possible. Two facilities GAO visited complied with most of the applicable federal regulations and industry tape storage guidelines.

NASA Has Not Performed an Agencywide Inventory of Tape Holdings

NASA does not know how many space science data have been retained or archived on magnetic tapes since it began space exploration in 1958. At the facilities it visited, GAO identified almost 1.2 million NASA tapes, which were stored and managed by various NASA and contractor operated data processing or tape storage facilities, academic institutions, or other federal agencies. Although every facility GAO visited maintained an inventory of its tape holdings, these varied in completeness.

Data Archiving for Past Missions Was Treated as a Low Priority Activity

NASA has not provided adequate management leadership or funding for its past archival efforts. No one was assigned overall responsibility to ensure that these activities were effectively preserving space science data; instead, the data archiving responsibilities were diffused among NASA's headquarters, field centers, and space science mission officials.

NASA has not enforced federal tape management regulations, or developed or adopted agencywide standards for minimum acceptable tape storage conditions, routine tape cleaning and maintenance, security and quality control, and inventory practices. Furthermore, although NARA and GSA are responsible for conducting oversight reviews of NASA's tape management program to assess its effectiveness and identify areas needing improvements, neither of these agencies has done so. As reasons for not doing so, NARA cited a lack of resources, and GSA offered no explanation but said it plans to strengthen oversight activities.

According to NASA and Jet Propulsion Laboratory officials involved in archiving space science data, these activities were often underfunded. This assessment was echoed by the National Research Council's Committee for Data Management and Computation which recommended in 1986 that NASA establish a budget providing balanced support not only for spacecraft development and mission operations, but also to process, analyze, and archive the acquired space science data. The Committee also noted that the management and archiving of space science data are as important as mission operations, and recommended that NASA allocate additional resources to its long-term space science data handling and archiving activities.

NASA Has Several Improvement Efforts Underway

NASA recognizes that significant efforts will be required to correct the problems noted. Among the positive steps taken are limited tape restoration programs, establishment of a task force to reassess the management of data, and a census of data stored at several locations.

Recommendations

GAO is making a series of recommendations to the Administrator of NASA to help ensure that its valuable space science data from past missions are adequately stored, maintained, and preserved. These include recommendations that NASA (1) conduct a thorough inventory of data, (2) assess their scientific value, (3) copy valuable data and release unneeded tapes for reuse or disposal, and (4) archive the data in facilities that meet NARA regulations. Four additional recommendations focus on management improvements by (1) developing and implementing appropriate standards, (2) clearly defining management roles and responsibilities, (3) ensuring that periodic oversight is performed, and (4) allocating adequate resources to data management and archiving activities. Details on GAO's recommendations to NASA, as well as others made to GSA and NARA, are in chapter 4.

Agency Comments

In commenting on a draft of this report, NASA strongly believes it is safeguarding space science data as a national resource for future generations, but recognized there was room for improvement and said it was addressing GAO's recommendations in ongoing or planned programs. While NASA's limited inventory and tape restoration programs are discussed in the report, its plans for implementing GAO's other recommendations are still evolving, and as such, could not be evaluated.

NASA questioned the report's fairness, balance, and tone. GAO thinks the report fairly describes NASA's management of space science data holdings from past missions. Recognizing that NASA has several important improvement efforts underway, GAO nevertheless believes that the serious conditions under which hundreds of thousands of tapes from past missions are stored, combined with the low priority accorded this important activity, unquestionably substantiate the report's conclusions and recommendations. GAO believes that unless NASA addresses the serious tape management and storage problems noted, irreplaceable data will in fact be lost to future generations.

GSA said it had strengthened its management oversight function. NARA agreed that data management had a low priority in NASA and believed this was applicable to records management as well. An evaluation of the comments made by NASA, NARA, and GSA (see appendixes IV, V, and VI) is included in chapter 4.

Contents

Table

Figures

Abbreviations

CODMAC	Committee on Data Management and Computation
GAO	General Accounting Office
GSA	General Services Administration
IMTEC	Information Management and Technology Division
IRM	Information Resources Management
IRAS	Infrared Astronomical Satellite
JPL	Jet Propulsion Laboratory
NARA	National Archives and Records Administration
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NSSDC	National Space Science Data Center
TSSF	Tape Staging and Storage Facility

Introduction

Since 1958, the National Aeronautics and Space Administration (NASA) has spent over $24 billion on space science. NASA has launched over 260 major space science missions and acquired, processed, and distributed massive volumes of data. It has helped to expand and deepen our understanding of our planet, solar system, and the universe. The data from these missions now includes well over a million reels of magnetic computer tape representing a significant national resource needed for future research.

Under the National Aeronautics and Space Act of 1958, Congress made NASA responsible for space exploration research and directed it to provide for the widest practicable and appropriate dissemination of space exploration information. The Office of Space Science and Applications is assigned overall management responsibility for NASA's data, while the Office of Management provides agencywide oversight of information resources management activities. The National Archives and Records Administration (NARA) and the General Services Administration (GSA) are responsible for periodic reviews of NASA's and other federal agencies' activities in managing and archiving their data.

NASA's Space Science Data Are Stored on Magnetic Tapes

The majority of data from past NASA missions is stored on at least 1.2 million magnetic tapes which have the capacity to store over 90 billion pages of text.[1] Although the agency is already storing massive amounts of data, these amounts will be dwarfed by the expected stream of data from its future missions. For example, the chief scientist for the Earth Observing System estimates that the system, scheduled for launch in 1998, is expected to generate one terabit[2] of data each day for at least five years. According to the Library of Congress' Assistant Director for Research, given this volume of data, every 12 weeks the Earth Observing System spacecraft will generate a volume of data[3] equivalent to the text contained in all 15 million books held by the Library of Congress. NASA has made the National Space Science Data Center (NSSDC) its principal archival and data dissemination facility. NSSDC, located at the Goddard Space Flight Center (Goddard) in Greenbelt, Maryland, manages over 113,000 magnetic tapes. NASA also stores over a million tapes in a

[1]This estimate is based on the storage capacity of a standard 2,400 foot long tape, with data stored at 6,250 bits per inch.

[2]One terabit of data equals to 10^{12} bits (1,000,000,000,000 or 1 trillion bits). About 700 high density (6,250 bits per inch) tapes would be required to store 1 terabit of data.

[3]This estimate is based on assumption that an average book contains 300 pages of text, with 400 words per page and 6 characters per word.

variety of NASA or contractor-operated storage facilities. The Tape Staging and Storage Facility (TSSF), in Landover, Maryland, is the largest, with responsibility for storing and tracking over 860,000 tapes from missions managed by Goddard. An unknown volume of NASA tapes is also stored by individual scientists and research teams at major universities. NASA's tapes are aging, with a growing number at least 15 to 20 years old.

Magnetic Tapes Require Maintenance

In the last two decades, computer magnetic tape emerged as the prevalent mass storage medium used by industry and government for both intermediate and archival data storage. Magnetic tape is durable, portable, and relatively cheap but must be properly managed, maintained, and stored to prevent data losses. Federal regulations and guidelines require government agencies to follow specific standards in the management, maintenance, and storage of magnetic tapes. These standards were adopted to ensure the long-term preservation of valuable data stored on magnetic tapes and the efficient management of storage resources.

According to NARA, the International Council on Archives, and industry, a magnetic tape that has been properly stored and maintained may last about 10 years. General industry practices and proposed NARA regulations require that all tapes 10 years old be copied. Data deterioration or losses are mainly due to physical damage to tape caused by mishandling, contamination, and poor storage environment.

NASA's Space Science Data Are a Valuable National Resource

Because many of the data retain their scientific value indefinitely and are difficult and costly to acquire, the scientific community sees them as a significant national resource that must be safeguarded and preserved. Although there are numerous characteristics determining the long-term value of scientific data, scientists agree that in general these include data that:

- are unique and may not be replicated by future missions;
- may be related to or enhanced by data acquired by other past and future missions;
- may be needed to plan future missions;
- entail continuous, multiyear, global coverage and may be needed for studies of long-term environmental changes;
- were not fully analyzed;

- were processed using old computer technology and analytical techniques and should be reprocessed and reanalyzed; and
- are of significant historical interest.

An argument for the preservation of data was also made by the National Research Council's Committee on Data Management and Computation (CODMAC) which noted that:

"Many of the uses of the [space science] data cannot be foreseen in advance. Frequently, new ideas for uses of the data emerge long after the data are acquired, as a result of the continuously evolving understanding of the physical processes under study... Even though some of the acquired data may never be fully utilized, it is often not possible to decide in advance which data will be of critical value in gaining future new scientific understanding."[4]

The long-term value of data and the need to preserve selected data from earlier missions are underscored by the need to develop multiyear data bases which would allow scientists to measure and track global changes in earth's environment. For example, the recent effort to evaluate the extent and impact of the global depletion of atmospheric ozone, the destruction of the tropical rain forests, and the changes in global drought patterns may require developing and using data bases that include data from earlier earth observation missions.

Future Data Pose Significant Challenges

During the next two decades, NASA will face significant challenges managing and archiving its data. Between 1980 and 2000, NASA has or plans to support 84 missions in four scientific disciplines, including planetary and lunar, earth sciences, space physics, and astrophysics. These missions will produce a volume of data unparalleled in NASA's history. For example, two of the planned missions, the Earth Observing System and the Hubble Space Telescope are expected to generate amounts of data many times greater than NASA has collected over the past 30 years. NASA scientists who develop advanced science data management systems recently noted that:

[4]Issues and Recommendations Associated With Distributed Computation and Data Management Systems for the Space Sciences, Committee on Data Management and Computation, Space Science Board, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, National Academy Press, Washington, D.C., 1986, p. 104.

"... it is anticipated that the future ability of NASA to function and perform meaningful space and earth related research will be significantly affected by its inability to manage and use its collected information to derive knowledge."[5]

[5]The Development of a Prototype Intelligent User Interface Subsystem for NASA's Scientific Database Systems, NASA Technical Memorandum 87821, June 1987, p. 1.

NASA's Tape Management Practices Place Space Science Data at Risk

NASA has failed to properly store, maintain, and manage its magnetic tapes containing valuable and irreplaceable data. It has not performed an agencywide inventory of its magnetic tapes and does not maintain a central listing of its data holdings. Therefore, NASA neither knows how many data were retained or lost on magnetic tapes since 1958, nor can it easily identify or retrieve data being stored. Problems with NASA's data archiving activities are not new. Several problem areas needing attention were identified by us and others in 1977, 1982, and 1988. Although there could be more, our review identified about 1.2 million tapes stored at various NASA and contract data processing or storage facilities, academic institutions, and other federal agencies.

NASA has no tape management standards of its own, and has failed to properly store or manage its magnetic tapes in accordance with standards established by NARA, GSA, National Institute of Standards and Technology (NIST), and tape manufacturers' instructions. As a result, the valuable and often irreplaceable data acquired by NASA at a cost of billions of dollars, are being managed and stored under deplorable conditions. According to JPL officials, many of its older data stored on magnetic tapes are deteriorating because of aging, lack of maintenance, and poor storage conditions. They noted that almost all of NASA's data are at risk, including holdings at universities and NASA centers. Moreover, some important data may have been irretrievably lost. For example, we found several hundred thousand magnetic tapes packed in boxes stored on loading pallets, strapped with steel bands under substandard conditions, and without adequate environmental control or maintenance. Accordingly, much of the data may be deteriorating and at risk of being permanently damaged or lost.

NASA has taken several steps to address the deterioration of its magnetic tapes, including limited and costly restoration of older tapes and transfer of selected data from older tapes to optical disks. However, we believe that NASA could have avoided the relatively high restoration costs[1] through proper storage and maintenance.

[1] NSSDC officials estimated that the center has spent about $250,000 to restore 8,760 tapes, at an average cost of $28 per tape. Similarly, JPL restored 12,500 tapes at a cost of $495,000, or about $37 per tape.

NASA Has Not Performed an Agency-wide Inventory of Its Space Science Data Holdings

NASA's tapes containing space science data are stored in various NASA and contractor facilities located at or near NASA field centers, as well as at numerous other locations. In general, these data fall into two categories: (1) raw and intermediate data,[2] and (2) data designated by scientists and by NASA as a formal archival product.[3] Raw and intermediate data are stored in many places, including NASA, contract tape storage facilities, federal records centers, other federal agencies, universities, and research institutions. NSSDC is NASA's principal facility responsible for archiving and distributing archival data.

NASA has not performed an agencywide inventory to determine the amount, type, and location of data collected and retained on magnetic tapes since it began space exploration in 1958. Moreover, because it does not maintain a central listing of its tapes, many of the stored data cannot be easily identified or retrieved. However, every facility we visited maintained inventories and data directories of their own tape holdings which varied in quality and completeness. For example, NSSDC maintains an automated inventory and catalog of all its tapes, while TSSF maintains only a partial inventory, and JPL's inventory of 130,000 tapes stored at the Federal Records Center in Laguna Niguel consisted of a listing of stored boxes, without details of the contents. During the course of our review, NASA advised us that it recognized the need for a comprehensive, agencywide inventory of these data and is planning to conduct a census of its space science tapes. NASA is also developing a master directory designed to provide electronic access to data catalogs. These and other initiatives are discussed in more detail in chapter 3.

In the absence of an agencywide inventory or central listing of magnetic tapes containing space science data, we relied on other sources of information, including NASA documents and interviews with NASA and JPL[4] officials, to identify facilities managing and storing NASA's tapes. Based

[2]The intermediate data include the original data transmittedby the spacecraft, and certain processed data, including ancillary information such as instrument calibration and spacecraft position. NASA provides these data to the scientists for their analysis.

[3]NASA identifies two types of archival data — the analyzed data records and the reduced data records. The analyzed data records are ones which the scientist designates as the best to display the scientific results of an experiment. The data are usually calibrated and may include only selected observations. The reduced data records include data modified by the scientists to include corrections for temperature, voltage, spacecraft drift, and other factors. Both types of data are produced by scientists under contract to NASA to analyze data acquired by specific missions or instruments. After completion of data analysis, the scientists create data sets for NASA archives.

[4]The Jet Propulsion Laboratory is managing magnetic tapes containing space science data from planetary missions. Until late May 1989, the Laboratory was storing approximately 130,000 tapes at the Federal Records Center in Laguna Niguel, California. These tapes are now stored at JPL.

on this information, we identified the NASA facilities we believe to be managing the bulk of NASA's data. Specifically, over 1.2 million magnetic tapes are managed or stored at NSSDC, Goddard's TSSF, JPL, and at the federal records centers in Washington, D.C., and Laguna Niguel, California. Nearly 50,000 tapes were also stored by three university-based institutions and one federal data center. Although there could be more, these facilities collectively store or manage about 1.2 million NASA tapes. We visited every facility listed below:

Table 2.1: Selected Tape Processing and Storage Facilities Managing NASA Space Science Data

Facility	Location
National Space Science Data Center	Goddard, Greenbelt, Maryland
Tape Staging and Storage Facility	Landover, Maryland
Los Angeles Federal Records Center	Laguna Niguel, California
Washington National Records Center	Washington, D.C.
Smithsonian Astrophysical Observatory	Cambridge, Massachusetts
Multi-mission Image Processing	JPL, Pasadena, California
Data Protection Services	Dominguez Hills, California
Infrared Processing and Analysis Center	California Institute of Technology, Pasadena, California
Center for Astrophysics and Space Sciences	University of California, San Diego, La Jolla, California
EROS Data Center	Sioux Falls, South Dakota

The Federal Government and Industry Prescribe Tape Management Standards

Poor management of magnetic tapes may cause partial or total loss of recorded data. Although a modern magnetic tape is sturdy and may last for up to 10 years, and research and empirical evidence have shown that the magnetic signal may remain strong indefinitely, the tape itself will deteriorate unless properly maintained. (Appendix II discusses the characteristics of magnetic tapes.) Concerns in government and industry about the preservation of magnetic tapes led NARA, NIST,[5] the International Council on Archives, and the industry to develop comprehensive tape management standards. These standards fall into two groups: federal regulations established by NARA;[6] and NIST[7] and industry[8] guidelines.

[5]NIST conducts research and provides technical services designed to help federal agencies run their programs more cost effectively.

[6]Code of Federal Regulations, Title 36, Part 1234.

[7]Care and Handling of Computer Magnetic Media, NBS Special Publication 500-101, National Bureau of Standards, June 1983. (NBS is now called NIST.)

[8]We contacted eight manufacturers of magnetic tapes or peripherals, one tape management consulting firm, and the International Council on Archives, and obtained their tape management guidelines.

Together, they constitute a set of safeguards and practices that are designed to reduce the potential loss of valuable data stored on magnetic tapes.

According to NIST, losses of data stored on magnetic tapes stem from contamination and physical or chemical deterioration of tapes due to inadequate housekeeping techniques such as lack of cleanliness, inadequate temperature and humidity control, the absence of tape maintenance, and improper tape handling. Data stored on damaged, contaminated, or deteriorated tapes can sometimes be partially or fully recovered through costly restoration and recovery procedures. Some data are completely lost.

Because NASA had not adopted the federal regulations as agency policy or developed its own tape management guidelines, we developed a tape management checklist, based on federal regulations, and NIST and industry guidelines, to assess each facility's practice. (Appendix I has more information on how we performed this assessment.) Although these regulations and guidelines cover many aspects of tape management, they focus on crucial factors in preserving magnetic tapes:

Covered by Federal Regulations

- temperature and humidity control;
- proper preparation of archival tapes designed for long-term storage;
- backup and storage of tapes containing valuable data at another location;
- adequate security and internal controls to safeguard equipment, software, and tapes from theft, tampering, or destruction; and
- quality control to detect deterioration of stored tapes.

Covered by Federal and Industry Guidelines

- clean environment and handling to prevent tape contamination and damage;
- fire protection;
- water protection;
- tape drive maintenance to eliminate hardware-related tape damage;
- routine, scheduled tape maintenance program; and
- tape transportation safeguards.

Lack of Compliance With Federal and Industry Standards

Eight of the 10 tape storage and processing facilities we visited did not comply with at least 2 of the federal regulations established by NARA. Further, 5 of these facilities, which store almost 500,000 of the 1.2 million tapes identified, did not comply with more than half the combined federal regulations and industry tape management guidelines. These facilities failed to meet such criteria as adequate temperature and humidity control, fire protection, water protection, or tape maintenance. In some instances, we found tapes stored in hallways, basements, and dusty warehouses not designed for tape storage. More important, we found some of the most significant tape management deficiencies in the two largest facilities responsible for managing irreplaceable data — NSSDC and TSSF. A good storage environment is possible. Two facilities we visited—the U.S Geological Survey's EROS Data Center and the Digital Equipment Corporation's Data Protection Services—were in full or partial compliance with most applicable federal regulations and industry guidelines.

The following table lists individual regulations and guidelines and the level of compliance we found during our review.[9] In noting the compliance level, we assigned

- a full compliance rating where total compliance with all regulations or guidelines was observed or documented;
- a partial compliance rating where the facility did not comply with one or more regulations or guidelines;
- a non-compliance rating where compliance with none of the regulations or guidelines was observed or documented; and
- a non-applicable rating where the facility was not responsible for certain aspects of tape management such as quality control.

[9]Subsequent to our visits, several facilities implemented or plan to implement various corrective actions. These actions are discussed in appendix 3.

Figure 2.1: Compliance With NARA's and Industry Tape Management Standards

NARA Regulations	National Space Science Data Center	Smithsonian Astrophysical Observatory	Multi-mission Image Processing Laboratory	Infrared Processing and Analysis Center	Center for Astrophysics and Space Sciences	EROS Data Center	Data Protection Services	Tape Staging and Storage Facility	Federal Records Center, Laguna Niguel	Washington National Records Center
Temperature control	○	○	△	△	○	●	●	○	○	△
Humidity control	○	○	○	△	○	●	●	○	○	△
Test/certify media	○	○	○	○	○	○	NA	NA	NA	NA
Off-site backup	△	△	△	●	△	○	NA	NA	NA	NA
Security										
Computer room	○	○	△	○	○	●	NA	NA	NA	NA
Tape library	○	○	△	○	○	●	●	△	△	△
Sample 3% of tapes	○	○	○	○	○	△	NA	NA	NA	NA
NIST and Industry Guidelines										
Tape handling	△	○	△	○	△	●	●	○	NA	NA
Fire protection	△	○	△	△	△	●	●	△	△	△
Water protection	○	○	△	○	○	○	●	○	△	△
Hardware maintenance	●	△	●	●	△	●	NA	NA	NA	NA
Tape maintenance	○	△	○	○	△	△	NA	NA	NA	NA
Tape transportation	○	○	○	○	○	NA	△	○	○	○

● Full compliance
△ Partial compliance
○ Noncompliance
NA Not applicable

Most facility managers generally agreed with our findings, and in many instances are planning to correct the deficiencies. Asked to name what, in their opinion, caused these deficiencies, the managers listed: (1) lack of knowledge about NARA tape management regulations, (2) budgetary constraints and the high cost of complying with every regulation,

(3) storage space limitations, (4) desire to maintain easy access to data unhampered by stringent security and access control, and (5) a belief that the various deficiencies had not caused an actual loss of stored data. Appendix III presents their detailed responses to our findings.

The following section contains our summary assessment of how well the 10 facilities implemented procedures and safeguards related to the critical factors.

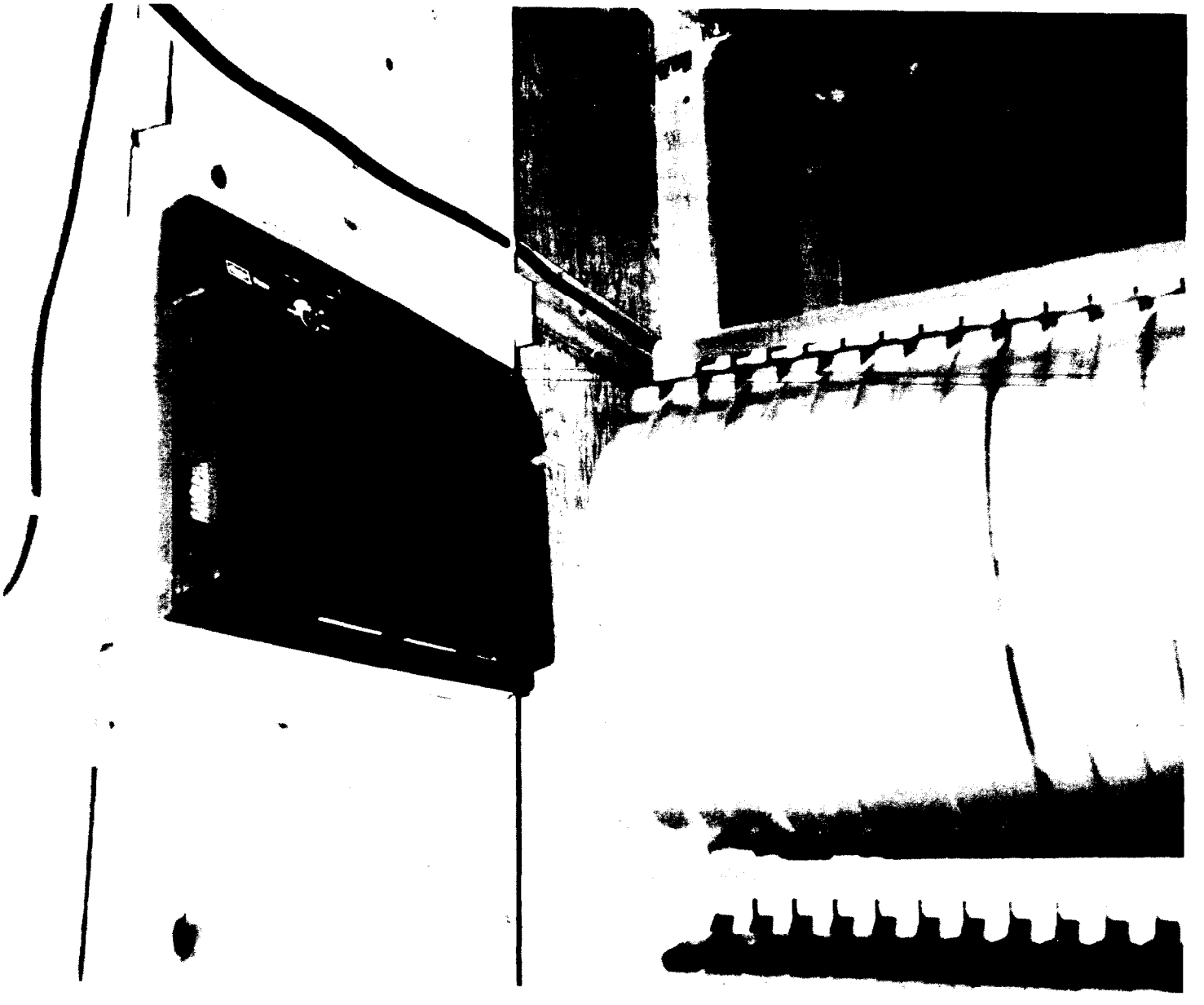
Temperature and Humidity Control

Only two facilities implemented adequate environmental controls. Eight facilities, including NSSDC, TSSF, and two federal records centers, either lacked temperature and humidity recorders, or stored tapes in areas where recorders were not calibrated.

To avoid environmental damage, NARA requires that the operating, storage, and test area in tape processing and storage facilities be kept at 60 to 72 degrees Fahrenheit and between 40 to 50 percent humidity. Extreme temperature and humidity levels or repeated temperature and humidity changes cause permanent tape damage and loss of data.

Figure 2.2 shows a wall-mounted air conditioning unit discharging refrigerated air directly on NASA tapes at one of the tape storage facilities we visited.

Figure 2.2: Tapes Stored Next to an Air Conditioning Unit



Preparation of Archival Tapes

None of the facilities we reviewed tested and certified all new tapes. NARA requires that all tapes designated for permanent retention should be tested and certified no more than 6 months before they are used for long-term storage. This regulation is designed to assure the long-term

preservation of the recorded data by removing contaminants and ensuring that the tape is free of manufacturing defects. Although most manufacturers test tapes before shipment, that does not guarantee a defect-free tape. According to the NIST, new tapes are sometimes contaminated with debris, and so, unless tested and certified, they will eventually become the source of errors when the data is written to or read from the tape.

Off-Site Backup of Original Tapes

Only one facility, the Infrared Processing and Analysis Center, which is responsible for managing data acquired by the Infrared Astronomical Satellite, provided for full backup of their original tapes.[10] NARA requires that a duplicate of tapes containing valuable data be stored at an off-site location. This regulation guarantees that a full set of tapes is available should the originals be destroyed through vandalism, earthquake, flood, or fire.

Other facilities provided on-site backup for some but not all their tapes. Managers said full backup was too expensive.

Security and Internal Controls

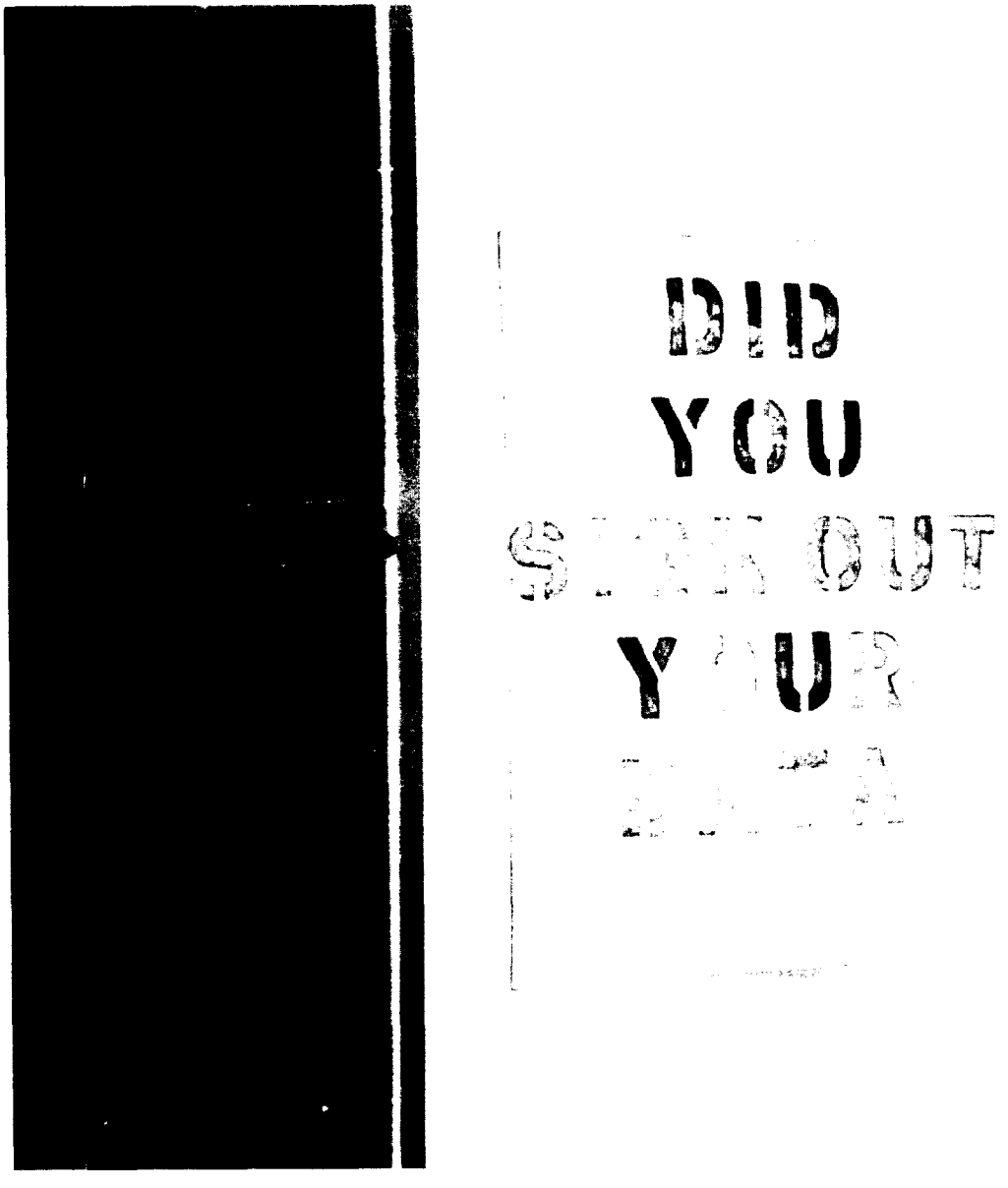
Four of the facilities did not control access to computer rooms and tape storage areas. Inadequate security and access control may result in theft, tampering, or destruction of computer equipment, software, and data.

The lack of security at NSSDC illustrates the need to secure valuable data. For example, during an unannounced computer security check, Goddard's security report noted "the doors wide open... picked up tapes, browsed through facility for several minutes.... no challenge ... wandered around freely."[11] The security officer noted that this was a follow-up visit, and that the facility "may never start to correct" the deficiency. Figure 2.3 illustrates the lack of security and tape management controls we found at one facility, where a posted sign requests that users "sign out" for all archival tapes removed from the often unattended and unsecured tape library.

[10]According to Center officials, the full set of Infrared Astronomical Satellite (IRAS) data—including raw data from the mission, intermediate data, and all archival data—is also stored overseas. In the Netherlands, the data are archived at the University of Groningen and Sterrewach Huygens Laboratorium at the University of Leiden. In the United Kingdom, the archive facility is the IRAS Post Mission Analysis Facility at Rutherford Appleton Laboratory. A full set of archival data is also stored by NSSDC.

[11]"Unannounced Computer Security Check", Goddard Space Flight Center, October 20, 1987.

Figure 2.3: Sign Reminding Staff to Sign-Out for Archival Tapes When the Tape Library Is Unattended



The lack of security endangers valuable data, computer equipment, and software. In most instances, the effort and cost to correct the most significant deficiencies are minimal, and may require only a modest expenditure for a card access lock for the computer room, or changes in facility operating procedures.

Quality Control

Only one of six facilities responsible for the monitoring of their tapes performed any quality control of stored tapes. NARA requires that each federal facility storing magnetic tapes annually sample 3 percent of all holdings to detect deterioration.

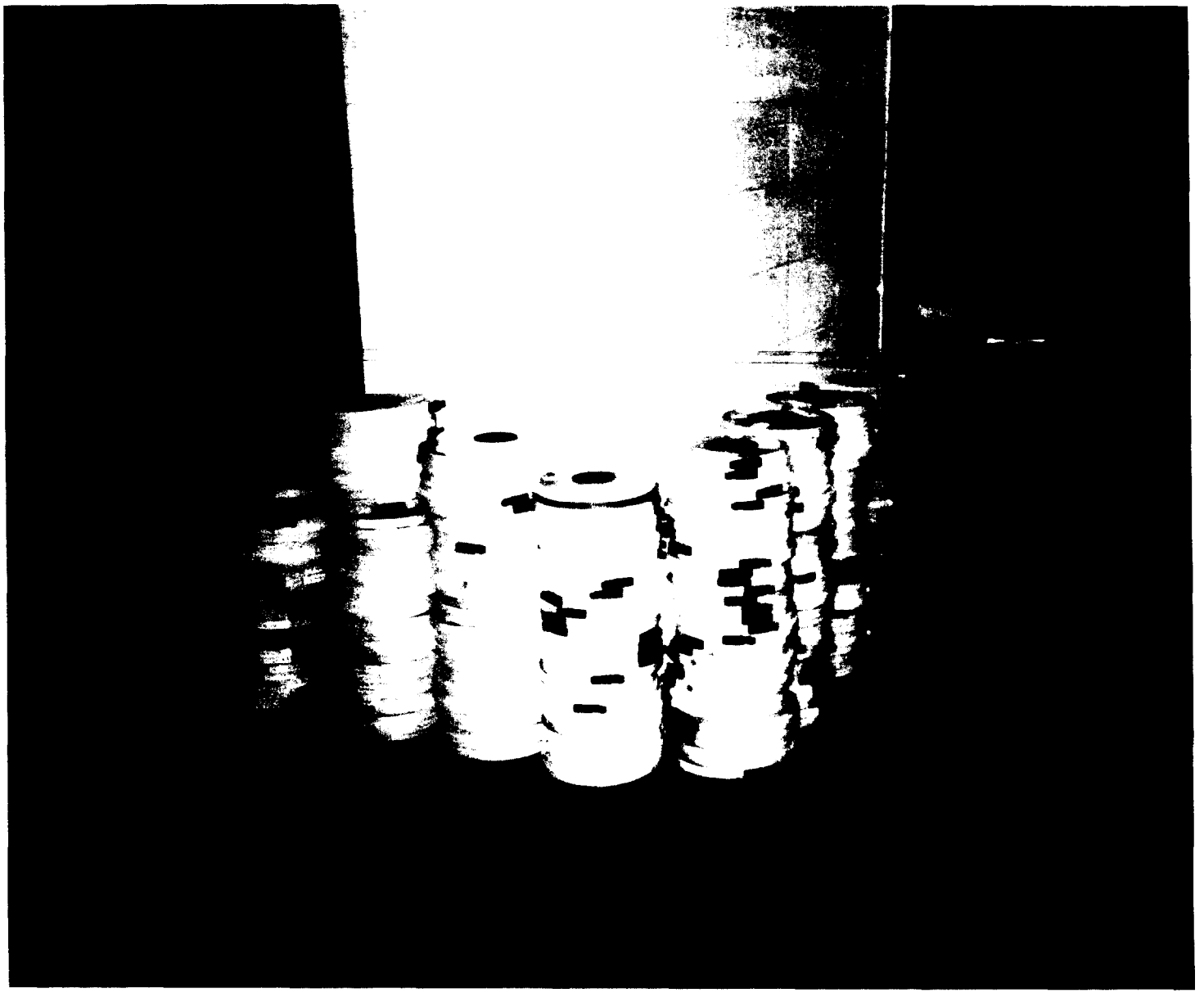
We agree that routine sampling and testing of stored tapes aids quality control. However, on July 11, 1989, we asked NARA to reevaluate its across-the-board 3 percent sampling regulation. Depending on the number of tapes stored, we were concerned that a fixed 3 percent sample without regard to statistical considerations, such as the size of the universe, could result in over or under-sampling, a potentially costly or risky practice. In September 1989, NARA officials informed us they were revising their regulations to require an annual sample size that would provide accurate results to within 5 percent at the 95 percent confidence level. Statistics aside, five facilities were not performing this valuable practice at all.

Clean Environment and Tape Handling

Three facilities either did not provide a clean environment for processing and storing magnetic tapes, or did not handle them in a manner designed to reduce tape contamination. Clean environment and tape handling standards cover a broad range of recommendations ranging from clean processing and tape storage areas to guidelines on the physical handling of tapes. Poor tape handling may cause tape contamination or physical damage and the loss of recorded data. For example, tapes may be contaminated through proximity to smoking, eating, and drinking. Other sources of contamination are stored paper products, inappropriate janitorial techniques, or dust-producing equipment such as high speed printers. Tapes may also be physically damaged by horizontal stacking, rough handling, or heat produced by computers and other equipment.

As shown in the following three figures, we found that several facilities were storing NASA tapes in a manner and in an environment conducive to damage. For example, Figure 2.4 shows one facility where we found hundreds of tapes stacked in a dusty hallway, while Figure 2.5 notes where we found over 4,000 tapes stored in a dirty basement subject to flooding. Finally, Figure 2.6 shows one facility where we found nearly 300,000 boxed tapes, stored on pallets, and strapped by steel bands. At this location, we observed instances where the downward weight of the tapes had warped the wooden pallets and the steel bands appeared to be crushing the contents of the tape storage boxes.

Figure 2.4: Tapes Temporarily Stored in a Hallway



Fire Protection

Eight facilities lacked adequate fire protection in their tape storage areas or were keeping combustible materials nearby. Two facilities had no smoke or heat detectors or automatic fire suppression systems. Eight had combustible materials stored in tape vaults and computer rooms.

Under NIST guidelines, tape storage vaults should: (1) have fire and smoke detectors, (2) have a fire suppression system, (3) be designed with fire protection as a major consideration, and (4) be free of combustible materials.

Figure 2.5: Tapes Stored in a Basement

Figure 2.6: Tapes Stored on Pallets Strapped With Steel Bands

Figure 2.7 shows a ceiling-mounted electric heater installed next to a plywood wall discharging hot air directly on NASA tapes at one of the tape storage facilities we visited.

Water Protection

NIST and industry guidelines recommend (1) the installation of floor-based water detectors, and (2) the availability of plastic sheets to protect stored tapes from overhead leaks. Only one facility installed water detection devices in its tape storage area, and only three facilities had plastic sheets on hand to cover tape racks in case of a leak. Undetected water leaks or flooding significantly damage magnetic tapes unless they are promptly treated. For example, because of lack of funding and a shortage of tape storage space, one facility is storing 4,000 tapes in a sub-basement which was flooded in 1985. Figure 2.8 shows a portion of these tapes that were about half submerged during the flooding. Contaminants and debris left a clearly visible water line on the tapes. In another instance, a roof-based air conditioning unit leaked on boxes stored near NASA tapes, as shown in figure 2.9.

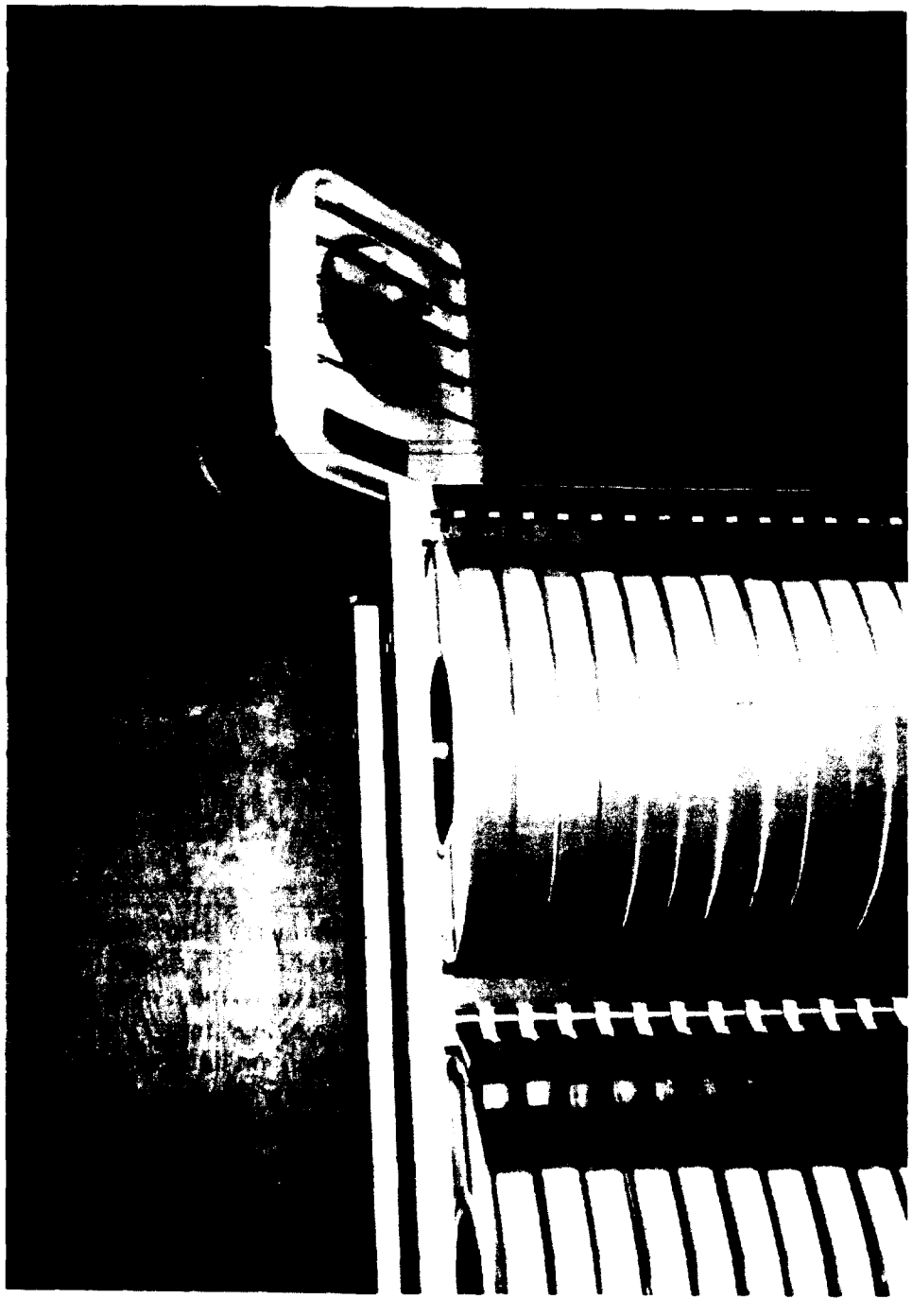


Figure 2.7: Electric Heater in Close Proximity to Stored Tapes

Figure 2.8: Tapes Likely Damaged by Flooding

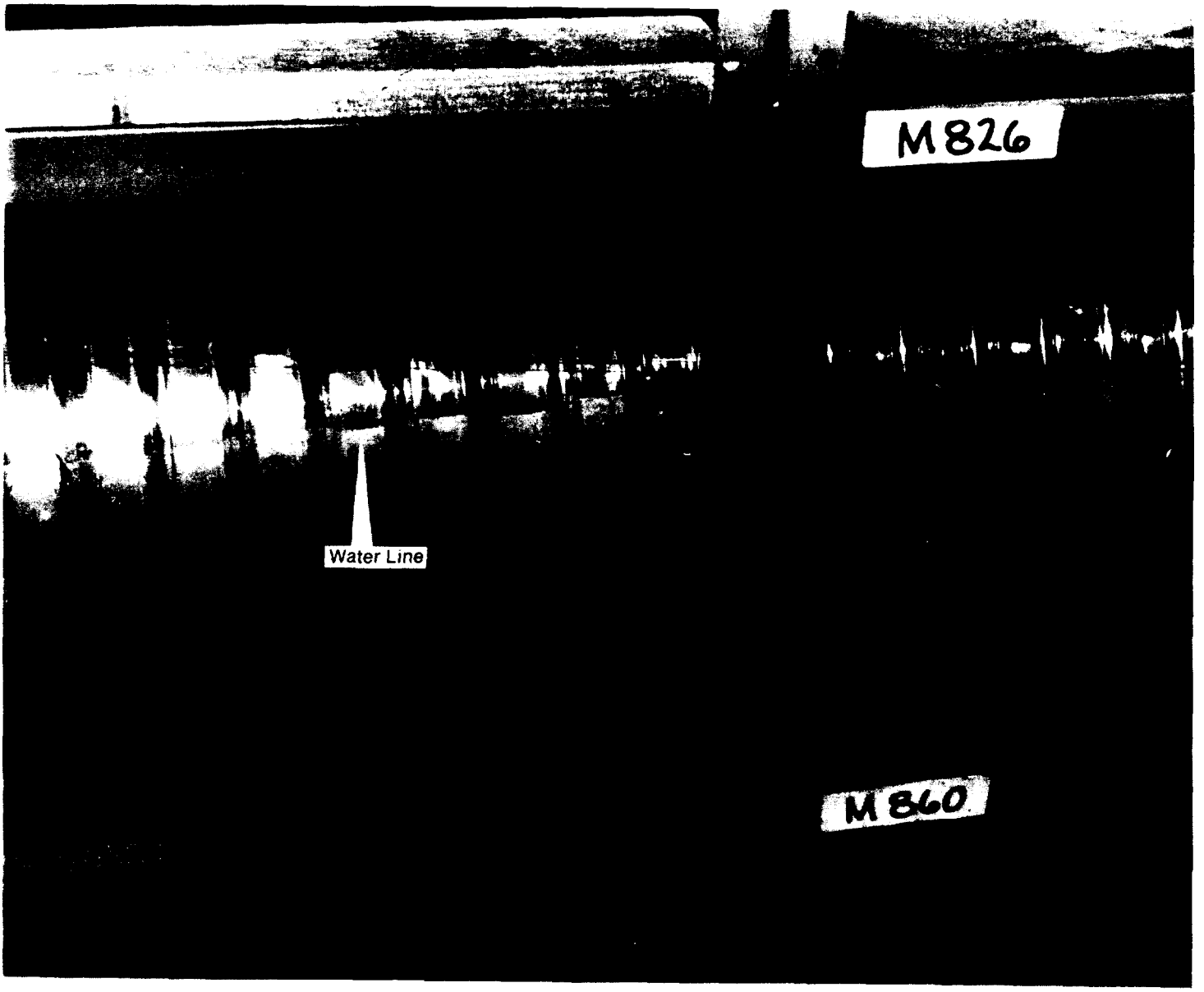


Figure 2.9: Water Leak Near NASA Tapes

Tape Drive Maintenance

Two facilities did not adequately maintain their tape drives. Poorly maintained drives may cause immediate or delayed tape and data damage. NIST and industry guidelines recommend a scheduled hardware maintenance program that includes the frequent cleaning of tape write/read heads and the removal of accumulated debris in the tape transport components. Other maintenance care should be focused on the periodic demagnetization of these heads, and the alignment and lubrication of tape drive components.

Routine Tape Maintenance

None of the facilities adequately maintained their tapes. Scheduled maintenance of tapes is critical, especially for tapes stored in vaults with poor environmental controls. In general, NIST suggests that tapes be periodically cleaned, rewound, and, if required, copied.

Tape Transportation Safeguards

Only one facility protected its tapes in transit. According to NIST, such tapes should receive special care, including packing and transportation in climate-controlled vehicles. Transportation hazards include excessive vibration, exposure to contaminants and stray magnetic fields, and extreme and uncontrolled temperature and humidity changes.

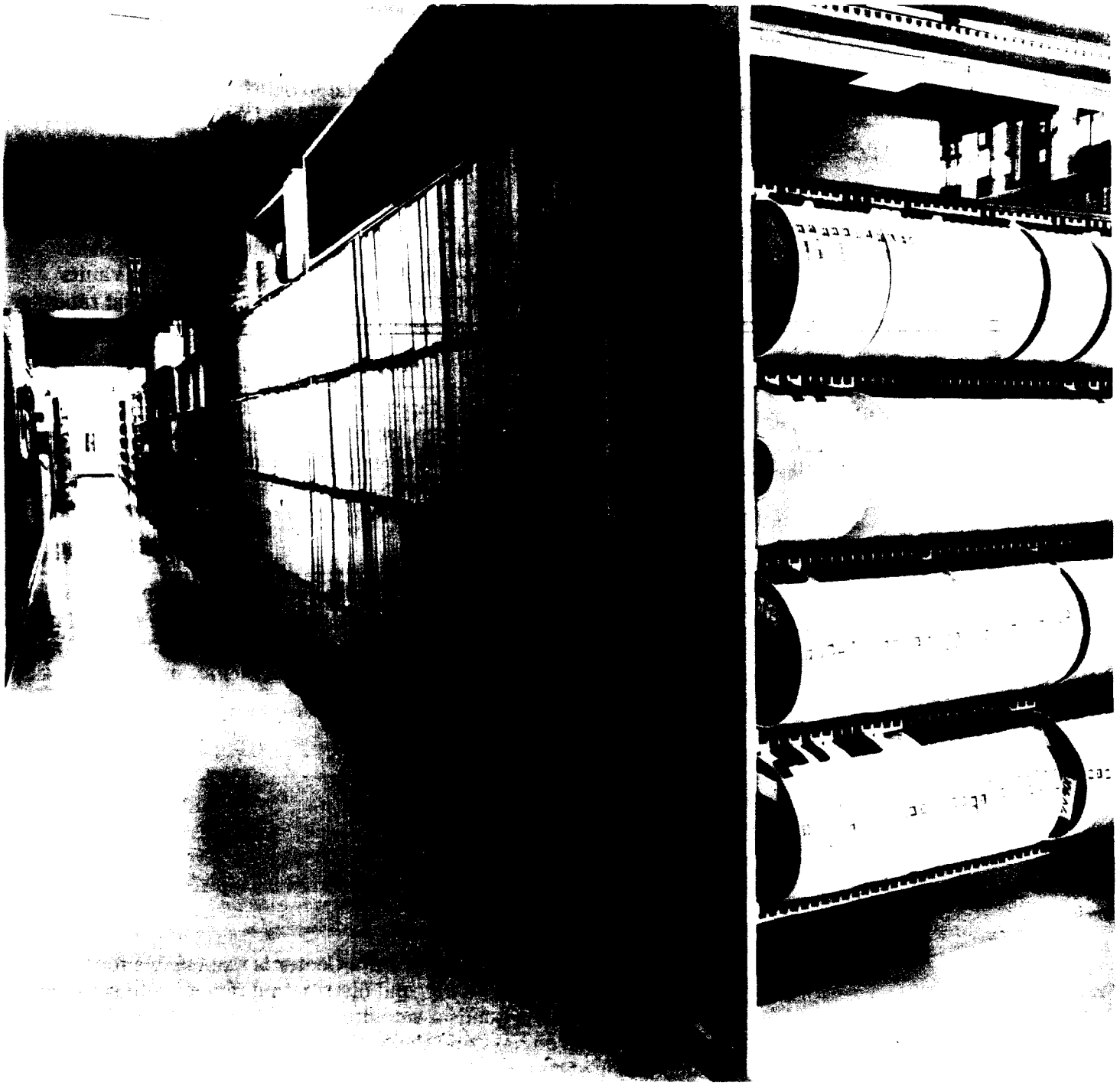
A Good Storage Environment Is Achievable

We visited two tape storage facilities with reputations for excellence in tape storage practices—the Digital Equipment Corporation's Data Protection Services, a commercial tape storage facility in Dominguez Hills, California, and the EROS Data Center, a federal facility in Sioux Falls, South Dakota.

The Dominguez Hills Data Protection Services provided tape archival and storage services to government agencies and to the private sector. The facility was under contract to JPL to store over 15,000 tapes. We found that its tape library fully met federal regulations and industry storage environment guidelines. Since our visit, the Dominguez Hills facility closed, and the laboratory transferred its tapes to another commercial facility in February 1989.

The U.S Geological Survey's EROS Data Center is responsible for processing, analyzing, archiving, and distributing remote land-sensing images acquired by the Landsat satellites and other remote land-sensing instruments flown on NASA and the National Oceanic and Atmospheric Administration's missions. The center manages over 117,000 tapes. We found the center's tape library, as shown in figure 2.10, to be in full or

Figure 2.10: EROS Data Center Tape Storage Vault



partial compliance with most of the applicable federal regulations and industry guidelines. It clearly demonstrates that a good tape storage environment is achievable.

NASA's Data Restoration Efforts

Recognizing that many of its tapes are deteriorating, NASA has taken steps to restore or preserve selected tapes held at NSSDC and JPL. Given limited resources, NASA does not plan to restore the hundreds of thousands of un-inventoried aging tapes stored in other NASA facilities, universities, and research institutions.

JPL's Restoration Programs

Concerned about the potential deterioration of its magnetic tapes, JPL restored approximately 12,500 tapes containing over 130,000 digital images from the Voyager, Viking, and Mariner 9 and 10 missions. These tapes had been stored at the Federal Records Center at Laguna Niguel and elsewhere.

According to the manager, this generally successful restoration, which cost $495,000 and took from 1983 to 1984, revealed that the attempt to restore tapes over 10 years old can often destroy them. Once the magnetic oxide coating has deteriorated, the tapes can be read only once, because reading recorded data strips their magnetic oxide layer. Thus, if the first reading was unsuccessful, the project could not recover the stored data on subsequent readings.

In July 1986, the laboratory sent a team to inspect its 130,000 remaining tapes stored at the Federal Record Center in Laguna Niguel and to assess possible damage caused by an earthquake. The team found that several shelves holding the laboratory's tapes received severe shaking and that several boxes containing tapes had fallen from the top shelves. Many sections of the acoustic ceiling had also been shaken loose. The team noted that "... the dust created by the falling sections into the boxes has surely contaminated the tapes at this point."[12] This contamination could have been significantly reduced if JPL had shipped its tapes in sealed boxes. We observed a high proportion of the laboratory's tapes stored in unsealed or partially open boxes.

In briefing JPL's Associate Directors, the staff noted that the laboratory's tapes were stored in substandard facilities and without disaster recovery backup or procedures to assure proper management of its

[12]JPL Interoffice Memorandum - Federal Archives Earthquake Damage, July 14, 1986.

tapes. The staff recommended that the laboratory develop a policy for protecting, handling, and storing magnetic tapes and suggested that a new facility be found to store the more than 130,000 tapes being stored at the center. In a letter dated December 4, 1986, the center's director underscored the need for prompt action:

"Our record center does not have an environmentally controlled storage conducive to the safe maintenance of computer magnetic tapes... You may store your magnetic tapes at this facility but we cannot guarantee the safe maintenance of your records."[13]

In December 1986, the laboratory began planning how to deal with these tapes. In discussing the potential preservation tasks, the staff noted:

"JPL ALDs (Associate Laboratory Directors) have recently been made aware of the deplorable conditions under which JPL data and data tapes are maintained in the Federal Records Center in Laguna Niguel. Their concern has prompted JPL to seek storage for data tapes under better conditions, but the costs are prohibitive, like a dollar a tape a month, for the large number of data tapes currently being 'archived'."[14]

According to the project manager's estimate, probably half the 130,000 tapes stored at the center were either damaged or degraded beyond restoration or contain data no longer worth keeping. Tapes more than 10 years old were at risk, and the project would not be able to recover between 20-25 percent of them.

In April 1989, the laboratory initiated a project designed to remove and restore all tapes containing valuable data stored at the Federal Records Center in Laguna Niguel. The 5-year, $1.8 millon project is to be implemented in two phases. During the first phase, the laboratory was to remove, in stages, the 130,000 tapes stored at the center. These tapes are to be evaluated for data identification, tape and data condition, and the value of data. According to the project staff, this phase will take about 2 years to complete. During the second phase, tapes containing data identified as valuable are to be copied to new tapes. This phase is planned to be completed in 1994.

However, in its May 1989 letter to JPL, the Federal Records Center in Laguna Niguel noted that it cannot adequately store magnetic tapes, and

[13]Letter from the Federal Records Center in Laguna Niguel to JPL, December 4, 1986.

[14]"JPL Planetary Data Restoration Task Planning Meeting," JPL memorandum, December 8, 1986 (emphasis added).

that it would ship them to another federal record center better equipped to store them. In late May 1989, JPL moved all its tapes from Laguna Niguel to its facilities and started implementing the project's first phase.

NSSDC Data Restoration Project

In June 1988, NSSDC began a program designed to restore about 30,000 tapes, many which are over 10 years old and deteriorating. The NSSDC restoration project is restoring about 10,000 tapes annually. According to NSSDC officials, as of September 1989, the Center successfully restored over 8,700 tapes at a cost of about $250,000. This cost includes labor, new tapes, a new tape drive, and software. According to NSSDC officials, this restoration succeeded because most of the restored tapes were the relatively newer, high-density kind produced in the 1970s. But project staff noted that, although all data were restored, some tapes had so deteriorated that data extraction required several attempts, and the staff often had to recover lost data segments from backup tapes. For example, to restore data from an early mission, the restoration project staff had to hand clean over 200 degraded tapes. As the NSSDC begins to restore the older, low-density tapes, more problems will be encountered.

Some Stored Tapes May Contain Data of Marginal Value

NASA and some scientific institutions may be spending limited resources to store thousands of tapes containing data without appreciable scientific value. These tapes may contain data that (1) were superseded by similar data with higher precision or resolution, (2) are poorly documented and cannot be interpreted, (3) are of questionable quality and completeness, and (4) are stored on deteriorated tapes and cannot be fully recovered. For example, JPL officials estimated that about half their 130,000 tapes formerly stored at the Federal Records Center in Laguna Niguel are damaged beyond recovery or contain data of little scientific value. The question of data value also applies to NASA's formal archival data sets maintained by NSSDC on over 113,000 tapes. In 1983, a group of scientists participating in a planetary data workshop noted that:

"The opinion that the current NSSDC is inadequate for curation, access, and distribution of planetary data is prevalent among users and data providers. Data archived there are of variable quality, some data sets have questionable accuracy, others are incomplete or have much lower temporal and spatial resolution than the original instrument data. Little processing history is provided with the data, and engineering information (when available) is supplied in hardcopy."[15]

[15]Trends in Planetary Data Analysis, Executive Summary of the Planetary Data Workshop. NASA Conference Publication 2333, 1984,p. 5.

NASA has taken steps to strengthen its archiving of planetary data through its Planetary Data System.[16] However, according to its manager, the system currently incorporates only a fraction of these data. The system is currently restoring data from past planetary missions, and eventually plans to incorporate most of these data in its data base. However, the system manager noted that there is no schedule for the completion of this effort, and that its completion is dependent on the resources NASA allocates to this task. If the conditions noted above also apply to data from other scientific disciplines, their value may also be questioned.

Chronic Problems in NASA's Archiving of Space Science Data Have Been Noted Before

An earlier GAO review and scientific advisory group reports noted chronic problems in NASA's data archiving practices and expressed concerns regarding the long-term preservation of data. In our 1977 report, we found that the acquired data was not archived in a timely manner, and that NASA was not enforcing its regulations concerning the archiving of data prepared by Principal Investigators.[17] In a 1982 report,[18] CODMAC noted that:

- data system and data analysis, including data archiving, were not adequately funded;
- data archives generally contained insufficient or inaccurate information about the archived data;
- data management responsibilities for both during and/or post mission phases were not clearly identified;
- archived data were often destroyed without consultation with the scientific community; and
- in some cases data acquired from past missions have not been properly archived.

[16]This JPL-based advanced data management and archiving system will consist of five or more electronically connected nodes responsible for processing, archiving, and disseminating data from past and future planetary missions. Using optical data storage technology, it is producing two Compact Disk Read Only Memory (CDROM) disks containing 4,000 Voyager images of Saturn and three disks containing 6,000 Jupiter images. NASA established the system in response to scientists' call for the development of a distributed data management and archival system operated and maintained by scientists.

[17]More Emphasis Needed On Data Analysis Phase of Space Science Programs (PSAD-77-114, June 27, 1977).

[18]Data Management and Computation, Volume 1: Issues and Recommendations, Committee on Data Management and Computation, Space Science Board, Assembly of Mathematical and Physical Sciences, National Research Council, National Academy Press, Washington, D.C., 1982, pp. 2-4.

Similarly, in its most recent report, CODMAC recommended that NASA should develop procedures to protect its data archives from deterioration of media, hardware failures, and tampering by individuals.[19]

[19]Selected Issues in Space Science Data Management and Computation, Committee on Data Management and Computation, Space Science Board, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, National Academy Press, Washington, D.C., 1988, p. 7.

Deficiencies Exist in NASA's Oversight and Management of Tape Archiving and Storage Activities

NASA's magnetic tapes are neglected. As discussed in chapter 2, facilities storing NASA's tapes are not complying with tape management standards and are failing to ensure that magnetic tapes containing valuable data are adequately preserved.

During the past three decades, NASA did not give adequate attention to the archiving and storage of its space science data. At best, NASA addressed the growing volumes of stored data and related tape storage and archival problems in a piecemeal fashion, and in general, has not acted on many recommendations put forward by CODMAC and other scientific advisory groups.

We attribute these deficiencies to a lack of (1) management attention and participation in tape management and storage activities, (2) oversight by NASA's information resources management officials and responsible federal agencies, and (3) adequate funding for tape storage and archiving.

Data Management Is Treated as a Low Priority Activity

In the past, NASA viewed data management and data archiving as a low visibility, low priority activity. Traditionally, the planning, development, and management of new missions consumed the bulk of NASA's resources; the storage and archival of data acquired by past missions was given only scant attention and meager resources. A recent CODMAC report also addressed this issue:

> "While the collection of data from space attracts much interest, the more mundane issues of handling, managing, and disseminating these data are given less than adequate attention. The accumulation of data continues as do the data management problems with the loss of valuable data and with the difficulty of providing access to the data."[1]

NASA's Office of Space Science and Applications, which has overall responsibility for managing NASA's space science data, did not adequately lead and manage projects, field centers, and facilities managing, storing, and archiving data. We believe this lack of attention to data management issues is partially responsible for the poorly defined management structure, which was noted in a 1986 CODMAC report. The report notes that NASA's data management is fragmented and poorly coordinated, and recommends that:

[1]Ibid., pp. 6-7.

"There should be explicit, clearly understood assignment within NASA of responsibilities for computation and data management functions to specific offices and individuals. Since the overall responsibility for the effectiveness and productivity of the science and applications programs rests with the Associate Administrator for Space Science and Applications, that individual should take lead in ensuring that the various functions are clearly defined, and that responsibilities are unambiguously assigned as necessary to accomplish this task."[2]

Lack of Management Oversight

NARA and GSA are responsible for periodic inspections of record and tape management practices of federal agencies.[3] Moreover, NASA's Information Resources Management (IRM) official is also responsible for ensuring that all facilities comply with NARA's regulations. However, we found that NASA's management of data has not been reviewed by either NARA or GSA, nor has it been reviewed by the Assistant Associate Administrator for IRM, NASA's Office of Management. Further, neither NARA, GSA, nor NASA's IRM officials have recently inspected or reviewed NASA's tape storage facilities or reviewed NASA's tape management and storage practices.

NASA's IRM Office Has Not Provided Adequate Oversight of Space Science Data Management

NASA's Assistant Associate Administrator for Information Resources Management, as the designated senior IRM official, is responsible for establishing agency policies for managing information processing resources and ensuring agency compliance with the applicable laws and regulations. NASA's IRM office is also responsible for oversight reviews of NASA's field centers, offices, and projects to determine compliance with mandatory information processing regulations, directives, and standards. Despite these responsibilities, the IRM office has not overseen NASA's management of its data holdings, because, according to the Director of NASA's IRM Policy division, the records management function was transferred to this office less than 4 years ago, in May 1986.

[2]Issues and Recommendations Associated With Distributed Computation and Data Management Systems for the Space Sciences, Committee on Data Management and Computation, Space Science Board, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, National Academy Press, Washington, D.C., 1986, p. 105.

[3]Under section 2904 of Title 44, United States Code, NARA and GSA must oversee records management programs operated by federal agencies.

NARA Has Not Reviewed NASA's Records Management Activities

NARA is responsible for the inspection and evaluation of agency records management programs. The objectives[4] of NARA's inspections are to:

- determine agency compliance with NARA's records management regulations; and
- evaluate the effectiveness of agency records management programs and practices relating to adequacy of documentation, maintenance and use, and records disposition.

NARA has never inspected NASA's records management program. According to the Assistant Archivist for Management and Administration, NARA lacks the resources to perform more than two reviews annually. However, a NARA representative told us they worked in other ways with NASA regarding their records' management activities. For example, it is evaluating a revision to NASA's records disposition schedule. In addition, several years ago NARA established a task force to develop appraisal criteria for NASA's records. The task force visited five facilities and three federal records centers, reviewed seven space science projects, and issued a report summarizing its findings.[5] Although the report addressed several records management issues, it did not address NASA's compliance with federal tape management regulations, nor did it identify the deficiencies in tape management and storage practices that we found during our review.

GSA Oversight of NASA's Record Management and IRM Activities Is Inadequate

GSA is responsible for inspecting and evaluating agency record management programs.[6] These inspections should ensure that every agency complies with NARA and GSA regulations, and that each economically and effectively manages its records.

GSA did not perform the mandated reviews of NASA's tape management practices nor did it review its IRM activities. According to the Deputy Director of NASA's IRM Policy Division, GSA has never reviewed NASA's IRM or records management and tape storage activities, such as visiting tape storage facilities to ensure their compliance with applicable tape management standards. Although officials from GSA's Office of Information Resource Management could not explain GSA's failure, they said it is

[4]Code of Federal Regulations, Title 36, Subpart C - Agency Program Evaluation, Paragraph 1220.50, Evaluation by NARA.

[5]Saving the Right Stuff, NARA, August 1985.

[6]Code of Federal Regulations, Title 41, Chapter 201, Part 201-22, Records Management Program, Paragraph 201-22.001-4, GSA Responsibilities.

planning to strengthen its oversight and schedule agency reviews every 3 years. They also told us that GSA will, in January-March 1990, review NASA's information resources acquisition practices, and that the reviewers will be informed of our findings.

Inadequate Funding for Data Archiving

The vast majority of funding for data storage is done on a mission-by-mission basis. Each mission is funded in two phases: (1) mission development and (2) mission operations and data analysis. The mission operations and data analysis phase includes funding for data processing, analysis, and storage. NASA and JPL officials told us that NASA usually underfunds the second phase and often uses those funds to cover first phase overruns. In addition, second phase funding for data storage assumes that most raw and intermediate data will be destroyed after it is processed, as required by NASA's regulations. However, organizations or scientists responsible for data are reluctant to destroy data they believe are potentially valuable. Instead, they store them in substandard conditions.

In addition to the mission-specific funding of data analysis and storage, NASA also funds NSSDC's long-term data storage and archiving. NSSDC, which is responsible for archiving data from all NASA's space science missions, and from selected NOAA, Department of Defense and international missions, had a 1989 budget of $3.2 million. This amount includes all its principal activities: data acquisition, processing, archiving, and distribution.

According to NASA and JPL officials in data management and archiving, data archiving and storage are often underfunded. CODMAC concurred and recommended that NASA establish a budget providing balanced support not only for instrument development, flight support, and immediate post-launch data handling, but also "... for the information processing, exchange, analysis, archiving, and other related activities."[7]

In effect, the report noted that NASA should allocate additional resources to manage and archive space science data so that these resources are commensurate with those for the development, launch, and operation of space science missions.

[7] Issues and Recommendations Associated With Distributed Computation and Data Management Systems for the Space Sciences, Committee on Data Management and Computation, Space Science Board, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, National Academy Press, Washington, D.C., 1986, p. 104.

A NASA official responsible for the planning and coordinating the data management and archiving told us that although NASA needs more resources, including funds and personnel, it must also balance these requirements against available resources and the needs of other programs.

NASA's Efforts to Strengthen Its Data Management

NASA recognizes that a significant effort will be required to correct existing data management problems. Besides the data restoration projects discussed in chapter 2, it is taking several steps to correct existing problems and to prepare for the data expected to be generated by its future missions. These steps include

- establishing a task force to reassess NASA's management of data;
- using optical disk technology to archive selected data;
- developing a Master Data Directory with information on the location of data with significant scientific value; and
- initiating a census of space science data stored at JPL and Goddard.

Data Management Task Force

To strengthen data management and oversight and to develop a coherent data management plan, the Office of Space Science and Applications and the Office of Space Operations established a joint task force in July 1988 to identify data management problems and prepare an information systems management plan by November 1989. The scope of the task force's charge includes the evaluation of:

"... full range of activities required to accomplish first-class scientific research... areas to be addressed are, flight data systems; experiment operations, including planning, scheduling and control; computer networking; computational systems; and data archival."

The task force's products are to include cost scenarios for different data management options, a draft of a new NASA data management policy, and an information system strategic plan. We met with task force staff and discussed the task force's activities and plans. Because they had not yet completed their work, it was too early to assess how the task force will influence NASA's management of its past and future data holdings.

Use of Optical Disk Technology

NASA is experimenting with advanced data storage technology and has established several projects using optical disks to store selected data. For example, at Goddard, one project is converting 10,000 tapes containing data from the Dynamic Explorer I and II to 243 optical disks, while another project implemented by NSSDC is using optical disks to store selected archival data. Similarly, JPL is using optical disks to store and disseminate planetary images obtained by NASA's deep space missions. While optical disk technology may offer improvements in NASA's data storage, archival, and dissemination, it is too early to assess its overall impact.

NASA's Master Data Directory

NSSDC is developing a NASA Master Directory, an on-line data search system designed to link users with existing data systems implemented by NASA and other federal agencies. In some cases, the directory provides an automatic network connection to data catalogs or information systems where more detailed information about data of interest may be found. According to NSSDC, the user may search for data by categories of interest such as science discipline, instrument, missions, or spatial coverage. The information displayed by the directory includes a descriptive title, summary abstract, key references, persons to contact, and storage media information.

Although the Master Directory is limited to data catalogs and data descriptions provided by the existing systems, other data of interest are being identified. NSSDC is planning to hire several scientists to identify additional data of significant scientific interest. According to its manager, the Directory project does not have the resources to identify all existing data of potential interest or their location. To obtain detailed information about the extent of all its data, NASA would have to perform a full-scale, comprehensive inventory and assessment of its data holdings.

Data Census

In August 1989, the Communications Division of the Office of Space Science and Applications initiated a NASA-wide census of data. Its purpose is to identify all NASA's data sets and thus to develop a "comprehensive picture of just what constitutes the NASA data base." The project is closely related to other activities, including tape restoration and the development of an archiving cost model. NASA is also planning to use the census information as input to its Master Directory project. Although the stated goal of the project is to inventory all NASA tape holdings, the first phase of the data census is limited to tape holdings maintained by

JPL and by Goddard. Because the project staff had not completed planning at the time of our review, it was too early for us to determine whether this effort will produce a comprehensive inventory of all NASA's data stored by NASA's centers, contract facilities, universities, individual scientists, and other federal agencies.

Conclusions and Recommendations

Conclusions

NASA's management of data acquired by past space research and exploration missions is plagued by serious problems, with hundreds of thousands of magnetic tapes with long-term scientific value improperly stored and inadequately maintained. Valuable data from past missions are stored on deteriorating magnetic tapes and some irreplaceable data sets may have been lost. Since NASA does not have an agencywide inventory of its data, it does not know what is being retained and where it is located.

Data management and data archiving have received little attention from NASA officials responsible for the management of the nation's space research and exploration. In the past, NASA responded to needs of the scientific community to push the frontiers of space exploration by emphasizing new missions designed to carry advanced instruments into Earth orbit and to other planets of our solar system. While this emphasis dramatically expanded scientific knowledge and ensured that the United States established and maintained its pioneering role in many important aspects of space exploration, we believe that this success was partially achieved at the expense of preserving NASA's data holdings acquired by past missions.

The potential scientific value of these data holdings is unquestionable, and NASA has started to take steps to preserve some of its existing data holdings and is evaluating its data management structures and activities. However, NASA should do more.

First, NASA's data management and archival activities have to be elevated to a position of importance equal to that held by mission development and operations. Second, given NASA's decentralized structure and its decentralized management of its space science missions, a focused organizational structure is needed with clearly defined authority and responsibility. Third, NASA must determine the amount, location, and scientific value of its data. Without an agencywide inventory, NASA cannot adequately plan or budget for space science data management. Fourth, all valuable data should be made readily accessible to scientists either through a central data directory or by other means. Finally, NASA needs to allocate adequate funds and staff to data archiving to ensure that its data are adequately maintained and stored.

These steps will require considerable effort, different funding priorities, and a dramatic change in NASA's mission-oriented culture, which emphasizes development, launch, and operation of spacecraft and views data management as a low priority activity. Without a major effort to

strengthen the management and archiving of NASA's data, and the allocation of necessary resources, valuable data will be lost. Furthermore, if NASA does not take the required steps to correct the existing deficiencies in its data management and archival operations, several of which have been known for the past decade, future missions will also be placed at risk, particularly if they rely on magnetic tapes as a primary data storage medium.

Clearly NASA must accept the major responsibility for the deplorable conditions under which scientific data are stored and maintained. Two organizations, NARA and GSA, have also not met their oversight responsibilities which, if properly exercised, could have brought the necessary attention and focus to have prevented or mitigated these problems.

Recommendations

Recommendations to the NASA Administrator

We recommend that the Administrator instruct NASA officials responsible for the management of data to:

- conduct a thorough inventory of all NASA's space science data stored at NASA centers and contractors, universities, research institutions, and other federal agencies;
- assess, in cooperation with the scientific community, the inventoried data for its scientific value and the integrity of its storage media;
- copy valuable data from deteriorating tapes to archival quality magnetic tapes or other storage media suitable for long-term retention of digital data, and release unneeded tapes for reuse or disposal;
- archive valuable scientific data in facilities that meet NARA regulations;
- develop and implement agencywide tape management and maintenance standards which include all NARA regulations and appropriate NIST guidelines;
- ensure that the offices and officials responsible for managing space science data are identified and their responsibilities clearly defined;
- ensure that NASA officials responsible for overseeing NASA's IRM periodically review NASA's data management and archiving to ensure compliance with NARA regulations; and
- ensure that NASA's data management and archiving are allocated adequate resources to properly store and maintain NASA's space science data holdings.

Recommendation to the GSA Administrator

We recommend that the Administrator periodically review and inspect NASA's records management practices as required by the Federal Information Resources Management Regulations.

Recommendation to the Archivist of the United States

We recommend that the Archivist periodically inspect and review NASA's records documentation and disposition practices as required by regulations.

Agency Comments and Our Evaluation

Commenting on a draft of our report, NASA contended it was safeguarding space science data as a national resource for future generations, but recognized room for improvement. It said it was addressing GAO's recommendations in ongoing or planned programs. Several of NASA's ongoing programs, including tape inventory and data restoration, are discussed in our report. Although these activities have been limited, NASA representatives told us they would be expanded in the future. Because NASA's detailed plans for implementing our other recommendations were still evolving when we finished our work, they could not be evaluated.

NASA expressed concerns that our report, while addressing what it termed "certain shortcomings in magnetic tape management," did not present a fair and balanced description of its efforts to manage space science data in a broader context. We disagree. As stated on page 48, our work focused on determining if NASA was adequately managing and archiving data from its past missions, which is now stored on magnetic tapes. In addition to fairly describing, and in most cases photographing, the conditions observed at 10 locations, we mentioned a number of instances where NASA is taking positive steps to address certain aspects of the tape storage and management problems (see pp. 31-33 and 40-42).

NASA also stated the report's tone was unnecessarily harsh, and that it contained sweeping generalizations that were unfounded and unsubstantiated. We disagree. Contrary to NASA's contentions, we believe our report fairly describes NASA's management of space science data holdings from past missions. Further, we think the seriously flawed conditions under which hundreds of thousands of tapes from past missions are stored, combined with the low priority accorded this important activity, unquestionably substantiate our conclusions and recommendations. Unless NASA addresses the serious tape management and storage problems noted, data from past missions will in fact be lost to future

generations. NASA's letter and our evaluation of the comments it made on a draft of the executive summary are in appendix IV.

GSA and NARA also commented on our report. GSA reported it had strengthened its management oversight function and planned to conduct a review of NASA in early 1990. (See app. V.) NARA concurred that data management was a low priority in NASA, and believed this applied to records management as well. NARA believes that while NASA records managers are aware of tape management regulations, they have not been effectively communicated to NASA program managers. NARA supported our recommendation that NASA conduct an inventory of its data tapes, but stated that in the past NASA had refused to do so. NARA said it had not inspected NASA because of the massiveness of the undertaking, requirements in other areas, and an expectation that records management activities would improve based on other working relationships established during the past 5 years. NARA agreed, however, to consider inspecting NASA, but not before fiscal year 1991. NARA also made several comments about the way we rated its storage facilities. NARA's letter and our evaluation of its comments are in appendix VI.

Objectives, Scope, and Methodology

On November 10, 1988, the House Committee on Science, Space, and Technology asked us to report on whether NASA is (1) adequately managing and archiving space science data from its past missions stored on magnetic tapes, and (2) whether a mechanism exists for obtaining input from the scientific community on what types of space science data should be preserved and archived. This report addresses the first question; a subsequent report will address the second.

To answer the first question, we:

- identified federal and private sector tape management regulations and guidelines and developed a tape management checklist to review NASA's tape storage practices based on 11 factors developed from NARA regulations, and NIST and private sector guidelines;
- reviewed NASA's policies and guidelines governing the management of data;
- reviewed reports and documents related to the management of data, including reports prepared by NASA, CODMAC, and various scientific groups and committees;
- interviewed NASA and JPL officials responsible for managing NASA's data;
- interviewed NARA and GSA officials responsible for overseeing NASA's data management;
- identified and reviewed tape management practices at 10 data processing and storage facilities using a tape management checklist (see table 2.1); and
- discussed NASA's tape management practices with GSA and NARA officials.

We used NARA regulations and NIST guidelines as the primary guide in developing our tape management checklist. We supplemented our checklist with guidance provided by major manufacturers of magnetic computer tapes, as well as the International Council on Archives.

To determine the extent to which each facility complied with the regulations and guidelines, we:

- used our checklist to discuss, observe, and document the conditions found at each location, always in the presence of facility representatives;
- photographed examples of the conditions noted or used photographs provided by the facility; and
- modified, where appropriate, the results of our visits, based on written comments provided by each facility (discussed in app. III).

We also talked to the National Oceanic and Atmospheric Administration and to the United States Geological Survey officials for a broad perspective on tape management activities in other federal agencies.

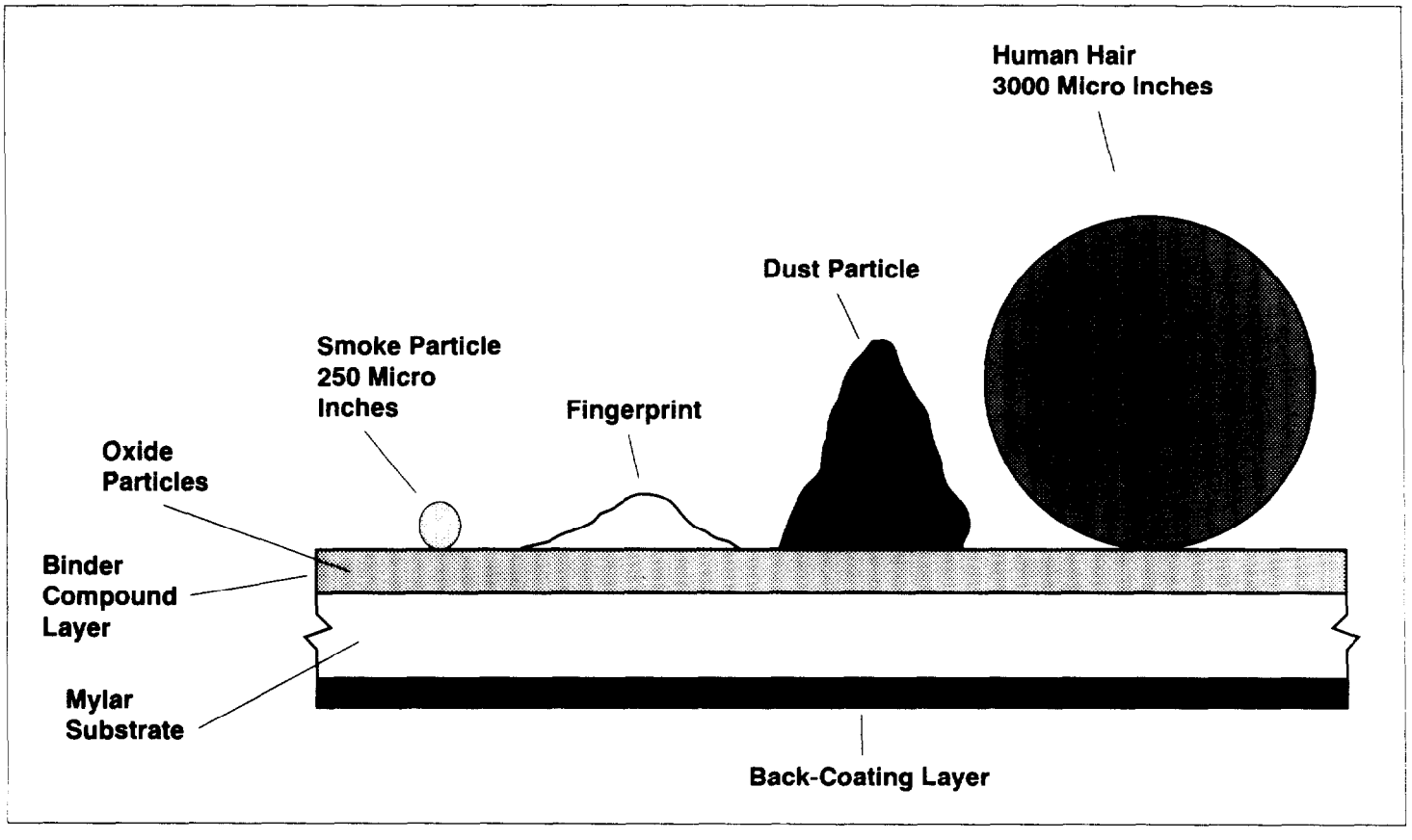
Our audit work was performed in accordance with generally accepted government auditing standards between November 1988 and January 1990 at various locations, including:

- NASA headquarters in Washington, D.C.;
- Goddard in Greenbelt, Maryland;
- NARA headquarters in Washington, D.C.;
- GSA headquarters in Washington, D.C.;
- National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service in Washington, D.C.;
- United States Geological Survey headquarters in Reston, Virginia;
- NIST headquarters in Gaithersburg, Maryland; and
- JPL in Pasadena, California.

Characteristics of Magnetic Tapes

A standard magnetic tape[1] consists of 2,400 feet of a thin substrate material, usually polyester film, coated with an iron oxide suspended in a binder. Other components include plasticizer, antistatic and wetting agents, lubricants, and agents designed to retard bloom and fungal growth. Figure II.1 shows the principal components of a magnetic tape in relationship with common contaminants. Figure II.2 is an electron microscope view of a foreign particle embedded in the binder of a magnetic tape.

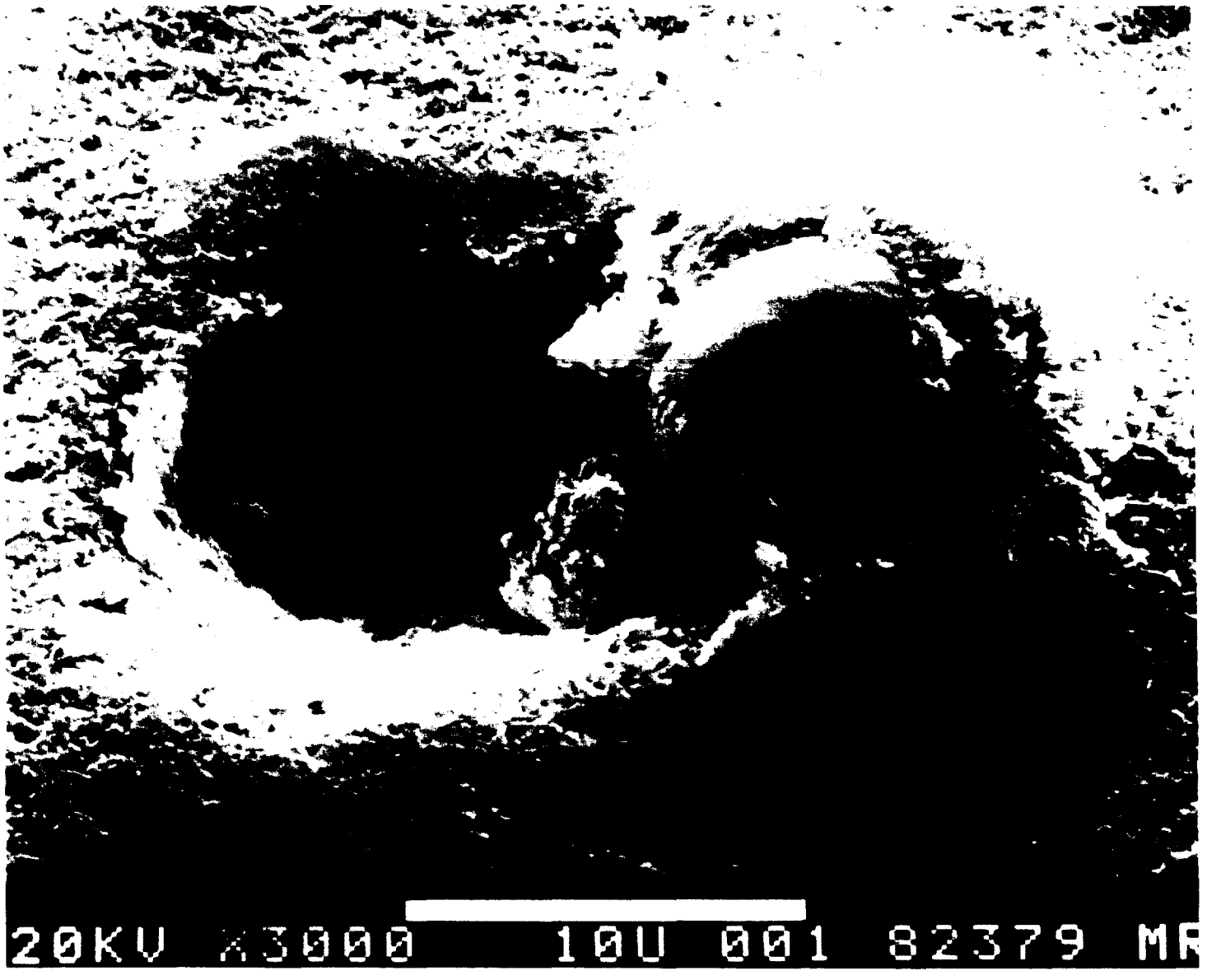
Figure II.1: Magnetic Tape and Its Principal Contaminants[2]



[1]In this report we are limiting our discussions to the most commonly used tape - the 2,400 feet long 6,250 Bits Per Inch (BPI) tapes. In addition to this type of tape, NASA is also using and storing a wide variety of tapes ranging from older, low density tapes to high density analog tapes.

[2]"Care and Handling Manual for Magnetic Tape Recording," in Magnetic Tape Recording for the Eighties, NASA Reference Publication 1075, NASA, April 1982, p. 133; and Tape Management and Evaluation, Data Devices International, Chatsworth, CA, 1982, p.10.

Figure II.2: Foreign Particle Embedded in Magnetic Tape[3]

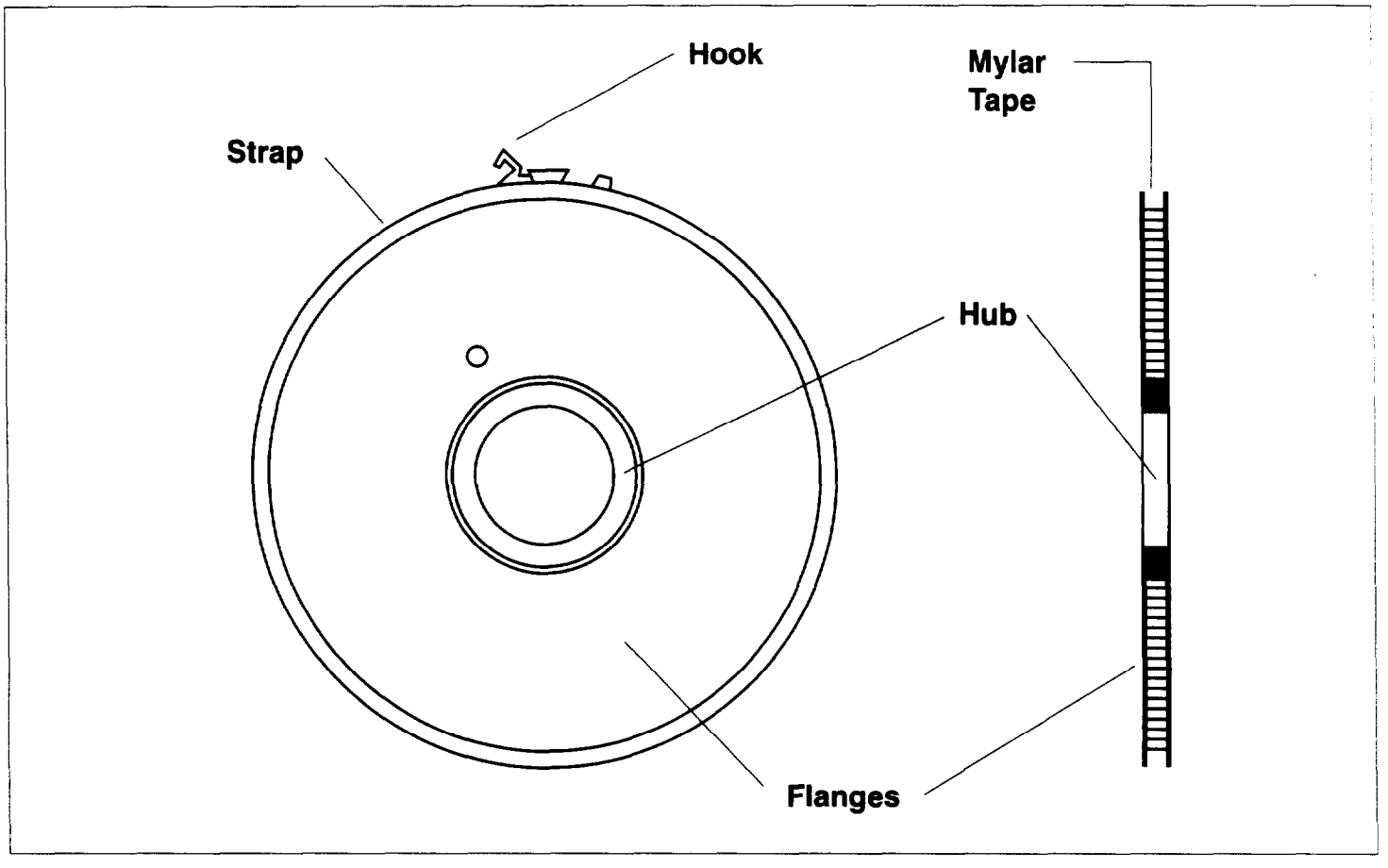


A standard tape, consisting of polyester substrate coated with binder and magnetic oxide, is wound around a tape hub and sandwiched between two flanges. In some instances, the flanges are secured by a

[3]Tape Management and Evaluation, Data Devices International, Chatsworth, CA, 1982, p. 7. (Courtesy of Data Devices International.)

strap or a wrap-around band and hung on a tape rack. In other instances, tape may be stored in a plastic or metal canister.

Figure II.3: Major Components of Magnetic Tape



Facility Compliance With Tape Management Standards

Our review of selected tape processing and storage facilities revealed significant deficiencies in most aspects of the tape management process. Our findings are grouped by two sets of standards—NARA's mandatory regulations and NIST's and industry guidelines, including recommendations provided by the International Council on Archives. Our rating of facility compliance with tape management regulations and guidelines is based on visits to each facility, discussions with facility staff, and on a review of relevant documents. When appropriate, we photographed significant deficiencies in tape management practices and summarized our findings in a tape management checklist.

Response to Our Findings

We asked each facility[1] to review and comment on our findings. To facilitate this process, we gave them (1) a copy of our checklist including notations of the facility's compliance level, (2) a table including an explanation of how we assigned compliance ratings, (3) a copy of NARA's tape management regulations, and (4) a copy of NIST's tape management guidelines. We modified our rating in instances where the facility provided additional information or explanation. The following section summarizes their comments.

National Space Science Data Center

The Center's official agreed in general that NSSDC does not comply with all federal regulations and guidelines and noted that the facility was built 20 years ago, before these regulations were issued. He also stated that the facility "adopted" NIST's tape management guidelines which are implemented as resources permit. In regard to the uncalibrated temperature and humidity recorder installed in the NSSDC's tape library, the official said that there is no reason to believe that the temperature of the archive area has ever exceeded the recommended range. In responding to our finding on the lack of security, the official noted that NSSDC has never lost a tape through unauthorized removal or for any other reason. We were told that the Center is planning to redefine procedures and readjust spending priorities there and at NASA's headquarters to comply more fully with relevant federal regulations and guidelines. The Center said it is very concerned that NASA's data, acquired at significant cost to the U.S. taxpayer, will be available to tomorrow's researchers to further increase our understanding of our earth, solar system, and the universe.

[1] We did not ask the Digital Equipment Corporation's Data Protection Services to comment because it is no longer operational. JPL transferred its tape holdings to another commercial facility.

We disagree with the Center's argument that its tapes are adequately stored. The Center is storing over 70,000 tapes in boxes at the Washington National Records Center with only partial environmental control and maintenance. Moreover, since the Center is not annually sampling its tape holdings, it cannot detect potential data losses. Similarly, while the lack of security at NSSDC's tape library may not have resulted in a documented unauthorized removal of stored tapes, this may occur unless the Center complies with NARA's access control regulations.

Smithsonian Astrophysical Observatory

Without commenting directly on our compliance ratings, the Observatory addressed several of our concerns. It noted that it (1) maintains a backup of tapes containing all intermediate and archival data, (2) regularly "spins" its tapes to prevent print-through, (3) plans to store and archive all its data on Write Once Read Many (WORM) and on Compact Disk Read Only Memory (CD-ROM) optical storage disks, and (4) plans to archive all original tapes at the NSSDC. Concerning the lack of security in the observatory's computer room and tape libraries, the official said that the nature of the data and the institution's research orientation do not warrant extraordinary access controls. NARA requires that only authorized personnel be given access to tape storage libraries and computer rooms. But we think an adequate access control may be implemented in a research setting without unduly burdening the users.

While the Observatory is maintaining backup of its tapes, many are with the originals. NARA requires that backup tapes be stored off-site to ensure their survival if the originals are destroyed. However, since the Observatory stored at least a part of its backup tapes off-site, we changed the backup rating from noncompliance to partial compliance.

Multi-Mission Image Processing Laboratory

No response received as of January 1990.

Infrared Processing and Analysis Center

The Center's official generally agreed with our findings and noted that the Center is planning to modify its practices to better comply with the relevant federal regulations and guidelines. As to the lack of security, the official partially disagreed with our findings, noting that all Center personnel are authorized to enter computer rooms and tape libraries, and that the introduction of a stringent access control may be counterproductive in a research environment. Nevertheless, NARA requires that

facilities that store and process magnetic tapes implement adequate access controls to ensure that only authorized personnel are allowed to enter storage libraries and computer rooms.

Center for Astrophysics and Space Sciences

The Center disagreed with us about its tape management practices, noting that the findings distort the Center's tape storage activities. In particular, the official noted that (1) most of the data in the Center's archive and all the data in storage are from programs that closed, and the university holds no obligation or responsibility to the government for these data; (2) until GAO's review, the government was entirely indifferent to the data and has never funded their preservation. These data were kept because the Center's scientists believe that they have a potential scientific value; and (3) tapes containing data for which the Center is responsible are kept in an air conditioned building with temperature range between 60 and 75 degrees Fahrenheit.

While we agree that the Center may not have an obligation or responsibility to maintain data from NASA's older missions, the Center's scientists believe that these data have potential scientific value and should be preserved. Therefore, in our opinion, if these tapes contain valuable scientific data, then NASA and the Center must ensure that they are adequately maintained and stored. The Center also noted that NASA did not inform the Center that it should comply with federal tape management regulations and guidelines.

EROS Data Center

Generally agreeing with our compliance ratings, the Center noted its funding is inadequate to comply with every federal tape management regulation and guideline. The tape storage and maintenance problems will be solved once the Center transfers its tape holdings to optical disks. The Center stated that it is not cost-effective to maintain a duplicate set of the Center's tape holding in an off-site location, since its fire suppression system provides adequate protection for the stored tapes. While a good fire suppression system may limit damage, it is a NARA regulation to store a backup copy of all original tapes containing valuable data at an off-site location to ensure the preservation of data in the event of a major disaster.

Tape Staging and Storage Facility

Having agreed that TSSF does not comply with NARA temperature and humidity regulations, NASA monitoring officials noted their subsequent installation of a temperature and humidity record in the tape storage

area. Agreeing that TSSF was in partial compliance with security regulations, he said it will post "authorized access only" signs at the entrance to the tape storage area. But this will not tighten the library's security. In regard to NIST's guidelines, the official responded that the facility will take corrective action when practical and if resources permit. Despite these deficiencies, he insisted the tapes have not been harmed. But having failed to sample and test stored tapes in accord with NARA's regulations, TSSF cannot possibly know if their tapes are unharmed. Until these deficiencies are corrected, they remain at risk.

We also found that TSSF was storing several hundred thousand tapes in boxes kept on pallets strapped by steel bands. The official noted that if the facility were to store these tapes on tape racks, the storage costs would be significantly higher, since the facility would require additional storage space. Granting his argument, the practice is nevertheless totally unacceptable and should be corrected.

National Archives and Records Administration

NARA stated that it has only a limited responsibility for NASA tapes stored at NARA's record centers. From NARA's perspective, as long as the tapes remain in NASA's legal custody, NASA is solely responsible for regulations such as tape cleaning, certifying, and backups. NARA also pointed out that NIST's guidelines were not incorporated in NARA's regulations and therefore are not applicable to NARA's Washington National Records Center and the Los Angeles National Records Center at Laguna Niguel. NARA's responses to our compliance ratings for both facilities are discussed below. We agree that NASA is responsible for the maintenance of its tapes stored at NARA's federal centers, and for that reason we did not rate NARA's compliance with such regulations in regards to its centers. However, we found that NARA records centers were not complying with NARA's own tape management regulations, and that NARA was also not providing oversight of NASA tape management practices despite its responsibility for doing so. While we agree that NARA is not required to implement NIST's tape management guidelines, we believe that following them would ensure the preservation of tapes stored at NARA's federal records centers.

Washington National Records Center

NARA did not fully concur with our compliance rating. Specifically, NARA noted that the Center:

- is in partial compliance with the temperature and humidity regulations in the storage vault holding NASA tapes by periodically measuring tem-

perature and humidity with a portable hygro-thermograph; we agreed and adjusted our rating accordingly;

- is now in full compliance with the access control regulations since the Center has stationed a guard in the facility's lobby to monitor the front entrance and exits;
- is in full compliance with the fire protection regulations because of the Center's adherence to fire codes and regulations, which mitigates fire hazards posed by combustible materials stored near NASA tapes.

We disagree because, according to NIST, combustible materials nearby constitute a fire hazard. We pointed out that a fire did occur in one of the Center's vaults as shown in the following figure:

Figure III.1: Records Damaged by Fire at the Washington National Records Center

- is in full compliance with the water protection guidelines and provides plastic sheets in the event of a water leak. We disagree since full compliance in this category would require the installation of water detectors.

NARA also stated that because NASA's tapes are stored in boxes, the Center does not require tape racks. We disagree, since the practice of storing tapes in unsealed boxes rather than in tape racks is not recommended by either NIST or the industry.

Federal Records Center, Laguna Niguel

NARA concurred with our rating for the temperature and humidity control, but disagreed with our rating for the fire and water protection guidelines, noting that the Center's storage area is adequately protected by an automatic sprinkler system. We disagree, because the Center did not install water detectors and was storing tapes in close proximity to combustible materials.

NASA's Comments and GAO's Response

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

January 5, 1990

Mr. Ralph V. Carlone
Assistant Comptroller General
Information Management and
Technology Division
United States General Accounting Office
Washington, DC 20548

Dear Mr. Carlone:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the General Accounting Office (GAO) draft report entitled, "Space Operations: NASA is Not Properly Safeguarding Valuable Data From Past Missions" (GAO/IMTEC-90-1, Code 510327).

We are very concerned that the report, while addressing certain shortcomings in magnetic tape management, does not present a fair and balanced description of our efforts to manage Space Science data in a broader context. We take especially strong exception to the implication that NASA is not safeguarding the space science data as a national resource for future science generations. NASA's unquestioned history and recent record of scientific success and accomplishments clearly vitiates what we consider to be a groundless implication. We believe that the tone of the report is unnecessarily harsh, and contains sweeping generalizations and extrapolations which we believe to be unfounded and unsubstantiated.

In our view the report lacks balance because it fails to reflect the emphasis placed on data management as an integral part of our current and planned science programs and the NASA commitment to stewardship of science data products. The report does not adequately acknowledge the outstanding record NASA has achieved in the area of storing and delivering scientific data and information from its space missions.

This is not meant to imply that NASA has had a perfect system for safeguarding valuable space science data stored on magnetic tapes in the past because we have not. We recognize that there is room for improvement and our cognizant managers have been and continue to be dedicated to achieving improvements. Your proposed recommendations reflect concerns that are being addressed in our ongoing and planned programs.

More detailed comments on the draft report are contained in an enclosure to this letter. We recommended that consideration be given to further illumination of the situation through additional discussions and identification of pertinent information which might produce a more balanced report. We are prepared to participate in a continuing dialogue at your convenience.

Sincerely,

John E. O'Brien
Assistant Deputy Administrator

Enclosure

Enclosure

NASA Response to GAO Draft Report GAO/IMTEC-90-1

The following provides specific comments relating to the assertions contained in the Executive Summary of the draft report. This material is organized in the same format used in the Executive Summary in order to facilitate cross-referencing.

"NASA Stores Many of its Tapes Under Substandard Conditions"

While the report cites lack of compliance with the National Archives and Records Administration (NARA) regulations it does not provide any evidence of significant loss of data due to tape handling and storage. In fact, we have to date experienced no significant loss of scientific data as identified by our science customers and, in our periodic tests to determine the degradation of sampled tapes, we have shown a more than satisfactory preservation of data. For example, recently we performed tests of 90 tapes selected from the period 1967 - 1975 in order to determine their continuing utility. Of these 90 tapes, 69 were read without a single "read" error, 10 tapes had less then 3 "read" errors, and the remainder had no more then 5 "read" errors. Of those tapes that had "read" errors, the data could still be retrieved by means of a "re-read" routine. These statistics are excellent indicators of the continuing viability of these data records. We are concerned that results have been subservient to blind compliance with guidelines in the view of the GAO auditors.

With no evidence of loss of data or other explicit tests of their assertions, this report results in a superficial analysis of tape handling, storage, and management, as prescribed by NARA regulations. The study evaluates facilities against a set of uniquely defined rigid standards which are very costly to implement. Most were found to come up short, including Federal Records Centers under NARA auspices where all governmental data is archived. It is interesting to note that NARA itself cited lack of resources to accomplish its "...oversight reviews of NASA's tape management program ...." If the agency establishing the regulations is unable to comply with its own directives, it may be worth reassessing whether the regulations are appropriate and feasible.

See comment 1.

"NASA Has Not Performed an Agency-wide Inventory of Data Holdings"

NASA does have a complete catalogue of all data holdings in all data centers. NASA also has the NASA Master Directory system which provides on-line information to the research community about existing data sets, including archive locations and means to get more information for ordering data products, etc. This major system enhancement is operational and has been extremely well received by the science user community. We are conducting an extensive census effort with our principal investigator community to identify the data sets still in preparation that should be included in archives

Enclosure

and made available to the general research community. As these data sets are identified, they will be added routinely to the NASA Master Directory to provide a complete and easily accessible reference for our entire community. This process was thoroughly described to the auditors during the course of the investigation, although not acknowledged in the Executive Summary of the report.

See comment 2.

The assertion focuses on the mechanics of counts of magnetic tape reels, totally ignoring the essence of the NASA mission which is to manage and make available the data and information stored on that medium.

"Scarce Resources are Used to Store Data of Little or No Value"

The assertion that NASA is using scarce resources to store data that may be of little or no scientific value is without merit and, in light of the activities underway at the time of the audit, particularly troublesome. The example cited refers to 130,000 tapes stored at a federal records center. NASA had initiated and was performing an analysis in conjunction with representatives of the planetary science discipline to determine their scientific value before summarily destroying the total inventory. NASA feels that prior to any decision to dispose of this data, a reasonable effort to determine the value is warranted. This approach is in keeping with the primary objective of not dispensing any space-derived data set without a conscious professional assessment of its ultimate worth to the science community.

The accusation that a group of scientists noted that much of the planetary data archived by the NSSDC are of uncertain quality or accuracy becomes obsolete when one recognizes the time frame of the situation cited. The particular statement appeared in a report documenting a 1983 workshop. Since that time, we have implemented a Planetary Data System that provides electronic access to these data in order for the discipline researchers to perform their analyses. This telecommunications system provides ease of access to the data as it is being analyzed and facilitates early recognition of any problems regarding data quality and accuracy before certification of a data set for inclusion in the archive system. We have also begun to implement a program whereby ongoing research is co-located with repositories of major data sets. This approach assures continuous evaluation of the data for their quality and utility for specific research investigations. The Infrared Processing and Analysis Center (IPAC) for astrophysics research is a model of this concept and is recognized by members of this discipline as a major contribution to the productivity of their research.

See comment 3.

"Data Archiving is Treated as a Low Priority Activity"

We find this assertion to be particularly ironic in light of recent Congressional actions taken with the NASA budget. NASA has continuously sought to assure appropriate funding for the data archival function. In FY 1989, NASA was directed to absorb a $10M cut apportioned between information systems and commercial programs. We were able in that budget to limit the actual reduction for information systems to $2.5M. In FY 1990, the Associate Administrator for Space Science and Applications took the initiative to submit a budget that increased funding for archiving by $3M in

Enclosure

FY 1990 and growing to over $5.0M in subsequent years. Final action by the Congress on the FY 1990 budget request was to direct a reduction of $5M in the overall information systems program.

Notwithstanding the statement by GAO that overall responsibility for data archiving has not been assigned, it is clear within NASA that management of our space-acquired data assets is assigned to the Office of Space Science and Applications (OSSA) These duties are accomplished within broad institutional policies and guidelines for information resources management provided by the Office of Management. The Communications and Information Systems Division has principal responsibility within OSSA for ensuring that science data are archived and made available to the general science community. This is accomplished in close conjunction with the science discipline divisions within OSSA where specific flight and research programs are implemented. A key element for implementing the archive program is the National Space Science Data Center which has been assigned since 1967 the responsibility for preserving project generated data.

Balancing our resources for data acquisition with those for data management and archiving is also a significant effort in the early planning and implementation of each of our new flight projects. Our "new start" cost reviews require that specific attention be given to addressing the resources required for ongoing data management. OSSA has implemented a NASA policy which requires that each flight project office generate a Project Data Management Plan (PDMP) which establishes detailed understanding of the expected data volume and characteristics, the data processing system design, and anticipated delivery schedules for archival data delivery.

The importance of long-term data management issues as a priority at the onset of a project is demonstrated by the Data Archival and Distribution System (DADS) for Hubble Space Telescope (HST) and the Data and Information System (DIS) for Earth Observing System (EOS) projects. In both examples, active forethought has been given to archival and distribution of data products of assured quality through the extended lifetime of their respective projects. The importance and criticality of science data handling to the success of the EOS mission is reflected by the fact that it represents one of the largest elements in overall program resource estimates.

In addition, OSSA has initiated an Information Systems Strategic Planning Project that has involved the space science research community as well as the Agency's operational elements to provide guidance on an appropriate approach to this overall function. The project report is in final preparation for publication and implementation has begun within OSSA as well in the Office of Space Operations.

See comment 4.

"Recommendations"

As evidenced by NASA's recognition in the worldwide science community as the foremost leader in providing scientific results from its flight missions and subsequent analysis, we cannot accept the reference to "chronic deficiencies in NASA's management of the existing space science data." Our record demonstrates that we have created a system that is responsive to the needs

Enclosure

See comment 5.

of the user community and reflects a conscientious effort to continue to recognize the need for continued evolution. We cannot identify any evidence of loss of critical data sets due to mismanagement or lack of systematic processes that guard the integrity of our archives. In our judgment, all of the recommendations are being addressed in our present ongoing programs and are being reflected in the evolution of our management of this function. We believe that this function is receiving continuing management attention and ongoing processes are in place to assure that we do not slacken our attention. It is truly unfortunate that the GAO (GAO/IMTEC-90-1) report does not capture this aspect of our management.

Enclosure

The following are GAO's comments on the National Aeronautics and Space Administration letter dated January 5, 1990. NASA limited its detailed comments to the draft executive summary of this report.

GAO Comments

1. "NASA Stores Many of its Tapes Under Substandard Conditions"

According to NASA, our report contains no evidence of any significant loss of data due to tape handling and storage, and its periodic tests to determine the degradation of sampled tapes show that it is satisfactorily preserving data. NASA says that with no evidence of loss of data or other explicit tests of our assertions, our report results in a superficial analysis of tape handling, storage, and management, as prescribed by NARA regulations. NASA also suggested that NARA may need to reassess whether its regulations are appropriate and feasible.

We disagree. First, we believe we have cited sufficient evidence of a major risk to NASA data. According to JPL officials with substantial experience and expertise in tape management and restoration, data have been lost. JPL estimates that about 50 percent of the 130,000 tapes it had originally stored at a federal records center may be damaged beyond recovery or contain data of little or no value. This evidence, combined with the serious physical storage conditions we noted elsewhere, substantiates our concern that NASA's space science data stored on magnetic tapes are at serious risk of becoming partially or completely unusable.

Second, NASA's assertion that its periodic testing of stored tapes provides excellent indicators of the continuing viability of its tapes is misleading. NASA's use of the word periodic implies that it has a regular ongoing program to monitor the condition of its tapes. Although NARA requires that each tape storage facility annually sample its tape holdings to detect tape deterioration, none of the facilities we visited performed the mandatory annual tests. Further, the test NASA referred to was a single test of 90 tapes, which is insufficient to detect tape deterioration and data losses because the sample NASA used was not statistically valid and represented only a small fraction of the 113,000 tapes stored by NSSDC. Therefore, the results cannot be projected to NSSDC's overall tape holdings, nor can they be projected to tape holdings maintained by NASA in other facilities. We considered performing actual tests for readability, but chose not to because of a very serious tape restoration problem discovered by JPL and the potential risk of losing NASA's valuable data. As explained on page 31, JPL found that trying to read tapes over 10 years old can often destroy them.

Third, regarding NARA's regulations, we believe that NASA had ample opportunity to challenge NARA's tape management regulations when they were published for comment in the Federal Register.[1] In commenting on the proposed revisions, NASA did not challenge two of the key tape management regulations—temperature and humidity control, and annual testing of stored tapes,[2] —and went further to suggest that the

"requirement to maintain magnetic computer tapes at a constant temperature of 62-68" F and a constant relative humidity of 34-35% should apply to Federal records centers also, because all of them do not provide these conditions."

Also, NASA did not challenge NARA's regulation for annual sampling and testing of stored tapes to detect deterioration. In commenting on a regulation directing agencies to copy permanent data before the tapes are 10 years old on to tested and verified new tapes, NASA did argue that this regulation may be costly, but suggested that this regulation "should be determined by the annual 3 percent test results."

2. "NASA Has Not Performed an Agency-wide Inventory of Data Holdings"

NASA's position that each of its data centers has a complete catalogue of all data holdings and that its Master Directory provides on-line information to the research community does not negate our finding that NASA does not maintain a central inventory of its magnetic tapes containing space science data. First, while we noted that each facility we visited maintained a tape and data inventory, these inventories were of varying quality and completeness. Second, the NASA Master Directory does not keep information on individual magnetic tapes, but provides limited information about data sets in selected scientific disciplines. According to NASA officials, the directory contains approximately 1,000 data sets, thus representing only a small fraction of the existing space science data now stored on magnetic tapes.

NARA requires that each agency maintain a complete inventory of its magnetic tapes. This regulation is designed to provide information needed for the development of specific disposition instructions for data stored on tapes, including retention periods for temporary and permanent records. NARA officials noted that in the past NASA has refused to

[1]Federal Register (53 FR 48936), December 5, 1988.

[2]NASA's "Comments on Proposed Revision of Code of Federal Regulations, Title 36, Chapter 12, Part 1234, Electronic Record Management," February 6, 1989.

perform such an inventory, noting that NARA's inventory regulation was too "intrusive."

About October 1989, NASA launched a commendable effort to inventory its tapes. At the time we completed our work, this "census" effort was limited to tapes managed by Goddard and JPL. In January 1990, NASA told us it planned to expand this census to include additional locations, but gave no specific details on the scope of this effort. Chapter 3 details NASA's Master Directory and its ongoing tape census.

3. "Scarce Resources are Used to Store Data of Little or No Value"

This section, although now deleted from the executive summary, is discussed on pp. 33 to 34 of the report. NASA asserts that our finding is without merit, but we disagree. The evidence we used to support our concern that scarce resources may be used to store some tapes that may contain data of marginal value is based on information obtained at two locations—JPL and NSSDC. According to JPL officials familiar with its restoration efforts, about half of the 130,000 tapes formerly stored at the Federal Records Center were probably damaged or degraded beyond restoration, or contained data no longer worth keeping. Thus, about 65,000 tapes kept by JPL in storage contained data of little or no value or data that cannot be restored.

In regard to the variable quality, questionable accuracy, and low resolution of the planetary data archived by NSSDC, NASA comments that the statement made by the planetary scientists in 1983 is now obsolete since NASA has implemented the Planetary Data System that provides electronic access to these data so the discipline researchers can perform their analyses. This implies that (1) NASA has improved the quality, accuracy, and completeness of these data, and (2) these data were transferred from NSSDC and are currently resident in the Planetary Data System.

We disagree with these implications. According to its manager, the system incorporates only a fraction of these data. The system is restoring data from past planetary missions, and plans to incorporate them in its data base. But there is no schedule for completion of this effort, which, in any case, depends on funds NASA allocates.

Nonetheless, we did note on p. 34 that NASA has taken steps to strengthen its archiving of planetary data through the Planetary Data System. If the conditions noted in the planetary data also applied to

data from other scientific disciplines, other tapes may contain data of marginal value.

4. "Data Archiving is Treated as a Low Priority Activity"

According to NASA, it has continuously sought to assure appropriate funding for the data archival function, but budget cuts in fiscal years 1989 and 1990 prevented it from doing so. The management of space-acquired data is assigned to the Office of Space Science and Applications, which, through project data management plans, requires new missions to specifically address the resources required for ongoing data management. Its commitment to long-term data management and preservation is demonstrated in the development of data systems designed to support new missions, including the Hubble Space Telescope and the Earth Observing System and by the Information System Strategic Planning Project.

We could not substantiate NASA's funding assertions for prior years, as well as fiscal years 1989 and 1990. Although Congress cut NASA's information systems budget both years, NASA officials could not document its plans to allocate additional resources to (1) improve its management of magnetic tapes containing space science data from its past missions beyond those resources allocated to the limited data restoration and data census activities, and (2) upgrade its tape storage facilities to conform with federal regulations.

We do not dispute that responsibility for data archiving is assigned to the Office of Space Science and Applications. Our point is that this office, for past missions, "did not adequately lead and manage projects, field centers, and facilities that manage, store, and archive data." In light of the deficiencies we noted during our visits to NASA's tape storage facilities, including the massive volumes of poorly maintained tapes stored in what NASA officials themselves described as "deplorable conditions," we could not conclude otherwise. Moreover, our concerns regarding the poorly defined management structure and responsibilities are also shared by NARA. In commenting on this report, the Archivist of the United States noted that, based on NARA's experience, our conclusion that NASA views data management as a low priority activity was not limited to data management, but also applied to records management as well.

We believe NASA's emphasis on ensuring that its new missions pay specific attention to the allocation of data management resources is a positive step that may help to ensure the preservation of valuable data from future missions. We applaud NASA's decision to require that each mission prepare a project data management plan. Yet, although this requirement was established in 1978, it has not been enforced. Not one NASA mission launched between 1978 and 1987 prepared such a plan.

We agree that new and sophisticated data management systems and strategies is another positive step in the long-term management and preservation of space science data to be acquired by the future missions. However, as evidenced by our findings, we did not find a similar commitment to the preservation of data acquired by the past missions.

5. "Recommendations"

Citing its recognition in the worldwide science community as the foremost leader in providing scientific results from its missions, NASA cannot accept the reference to chronic deficiencies in its management of existing space science data. NASA notes that it cannot identify any evidence of loss of critical data sets due to mismanagement or a lack of systematic processes that guard the integrity of its archives. We disagree.

Although NASA appears to be heading in the right direction towards handling data from future missions, we do not believe the deficiencies in managing data from past missions occurred overnight. Beginning with early spacecraft, data began to accumulate. Although the problems may have been insignificant at first, NASA now has well over 1 million tapes that must be identified, maintained, and, where appropriate, preserved for future science generations. In light of the poor storage conditions we noted at several locations, combined with the lack of proper maintenance, we believe that NASA would find data losses if it complied with NARA's regulation and periodically sampled its tape holdings to detect tape and data deterioration. JPL's current restoration of the 130,000 tapes formerly stored at the Federal Records Center in Laguna Niguel substantiates our concerns and provides NASA with a wealth of information on the effects of a substandard tape storage environment on magnetic tapes and on the extent of data losses. We suggest that NASA use this information to develop programs designed to protect the hundreds of thousands of magnetic tapes stored without adequate environmental controls in other NASA and contractor tape storage facilities.

NASA stated that our recommendations were being addressed in its present ongoing programs and were being reflected in the evolution of its management of this function. While we agree that NASA is planning to partially implement two of our recommendations, it is too early to evaluate if these or other planned actions will be successful.

NARA's Comments and GAO's Response

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

National Archives

Washington, DC 20408

DEC 27 1989

Mr. Ralph V. Carlone
Assistant Comptroller General
Information Management and
Technology Division
General Accounting Office
Washington, DC 20548

Dear Mr. Carlone:

The National Archives and Records Administration (NARA) is pleased to provide comments on your draft report entitled SPACE OPERATIONS: NASA Is Not Properly Safeguarding Its Valuable Space Science Data (GAO/IMTEC-90-1).

Based on our experience with NASA, the report's assertion that data management has a low priority within NASA is applicable to records management as well. We would also like to point out that the records management function in NASA is separate from the organization responsible for the "data archiving" at the National Space Science Data Center, the Tape Staging and Storage Area, and the Jet Propulsion Library. While the NASA records managers know about NARA tape requirements, the requirements are not being effectively articulated to NASA program managers.

We support the report recommendation for an inventory of NASA's data tapes. NARA has recognized a need for this, as well as for non-electronic records, but in the past NASA has refused to undertake an inventory. As one earlier assessment put it, NASA's position was that NARA's records management requirements were too intrusive.

NARA has been working with NASA in the areas of records management mainly related to revision of the NASA records disposition schedule. As pointed out in the report, NARA has not inspected NASA. This is due to a combination of factors: the massiveness of the undertaking, our own requirements in other areas, and the expectation that records scheduling and NARA/NASA relations would improve significantly as a result of Saving the Right Stuff. We have seen movement in some areas, and have been working with NASA regularly for over five years. We will consider inspecting NASA, as the report recommends. If we decide to do so, the inspection could not begin until FY 1991.

National Archives and Records Administration

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We continue to disagree with the report's rating of Federal Records Center compliance with fire and water protection requirements. From both cost and operating viewpoints, it is not feasible to provide separate storage areas for computer tape storage in the present Federal Records Centers to preclude storing tapes with combustible paper records. We would like to point out that the cited paper records fire in the Washington National Records Center was caused by arson which could just as well have been set in computer tape storage. Computer tapes are also combustibles with approximately twice the BTUs when compared to the same volume of paper records.

Floor water detectors are more appropriate for relatively small computer facilities and tape libraries, rather than the 40,000 square foot records storage areas in Federal Records Centers that have all records shelved at least three inches above the floor level. Moreover, the Federal Records Centers are equipped with automatic sprinklers with water flow alarms to a central station or fire department with responsibility to respond at any time.

We would also like to point out two inaccuracies in the draft report. On page 30, the NARA requirement for preparation of archival tapes is misstated. 36 CFR 1234.4 (a) states that all tapes used to record information for permanent retention should be tested and certified no more than 6 months before use. On page 50, the draft report contains inaccurate statements regarding earthquake damage to the Los Angeles Federal Records Center. No boxes containing JPL magnetic tapes fell from shelves and the ceiling tile collapse was limited to space outside the records storage area.

Finally, we believe that the discussion on page 83 of the 70,000 National Space Science Data Center tapes at the Washington National Records Center (WNRC) needs clarification. As noted later in Appendix III, the WNRC has been rated as partially complying with environmental controls and has achieved full compliance with access control requirements.

We appreciate this opportunity to comment on the draft report. If you have any questions about our comments, please call James Megronigle on 523-3621.

Sincerely,

DON W. WILSON
Archivist of the United States

The following are GAO's comments on the National Archives and Records Administration letter dated December 27, 1989.

GAO Comments

NARA disagreed with our findings that the Washington National Records Center and the Federal Records Center in Laguna Niguel are in partial compliance with fire and water protection guidelines, noting that (1) it is not feasible to provide separate storage areas for computer tapes, and (2) water detectors are more appropriate for relatively small computer facilities and tape libraries.

According to NIST and industry guidelines, magnetic tapes should not be stored together with large volumes of paper records, regardless of whether the storage areas are equipped with automatic fire sprinklers or not.

In regard to the two inaccuracies in the draft report identified by NARA (incorrect citation of NARA regulation and the extent of earthquake damage at the Federal Records Center in Laguna Niguel), we corrected the identified citation, but we disagree with NARA's assertion regarding the earthquake damage. In a memorandum prepared by JPL staff following their visit to the Federal Records Center in Laguna Niguel, the staff noted:

"Visiting the area, we noted that the steel shelves, which are about eight feet tall and three feet wide, were moved two inches to the side, toppling several boxes of our tapes from the top shelf to the floor. We were told that many sections of the acoustical ceiling were shaken loose and fell onto the boxes of tapes, as well as the floor."[1]

[1]JPL Interoffice Memorandum - Federal Archives Earthquake Damage, July 14, 1986 (emphasis added).

GSA's Comments

[illegible] 1 4 1989

Mr. Ralph V. Carlone
Assistant Comptroller General
Information Management and
  Technology Division
General Accounting Office
Washington, DC 20548

Dear Mr. Carlone:

This is in response to your letter of November 27, 1989, requesting comments on draft General Accounting Office Audit Report GAO/IMTEC-90-1.

Chapter 4: Conclusions and Recommendations, under the subparagraph "Recommendation to the GSA Administrator", recommended "...that the Administrator periodically review and inspect NASA's records management practices as required by the Federal Information Resources Management Regulations."

General Services Administration has strengthened its Procurement and Management Reviews Branch which is responsible for review of Information Resources Management programs at the Federal agencies. In the January-March 1990 timeframe, this branch will conduct an Information Resources Procurement and Management Review at the National Aeronautics and Space Administration. The final report will be made available to GAO.

If additional information is needed, please contact either Thomas Horan on 566-1332 or Douglas Arai on 566-1180.

Sincerely,

for Wanda R. Kopacz

Thomas J. Buckholtz
Commissioner

Major Contributors to This Report

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