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A Guide To The National Space Science Data Center

June

1990

NASA
Goddard Space Flight Center
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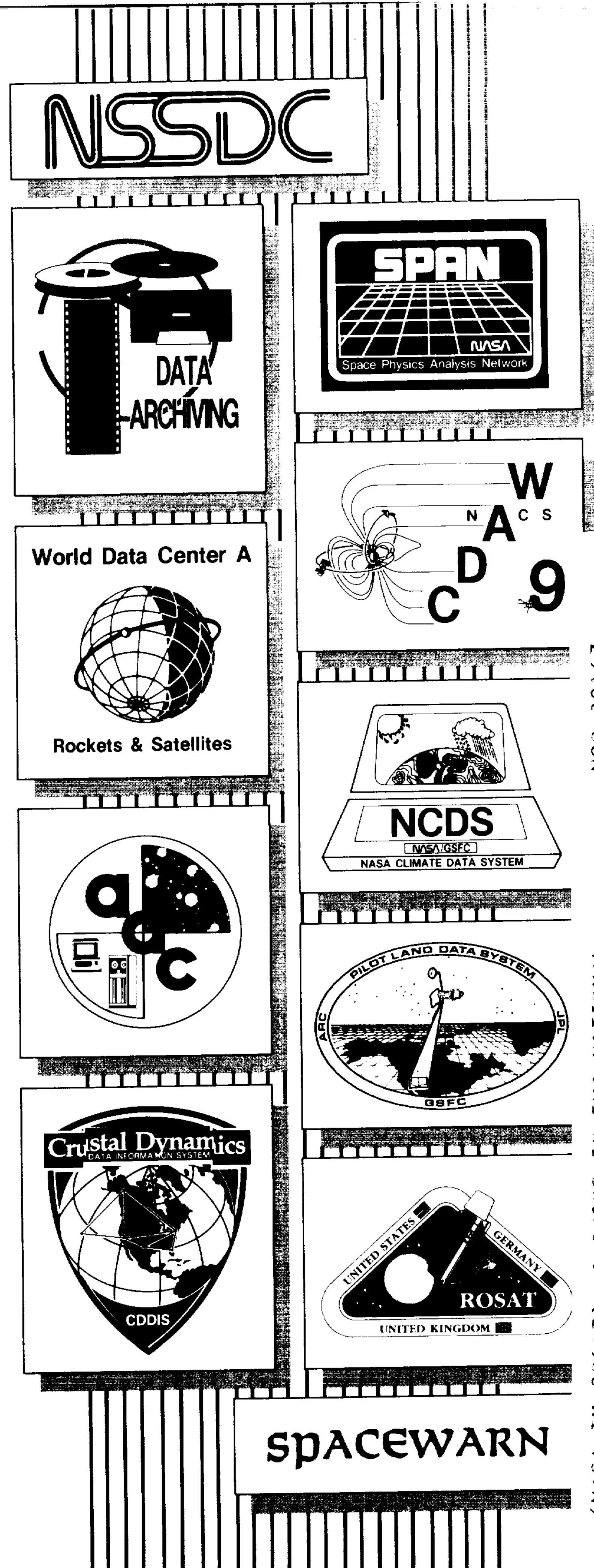

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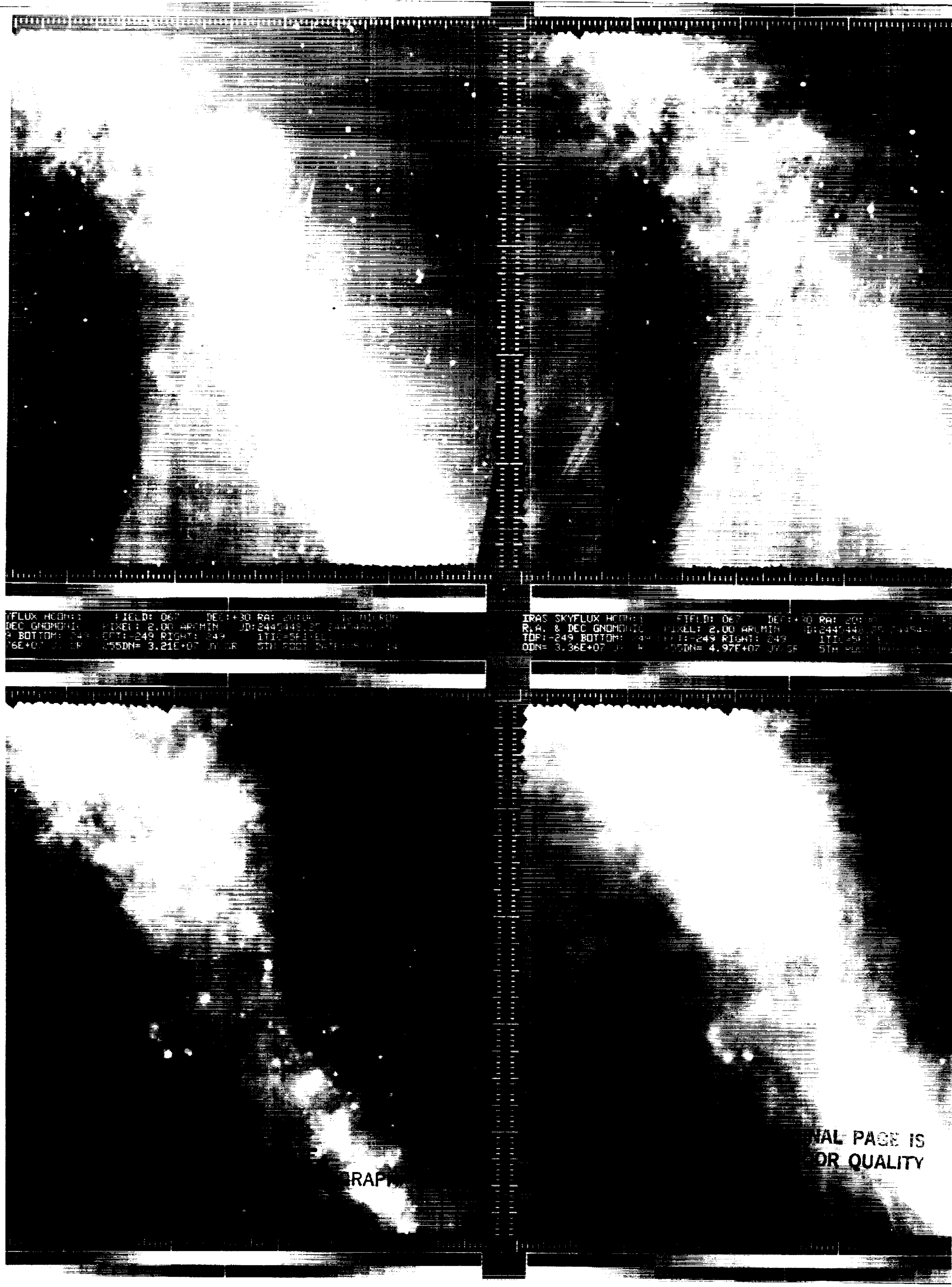
PREFACE

This is the second edition of a document that was published to acquaint space and Earth research scientists with an overview of the services offered by the National Space Science Data Center (NSSDC). As stated in the previous edition, the NSSDC was established by the National Aeronautics and Space Administration (NASA) over 20 years ago to be the long-term archive for data from its space missions. However, the NSSDC has evolved into an organization that provides a multitude of valuable services for scientists throughout the world. This document includes brief articles concerning these services. At the end of each article is the name, address and telephone number of a person to contact for additional information concerning that particular service.

NSSDC personnel are highly talented individuals, skilled in a variety of scientific and technological disciplines. Together they strive for a common goal and that is to provide the research community with data and attendant services in the most efficient, economical, and useful manner possible, both now and in the future.

I would like to thank those who contributed articles for this document. A special thanks goes to Lloyd Treinish, William Campbell, and Dr. Joseph King for their technical assistance. Special thanks also go to Len Blasso and Miranda Knowles (Science Applications Research) for their editorial assistance, and to Rudy Pauley and his staff (NYMA) for the marvelous prints of satellite and shuttle imagery. And finally, thanks to Charlotte Griner (McDonnell Douglas Space Systems Company) for compiling and preparing the document for publication.

Dr. James Lauer Green, Director
National Space Science Data Center
June 1990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NSSDC NATIONAL SPACE SCIENCE DATA CENTER

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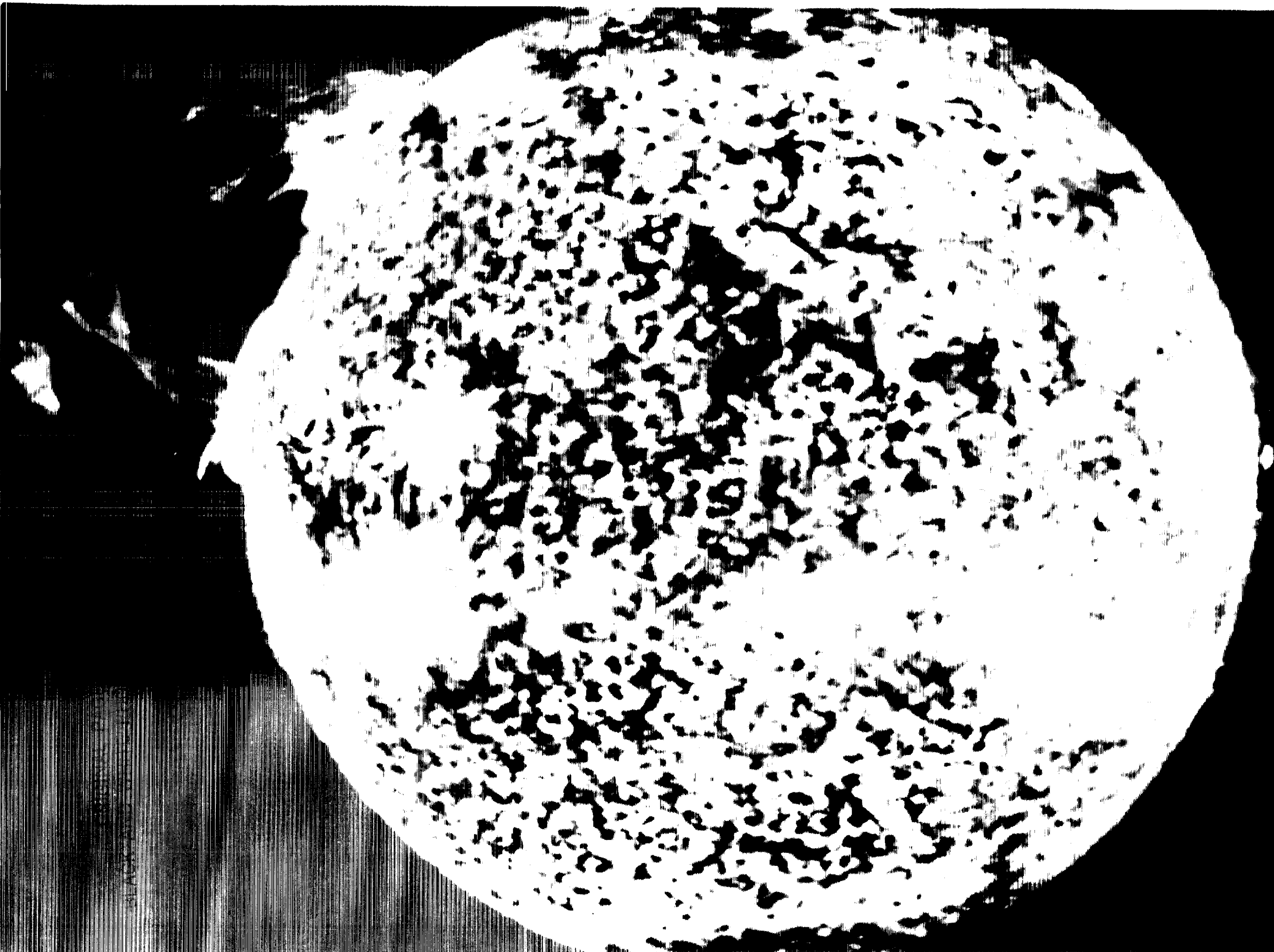

Chapter 1

INTRODUCTION

THE NATIONAL SPACE SCIENCE DATA CENTER

The National Space Science Data Center (NSSDC) was established in 1966 by NASA to further the use of data obtained from space and Earth science investigations, maintain an active data repository, and support scientific research. The NSSDC supplies the means for widespread dissemination of data beyond that provided by the original investigators. These services are provided to foreign requesters through the World Data Center A for Rockets and Satellites (WDC-A-R&S), which is located within the NSSDC at the Goddard Space Flight Center (GSFC).

The NSSDC actively collects, organizes, stores, announces, disseminates, exchanges, and refers to a large variety of scientific data that are obtained from spacecraft and ground-based observations. Disciplines that are represented include astronomy, astrophysics, atmospheric sciences, ionospheric physics, land sciences, magnetospheric physics, ocean sciences, planetary sciences, and solar-terrestrial physics. The data are contained on more than 120,000 magnetic tapes, tens of thousands of film products, and optical, video, and magnetic disks. The NSSDC periodically publishes information catalogs and data inventories for the entire archive, a subset of which is maintained on line and is reachable over many international computer networks.

The primary responsibility of the NSSDC is to ensure accessibility and utilization of NASA spaceflight mission data; however, some data provided by non-NASA sources are also maintained. In addition, the archive includes important comprehensive information about the data, such as general documentation, indexes, and any transportable, well-documented software.

As the volume and complexity of space and Earth science data grow and the requirements of the scientific community expand, the traditional data management approach must be augmented. This is especially important for correlative studies of multidisciplinary data sets. A unique staff of computer science professionals at the NSSDC is pursuing a vigorous program in advanced data system development and computer science research to meet these challenges.

Much of the research performed in the space and Earth sciences is based on cooperative efforts among separate research groups. To enable these groups to communicate easily and share software and data, the NSSDC manages the Space Physics Analysis Network (SPAN), an international network of thousands of computers supporting a full range of scientific disciplines. The NSSDC is continually investigating and applying new communications technology to increase the reliability, performance, and transmission capacity of the network.

In 1978, the NSSDC constructed a centralized data base system containing a diverse collection of geophysical parameters. This initiative addressed the need of the International Magnetospheric Study community for a mechanism to facilitate collaborative data analysis. That data base was used at the first Coordinated Data Analysis Workshop (CDAW). Since then, other distinct data bases have been built. Several CDAWs have been hosted at local and remote sites to allow rapid access, manipulation, and comparison of exciting solar-terrestrial data. The CDAW concept has evolved into an advanced data analysis system that is being applied to several other disciplines.

Recognizing the need and advantages of online interactive search for data, the NSSDC has designed a Master Directory to aid users in selecting and locating data sets by keyword search or by spacecraft, experiment, and investigator specifications. Discipline-oriented advanced data systems such as the Crustal Dynamics Data Information System (CDDIS), NASA's Climate Data System (NCDS), and the Pilot Land Data System (PLDS) are now managing an expanding collection of atmospheric, land, and ocean science data. In addition to allowing easy online access to data, these systems also provide comprehensive information about data and employ a discipline-independent abstraction for complex data to support generic display and analysis tools. This approach has evolved into a standard method for storing space and Earth science data for a variety of applications, and is known as the NSSDC Common Data Format (CDF).

The ability to provide pictorial or visual representations is critical to the understanding of data, particularly for correlative data investigations. The NSSDC Graphics System (NGS) uses the latest methods in computer graphics and imaging, and state-of-the-art hardware. Along with the endeavors in generic data display, the NSSDC has a continuing program of developing new tools to manipulate and analyze arbitrary data streams. These include methodologies by which a user can compose customized analysis algorithms and couple them with any data and with sophisticated display techniques.

Techniques are being developed to enable the distributed management of both homogeneous and heterogeneous data bases independent of location, organization, discipline, architecture, or format. The Distributed Access View Integrated Database (DAVID), a prime example of such research and development, provides uniform viewing or access to multiple data bases.

Research is ongoing in the development of an end-to-end Intelligent Information Fusion System (IIFS). This requires the development of intelligent user interfaces, spatial data management, automatic data labeling and cataloging capabilities, object-oriented DBMSs, advanced data structures and knowledge acquisition tools. Such a system would remove the need for a data system user to understand the current data or information content, system architecture or query language, thereby significantly improving user performance.

The NSSDC is striving to develop truly modular software that is easily and inexpensively maintained, with well-defined interfaces and functionality. This approach enables such software to be portable so that it can be shared among the NSSDC and other computer facilities.

The scientific acquisition staff at the NSSDC works closely with projects and Principal Investigators (PIs) in various disciplines to ensure that incoming data are of the highest quality and the greatest utility to the entire scientific community. These scientists are available to work with individual NSSDC users to address their specific requirements. They are also dedicated to data analysis and generation of "value-added" data, which may be of special interest and convenience to a subset of the scientific community. For example, real-time data were collected and transmitted to the PIs over SPAN during the historic encounter of the International Cometary Explorer (ICE) with the comet Giacobini-Zinner in September 1985, and the Voyager encounters with the outer planets: Jupiter, Saturn, Uranus, and Neptune.

In its role as WDC-A-R&S, the NSSDC serves as the World Warning Agency for Satellites (WWAS) and, as such, it assigns unique international identification numbers to spacecraft as they are launched and announces these launches on behalf of the Committee on Space Research (COSPAR) through telexes and the monthly publication of the *SPACEWARN Bulletin*.[51]

The NSSDC also operates the Astronomical Data Center (ADC), which acquires, checks, maintains, documents, and distributes machine-readable astronomical catalogs of non-solar-system objects. Over 500 such catalogs are in the ADC archive.

The NSSDC distributes the *NSSDC News*[38] quarterly. New data sets, methods, services, and other items of interest are discussed in the newsletter. In addition, it publishes user guides and tutorials for its interactive software systems, programmer guides for its software products, and reports on its research activities.

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WORLD DATA CENTER A FOR ROCKETS AND SATELLITES

The World Data Center A for Rockets and Satellites (WDC-A-R&S) is operated by the NSSDC (see *Guide to the World Data Center System, Part 1, The World Data Center System*[26]).

The subcenters for rockets and satellites do not hold any data, contrary to the role of other discipline subcenters in the World Data Center System. However, all data and services of the NSSDC are available to professionals outside the U.S. through WDC-A-R&S.

Many of the NSSDC publications are issued jointly with WDC-A-R&S. Examples are detailed catalogs and spacecraft listings, such as the *Report on Active and Planned Spacecraft and Experiments (RAPSE)*,[25] which lists satellites currently operating in space or planned for future launch, with details of orbits, instruments and project scientists. It operates the WWAS and the SPACEWARN System for the International URSIGRAM and World Days Service (IUWDS). In this capacity, it formally assigns international spacecraft identifications on behalf of COSPAR and publishes special data reports for selected satellite programs such as the monthly *SPACEWARN Bulletin*,[51] which contains timely information about satellite launches.

The center is open to visitors from all countries during normal working hours; however, advance notification is recommended.

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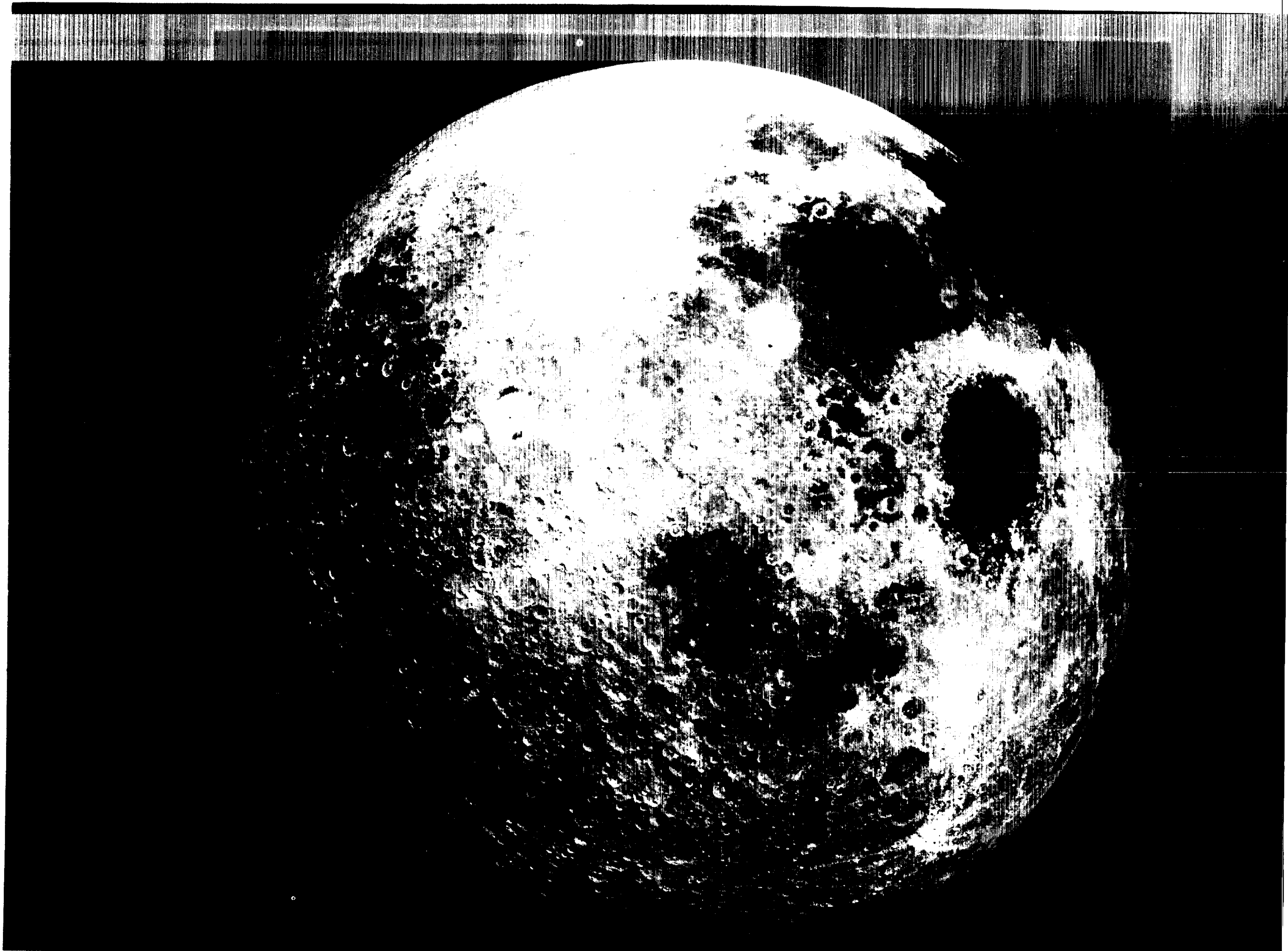

CHAPTER 2

ONLINE INFORMATION AND DATA SYSTEMS

NSSDC ONLINE SERVICES

The NSSDC is making an increasing number of data sets and services available on line to facilitate rapid access over networks and dial-up lines. This is as an alternative to the classical mode of replicating and mailing data volumes (e.g., magnetic tapes) in response to requests mailed or telephoned to the NSSDC.

Some of the services which are discussed in detail elsewhere in this document are funded out of specific NASA discipline organizations for the benefit of scientists supported by those offices. These cases, including NCDS, PLDS, and CDDIS, require that users have individual accounts on the NSSDC Computer Facility (NCF).

Other services are offered through the NODIS system (NSSDC account) on the NCF. This account is available nearly 24 hours a day, 7 days a week to anyone who can reach the NSSDC computers via dial-up or via networks (see Chapter 3 titled *Electronic Access*). The services typically involve access via menus to information or limited amounts of data, and do not involve much central processing unit usage. As of this writing, such access is free.

Data available via this NSSDC account include International Ultraviolet Explorer (IUE) extracted spectra data, Nimbus 7 Gridded Totai Ozone Mapping Spectrometer (TOMS) and Coastal Zone Color Scanner (CZCS) data, and the OMNI data set of hourly solar wind parameters. Information items include the (not yet fully populated) NASA Master Directory, a personnel data base containing over 30,000 users of NSSDC services, and the American Institute for Aeronautics and Astronautics (AIAA) Canopus newsletter. Access to ionospheric (IRI), atmospheric (MSIS), magnetospheric magnetic field, and magnetospheric energetic trapped particle (AE8 and AP8) models are available for downloading or executing. One option enables free form communication with the NSSDC, with which requests for offline data services may be made.

It is anticipated that the volume and range of data available electronically from the NSSDC will increase greatly in the coming years. It is possible that the informational aspects of the data systems whose access now requires individual accounts may be folded into the free-access NSSDC account.

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THE NASA MASTER DIRECTORY

The NASA Master Directory is an online search system providing brief overview information about NASA and important non-NASA space and Earth science data, and online information systems. In many cases the directory offers automatic network connections to online information systems where more detailed information about data of interest may be obtained. Often, the data may be directly accessed or ordered through these online systems. The Master Directory is easily accessed via network or dial-in lines (see below), and can be used by an inexperienced person without the need to consult a user's manual (online help is available).

The user may search for data of interest through a variety of methods such as measured parameter, science discipline, location or spatial coverage, overall time period, data source (e.g., spacecraft, ground observatory), sensor, investigator, campaign or project, etc. The information displayed by the directory includes a descriptive title, summary abstract, key references, persons to contact, archive information, storage media information, and the values associated with the search keywords mentioned above. If a connection to another system with more detailed information is available, the connection can be invoked through the use of a simple LINK command.

If the user just wishes to use particular information systems, the directory will provide a list of such systems as well as options to link to them if such a connection is possible. NASA discipline-oriented data systems such as the Planetary Data System (PDS), NCDS, NASA Ocean Data System (NODS), PLDS, and directories of other government agencies such as the National Oceanographic and Atmospheric Administration (NOAA) are important examples.

Currently, the method of access to the NASA Master Directory depends on the user's mode of connecting to the NSSDC computers. To access it from a computer connected to SPAN, the user should issue the command SET HOST NSSDCA at the $ prompt, followed by the entry of NSSDC to the Username: prompt. No password is required. Entry to the Master Directory as well as to other online services available from the NSSDC is offered in the initial menu. Dial-in users should call (301) 286-9000 (FTS 888-9000) and enter NSSDCA at the ENTER NUMBER: prompt, then proceed as stated above with the Username: prompt. For access through Internet, use the command TELNET 128.183.10.4 or TELNET NSSDCA.GSFC.NASA.GOV, enter NSSDC again at the Username: prompt, and proceed as above. These procedures are subject to change, so inform the contact person at the address listed below if you are having problems.

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INTERNATIONAL ULTRAVIOLET EXPLORER REQUEST SERVICE

The International Ultraviolet Explorer (IUE) spacecraft, launched in January 1978, was placed in a geosynchronous orbit over the Atlantic Ocean, enabling operations around the clock. The satellite was jointly developed by NASA, the European Space Agency (ESA), and the British Science and Engineering Research Council (SERC). IUE is currently NASA's only operating spaceborne telescope.

A network request service is available that allows IUE archival data to be requested and transmitted via SPAN from the NSSDC to the requester's node. For requesters desiring a small number of spectra, the use of SPAN eliminates the need to use magnetic tapes.

To acquire IUE data over SPAN, a requester must log onto the NSSDC account and select the IUE item from the menu. The requester will receive a prompt for the necessary information. The requested spectra will be retrieved from an IBM 3850 mass storage system or a raw data tape archive and placed on local NSSDC systems. The requester will then be notified that the data are available for a specified period of time, during which the data may be copied via SPAN to the requester's node. If the requested spectra are not available from the mass storage, a message will be sent describing the current status of the request.

The Uniform Low Dispersion Archive (ULDA) is a compacted subset of the IUE archive that is accessible via SPAN from within the NSSDC account. The purpose of the ULDA is to allow a "quick look" at selected data to determine its usefulness before requesting the complete spectral image.

The NSSDC is the national host for users of the ULDA system within the United States, and to astronomers in other countries that do not have an established national site. The NSSDC is running ULDA version 2.0 which contains 37,236 low resolution spectra taken before January 1, 1987. The images contained in the ULDA have not been reprocessed with the latest version of the IUE Spectral Image Processing System (IUESIPS).

Any user can directly access the ULDA data or search routines. Through a series of search and save file menus a user can initiate a new search for data or recover a previous file that may not have been successfully networked to the user's node. The search menus start with a specific search target and regress to a wider more general search window with each menu display. A "?" in any of the search displays could yield further examples and/or clarification of what is expected within that particular panel.

In order to view the images selected, the user will need a program called UNSPL to decompress the compacted files retrieved. Both the UNSPL program and an *ULDA User's Guide*[41] are available by contacting the NSSDC ULDA manager at (301) 286-2899, or via SPAN at NCF::ULDA.

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ROSAT MISSION INFORMATION AND PLANNING SYSTEM

The Roentgen Satellite (ROSAT) Project is a cooperative venture between the United States, Federal Republic of Germany (FRG), and the United Kingdom (UK). The purpose of the ROSAT mission is to study stellar X-ray sources in the manner of the Einstein Observatory. The ROSAT spacecraft, designed and operated by the FRG, is managed by the Deutsches Forschungs Anstalt fuer Luft und Raumfahrt (DLR) on behalf of the Bundes Ministerium Forschung und Technologie (BMFT), and will fly three major instruments: a Position Sensitive Proportional Counter (PSPC) designed and built by the FRG, a High Resolution Interferometer (HRI) designed and built by the U.S., and a Wide Field Camera (WFC) designed and built by the U.K. The ROSAT Satellite is tentatively scheduled to be launched in May 1990.

The Space Data and Computing Division at GSFC was selected to develop and support the U.S. ROSAT Science Data Center (USRSDC). The NSSDC will eventually be responsible for the public dissemination of the ROSAT data following the mission. To ease the transfer of the data into the NSSDC archives, NSSDC was chosen to design the mission planning software to create, maintain, and track ROSAT Observation Requests (RORs). The RORs comprise the body of the ROSAT data of interest to the public.

As a first effort, the Mission Information and Planning System (MIPS) (see Figure 1) was developed to assist scientists in preparing ROSAT proposals for observing X-ray sources by the ROSAT satellite in response to the ROSAT NRA. The MIPS is also used to support NASA Headquarters and the ROSAT Users Committee with the evaluation, selection, and scheduling of U.S. proposals. It also provides necessary schedules and reports to NASA Headquarters, the U.S. ROSAT User Committee, and general observers, and will directly interface with the West German mission planning software. Mission planning personnel will use the resulting observation schedules as a basis for the tracking of the processed data and its subsequent archiving in the NSSDC. Guest observers will be able to access information on approved targets and processing completion dates.

MIPS supports guest observers in determining targets of interest, coordinating proposals, and inspecting the catalog of ROSAT observations, and the catalogs of previous X-ray astronomy missions of the

Einstein Observatory and the ESA's European X-Ray Observation Satellite (EXOSAT). It also provides an electronic mail facility to enable communication between general observers and an online bulletin board for the review of common observer news and information.

MIPS has been implemented on a dedicated DEC MicroVAX II system utilizing the INGRES data base management system. This MicroVAX II is presently a node on the SPAN network, the ARPAnet/Internet network and BITnet.

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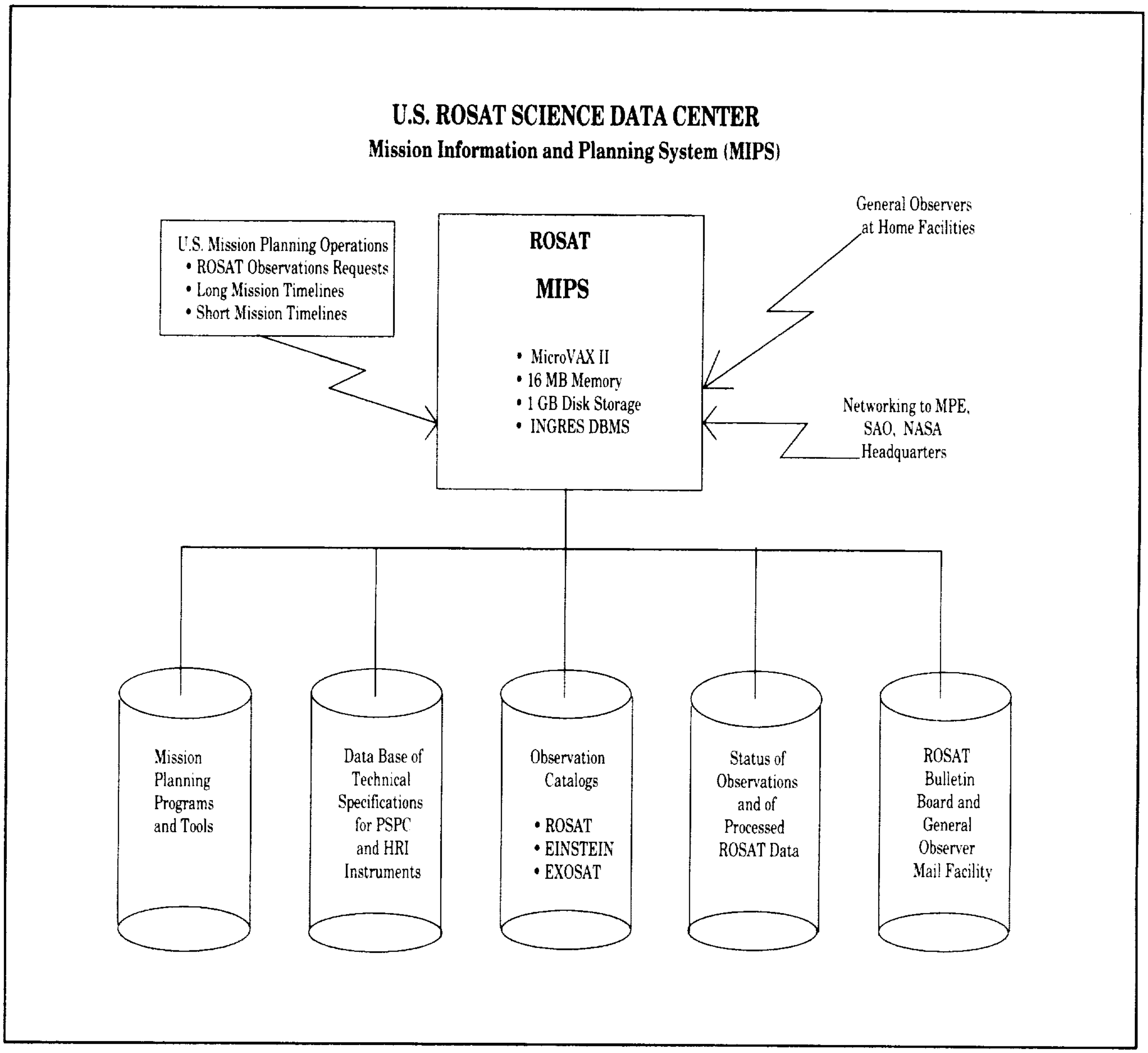

Figure 1: Overview of the Capabilities of ROSAT MIPS

ONLINE ASTRONOMY CATALOG ORDERING SYSTEM

The Astronomical Data Center (ADC) Online Information System provides interactive access to the ADC Status Report on Machine-Readable Astronomical Catalogs for users of the NSSDC VAX 8650 computer. It is designed to allow users to locate catalogs by subject and keywords, and to submit requests for data directly over the SPAN network.

The system has three options to search for catalogs. (1) Catalogs are listed by the ADC or Centre de Donnees de Strasbourg (CDS) number, and grouped in the categories of the CDS numbering system: positional data, photometric data, spectroscopic data, cross-identification catalogs, combined and derived data, miscellaneous data, nonstellar and extended objects, and catalogs sorted by plate areas. When one of the eight categories is selected, the system displays the catalogs in that category. (2) Catalogs can be displayed in alphabetical order according to a short title assigned to each. (3) Catalogs can be listed by keyword. More than 170 keywords have been selected based on catalog types, objects (targets), main contents, and observational methods. Up to five keywords have been assigned to each catalog based mainly on its primary data, since the referencing of secondary data would not only confuse the location of specific catalogs but would result in the association of large numbers of keywords for many catalogs. However, in cases where the secondary data of a major catalog have been used as a frequent reference source for the data, an associated keyword may be included.

When a catalog is selected, the system shows basic information about the catalog: full title, author(s), source reference(s), file structure (logical record length and number of records), and current status of the catalog. For further information about the catalog, a brief description and bibliographical reference(s) can be displayed if available.

The system also receives interactive requests for data. A user may receive data via electronic networks or on tape by U.S.mail. For receiving data via electronic networks, the requested data set (catalog) must be smaller than two megabytes and the user must have a SPAN, BITnet, or Internet address. A user who wants to receive the data on tape by U. S. mail must generally supply a sufficient number of standard 2400-foot tapes to hold the requested data, after submission of an interactive request for the data.

The system is accessible over SPAN or by dialing the NSSDC VAX 8650 directly. The SPAN node is NSSDCA and the user name is ADC. Valid users may obtain the account password by contacting the ADC.

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STARCAT/SIMBAD

The NSSDC has access to major retrieval systems for astronomical data through the locally installed STARCAT (Space Telescope ARchive and CATalog) system developed at the Space Telescope/European Coordinating Facility (ST/ECF) and the European Southern Observatory (ESO).

The STARCAT system is a collection of software and associated astronomical data, the latter consisting of full catalogs and various observing logs from spaceborne astronomy missions. These data are resident on a Britton Lee 700 data base machine at the NSSDC. The software system runs on the NSSDC VAX 8650 computer and allows, in addition to data retrieval, various other capabilities related to astronomical computing, such as coordinate conversion, a calculator pad, and extensive help facilities. STARCAT will also serve as the interface to the ST/ECF archive of Hubble Space Telescope data, which is the principal reason for development of the system.

The SIMBAD (Set of Identifications, Measurements and Bibliography for Astronomical Data) data bank is an object-oriented system designed to provide the latest observational data and bibliographic information for individual astronomical objects outside our solar system. The data bank and its software system have been developed by the CDS over a period of more than 15 years and through the combined efforts of the international network of astronomical data centers. The ADC at NSSDC has played a key role in this development by supplying high quality and well-documented catalogs to the CDS for incorporation into the data bank. SIMBAD currently contains approximately 650,000 stars, 100,000 nonstellar objects, and 2,000,000 identifications from more than 400 source catalogs and data compilations. The bibliographical data base includes about half a million references for 150,000 objects, as taken from 90 regularly scanned journals and miscellaneous publications. The bibliography for stars is reasonably complete back to 1950, while that for nonstellar objects officially commences in 1983, although earlier references are present for a great many objects. The online storage required for SIMBAD data is currently about 200 megabytes.

A user of SIMBAD can search for astronomical objects by any of their plethora of identifications (some objects have as many as 30 or more), by astronomical coordinates and an associated range (e.g., all objects in a given field of view), or by a sampling procedure that selects objects according to specific criteria. Basic data for each selected object are displayed, followed by all identifiers by which the object is known. One can then retrieve a list of observational data for the object and a tabulation of all published papers that discuss the object. Complete titles and citations are given for each reference so that the user can select those that require further investigation.

Although NASA and NSF now support, through the Smithsonian Astrophysical Observatory (SAO), a permanent network link to France and the cost of SIMBAD usage for American astronomers (see *AAS Newsletter,*[3] N. 45, p. 10, June 1989), the ADC maintains a request service for astronomers who do not have a SIMBAD account with the SAO but who wish to have small searches done. SIMBAD output can be printed and mailed to requesters or can be sent via the various computer networks.

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NASA CLIMATE DATA SYSTEM

The NASA Climate Data System (NCDS) is an integrated scientific data and information system that supports researchers in the atmospheric, ocean, and Earth sciences by allowing them to interactively locate, access, manipulate, and display climate related data. NCDS enables researchers to find and learn about data of interest by accessing a comprehensive catalog of data descriptions and an inventory of temporal and volume information, to access subsets of online or offline data, and to view and manipulate these data.

NCDS is now an operational data system at the NSSDC. After many years of development with limited operations as the Pilot Climate Data System (PCDS), the system has now reached a state of operational maturity. NCDS is available on the NSSDC DEC VAXCluster (VAX/VMS) to the international user community over a wide variety of networks, including SPAN and Internet.

NCDS continues to build upon off-the-shelf (both commercial and public domain) software packages. The Oracle data base management system serves the Catalog, Inventory, and Data Access Subsystems; IDL supports the Data Manipulation Subsystem; and Template serves the Graphics Subsystem. The Transportable Applications Executive (TAE-Classic) provides the basic structural framework for the user interface. The NSSDC Common Data Format (CDF) is used by the Data Access, Data Manipulation and Graphics Subsystems for direct utilization of online data stored on magnetic and optical disks.

NCDS provides access to approximately 500 GB of data, mostly offline, spanning about 46 distinct data sets. A portion of the data sets held by NCDS reside online, along with samples of offline data (about two GB total). The majority of data sets held by NCDS fall into four primary subdisciplines, the first of which is solar activity/irradiance. The Nimbus 7 Earth Radiation Budget (ERB) instrument, the Solar Maximum Mission (SMM) ACRIM, the Earth Radiation Budget Experiment (ERBE) scanner, and the SME Solar Ultraviolet Spectrometer provide the bulk of the data.

A second subdiscipline is Clouds and Radiation. The Earth Radiation Budget Experiment (ERBE), the International Satellite Cloud Climatology Project (ISCCP), and its related First ISCCP Regional Experiment (FIRE) are three primary projects supported by NCDS. The Nimbus 7 ERB and the NOAA satellite series AVHRR instruments also offer valuable data for analysis.

A third grouping of NCDS data is the general category of Global Climatologies and Oceanographic data sets. In this category, users find sea surface temperature data from the Climate Analysis Center, Fleet Numerical Oceanography Center, NOAA's Satellite Data Services Division (SDSD), and the Comprehen-

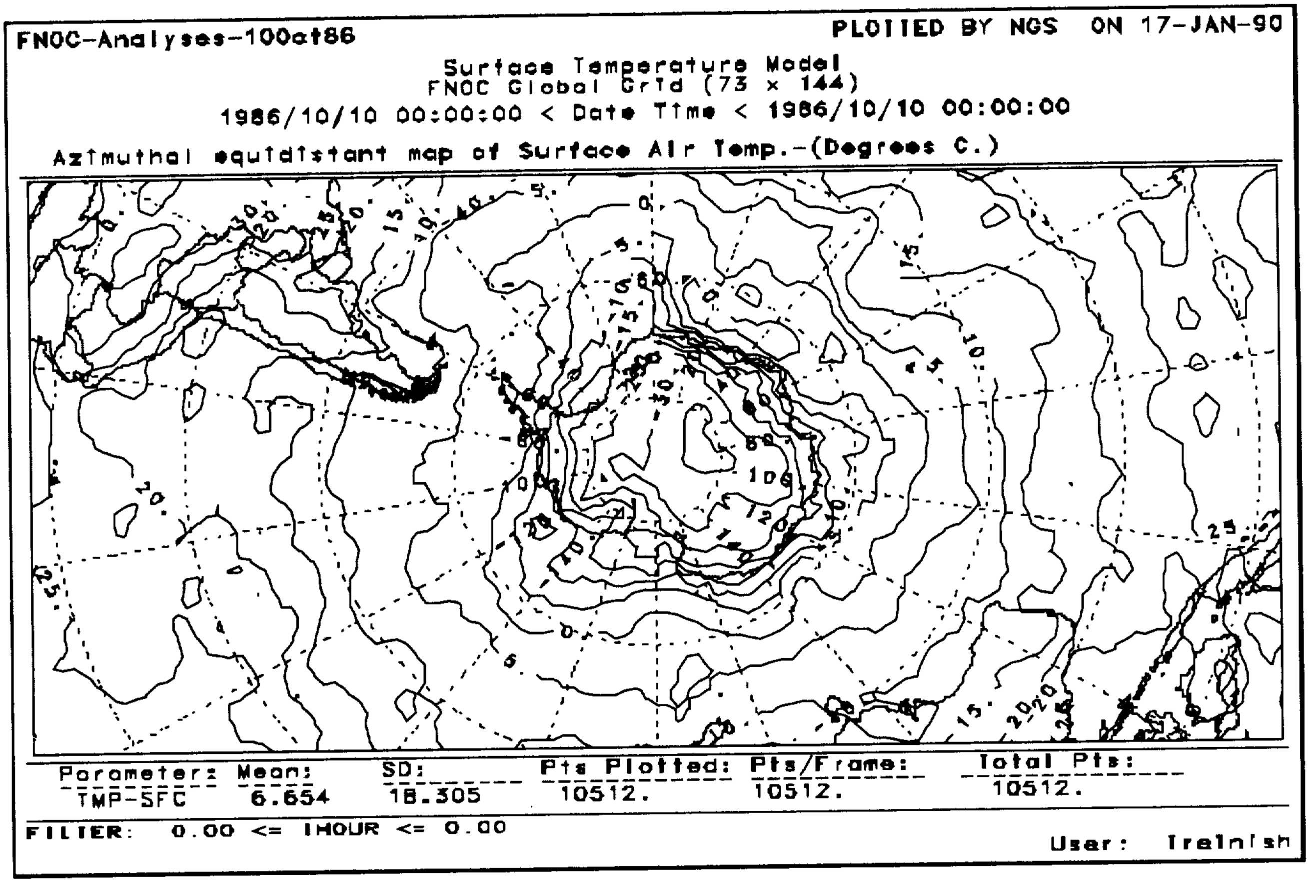

Figure 2: Sample Plot of NCDS Data Set

sive Ocean Atmosphere Data Set (COADS). Several of these same data sets, along with the National Meteorological Center's analyses, provide winds, humidity, fluxes, and other meteorological parameters. The First GARP Global Experiment (FGGE) data still remain popular, especially since their recent reanalysis. The Angell and Jones temperature deviation data sets are also available. The World Monthly Surface Station Climatology (NCDC and NCAR) data set, which spans the period from 1731 through the present, represents the longest period of record of any data set held by NCDS.

The fourth category is that of Atmospheric Constituents. Ozone, aerosols, nitrogen dioxide, and/or water vapor are the major species derived from Nimbus instruments such as BUV, SBUV, LIMS, TOMS, and SAM II. SAGE I and SAGE II on the Atmospheric Explorer Mission (AEM) and on the Earth Radiation Budget Satellite (ERBS), respectively, have collected data on the same four species.

In addition to the expansion of its comprehensive data holdings, NCDS now offers an improved user interface, better performance, and new versions of off-the-shelf software packages. Software development activities occur in parallel with the user support and data management efforts. Implementation is focused on the seamless integration of the off-the-shelf software and custom software. For example, NCDS must accommodate a variety of often obscure data formats for the data sets that it supports for both inventory and access purposes. New CDF-based tools for easy listing and subsetting have been developed to expedite the transfer of data from the NSSDC to the user's computer system. An experimental data base for online data has been installed, freeing the user and developer from user interface overhead. The 46 data sets to which the system provides access are further subdivided into 115 data types for efficient storage in CDF. The functionality of the manipulation and visualization tools available for data sets in CDF has also been improved (see Figure 2).

The major accomplishment by NCDS in fiscal year 1989 was significantly expanding the scope of its operational services by providing timely access to a wide range of data. These efforts culminated in the first NCDS workshop which brought over 200 interested users from around the world to Goddard Space Flight Center to evaluate and experiment with the system. Data producers (of data sets held by NCDS), data center representatives, scientists, and data system specialists had an opportunity to use NCDS and to discuss their applications with NCDS data holdings. This workshop brought the unique concept of a truly integrated, data-independent system into reality for many participants, and illustrated its potential for supporting scientific research.

Figure 2 is an example of the type of data visualization that can be generated by the NCDS Graphics Subsystem. It is a contour map of the temperature of the Earth's surface as viewed on an azimuthal equidistant map projection showing approximately the southern two-thirds of the southern hemisphere. This map is derived from a data set developed by the U. S. Navy Fleet Numerical Oceanography Center (FNOC) based upon 12-hour observations by the Navy's Operation Global Atmospheric Prediction System. The full support of the FNOC data set was added to the NCDS in FY89. FNOC has been analyzing many oceanographic and meteorological parameters since the early 1960s. The scope of this data set has expanded in recent years to include, for example, global coverage every 12 hours since 1983. A nominal grid of 200 x 200 cells has been derived from the model-based global surface temperatures for October 10, 1986, at 00:00 GMT and is displayed in the figure.

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TOMS OZONE DATA

The NSSDC currently archives some of the key data sets for the study of stratospheric ozone, a subject that has received considerable attention lately among climate research scientists and in the news media. Ozone, a strong absorber of the solar ultraviolet radiation, is essential to life on our planet. It is now well established that man-made chemicals such as chlorofluorocarbons (CFCs) can destroy ozone resulting in a potentially adverse impact on life on this planet.

One of the key instruments for measuring the total ozone column globally is the Total Ozone Mapping Spectrometer (TOMS) currently flying on NASA's Nimbus 7 satellite. It produces daily global maps of the total ozone column and was instrumental in the discovery and subsequent studies of the so-called "Ozone Hole" over the Antarctic continent. More than ten years of TOMS data are available from the NSSDC.

To support atmospheric scientists doing research on ozone depletion, the NSSDC continually places the latest gridded TOMS ozone data on line. These data are available about six weeks after acquisition. By specifying time and location, a user can log onto a public account set up by the NSSDC and either look at character-coded maps or download numerical values to a personal computer. Scientists using SPAN can also mail the subsetted data to their own accounts for further analysis.

In addition, the entire TOMS archive from November 1, 1978, through December 3, 1988, is available on line in CDF on optical disk and is supported by NCDS. Value-added data sets, including monthly gridded means and daily zonal means, have been prepared and are available. Data for the year 1989 will be added to this online archive when they become available.

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PILOT LAND DATA SYSTEM

The Pilot Land Data System (PLDS) is a distributed prototype information system whose objective is to support land scientists in their research by helping them identify and acquire data of use to them, and by providing them a mechanism to access remote computer facilities using electronic communications.

The PLDS is a multicenter cooperative data system with the NSSDC as project office and lead center, and the Ames Research Center (ARC) and the Jet Propulsion Laboratory (JPL) as participating centers. Currently, the data system is emphasizing the needs of the broad NASA-funded land science community. Its long-term objectives are as follows:

- Provide information about available scientific data with enough granularity and associated information to allow investigators to determine if the data they want for their research is available.

- Provide access to existing scientific data once scientists have identified which subset of data they want to acquire.

- Provide access to existing tools to analyze and process that data, such as the LAS at GSFC and the VICAR at JPL.

- Provide information about access to existing computer facilities at participating sites.

- Provide electronic communications to sites where significant amounts of land science data reside, or to computing facilities where the data can be processed or analyzed.

The data system is in the process of preparing for a small scale operational period which will run six to nine months in mid-1990. Data sets are being added, and software distributed between the nodes so that the capabilities listed above will be provided in a

Data Set	Number of Granules/ Tapes	PLDS Node
Aerial Photograph	17,836/0	ARC/JPL
AIS	future†	JPL
AMS	99/44	GSFC
AVHRR-GAC	0/110	GSFC
AVHRR-LAC	806/525	GSFC
AVIRIS	564/564	JPL
Botanical Sample	1,219/0	JPL
DEM	54/1	JPL
Earthquake Epicenter	983/0	JPL
Geological Sample	4,800/0	JPL
MSS	0/120	GSFC
Thematic Mapper	169/8	GSFC/JPL
Landsat Browse (TM & MSS fr. LandSat 4-5,)	future	GSFC
NERDAS	0/48	GSFC
NDVI	future	GSFC
PFES	future	JPL
PIDAS	future	JPL
SAR Data Catalog (SIR-A & B, Seasat, Quadpole SAR)	future	JPL
SMMR-PDVI	12/1	GSFC
SMMR-Snow	106/1	GSFC
SMMR-TAT	0/8	GSFC
Sun Photometer	future	ARC
TIMS	2,361/110	ARC/ GSFC/JPL
NS001-TMS	2,791/221	ARC/ GSFC/JPL
Daedalus-TMS	8056/0	ARC/JPL
Topographical Map	361/0	JPL
VISSR	0/50	GSFC

† = available late-1990

Table 1: Operational Period Data Sets

uniform and consistent manner throughout the data system when it begins this operational period.

Data sets now available are listed in Table 1. Temporal and spatial coverage will be very limited for some of the satellite data; however, many of the data sets overlap in time and space. The most complete holdings contain data collected from sensors borne on aircraft.

The PLDS User Support Offices located at ARC, GSFC, and JPL can be contacted for assistance or documentation on use of this data system.

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CRUSTAL DYNAMICS DATA INFORMATION SYSTEM

The Crustal Dynamics Project was formed by NASA to advance the scientific understanding of Earth dynamics, tectonophysics, and earthquake mechanisms. The project uses two types of space-age techniques in this study: laser ranging to an artificial satellite or the moon, and Very Long Baseline Interferometry (VLBI). As part of its data management, the project has designed and implemented a centralized Crustal Dynamics Data Information System (CDDIS) (see Figure 3). The CDDIS has been fully operational since September 1982. The main purpose of the CDDIS is to store and disseminate all geodetic data products required by the project in a central data bank, and to maintain information about the archival of all project-related data. All authorized principal investigators, staff, and cooperating institutions have access to the CDDIS by means of network or dial-up telephone lines. The CDDIS is operational on a dedicated DEC MicroVAX II computer and is currently accessible through SPAN, Internet, BITnet, and GTE Telenet facilities. The menu-driven system provides the user with access to the different parts of the CDDIS, and data retrievals or queries are possible with user-friendly interfaces.

The archive of preprocessed laser and raw, correlated VLBI data is retained offline in the CDDIS tape library. All other information can be accessed through a data base utilizing the Oracle data base management system (DBMS). The laser, VLBI, and Global Positioning System (GPS) data sets accessible through the CDDIS fall into four major categories:

Preprocessed Data

These include catalogs of preprocessed SLR (Satellite Laser Ranging) data from 1976 through the present, and VLBI data from 1976 through the present. SLR data from the LAGEOS, BE-C, Starlette, and EGS satellites are stored on line in a data base; the actual data are archived off line on magnetic tape. The VLBI data consist of online experiment listings in the data base and a magnetic tape archive of the actual experiment data.

Analyzed Data

These include SLR, LLR (Lunar Laser Ranging), VLBI, and combined analyzed results supplied by the project's science support groups and other analysis centers, and project investigators at GSFC, JPL, National Geodetic Service, Massachusetts Institute of Technology (MIT), the University of Texas, and many other institutions around the world. These analyzed results currently span different time periods from 1976 through the present and are accessible through a data base management system. They include precision baseline distances, Earth rotation and polar motion determinations, length-of-day values, and calculated station positions.

Ancillary Data

This information includes descriptions of Crustal Dynamics Project site locations, a priori monument coordinates and calibration data, and a priori star coordinates. These data sets are contained in the online data base.

Project Management Information

This category is accessible through the CDDIS data base to authorized project personnel only and includes mobile system schedules, occupation information, and configuration control information. In addition, CDDIS operational information is kept in the data base and is accessible to CDDIS staff only. It includes logs of all laser, VLBI, and GPS tapes received from the many global sources, as well as logs of all tapes created by the CDDIS for outside users. Listings of CDDIS backup tapes are also retained.

In addition to the online, menu-driven user view, the CDDIS is also tasked to assist the investigator community with its data requirements. These data services of the CDDIS primarily consist of receiving and archiving Crustal Dynamics-related data on magnetic tape and cataloging these data in the CDDIS data base. All data received by the CDDIS from the many contributing global sites must be verified and often must be reformatted before distribution. The CDDIS is then responsible for the dissemination of these data to authorized Principal Investigators located in the United States or at institutions in other countries. Efforts are made by the staff to send the data in the most convenient format to the investigators. Data can be made available in the form of printout listings, magnetic tape, or network files.

A user's guide, *Quick-Look Guide to the Crustal Dynamics Project's Data Information System,*[35] provides brief descriptions of the DIS and its menu items, as well as detailed instructions on how to access the system and whom to contact when problems occur. A regular bimonthly publication, the *DIS Bulletin,*[37] is available to project investigators and affiliates. The principal purpose of this bimonthly publication is to familiarize the Crustal Dynamics Project investigator community with the data held by the DIS, and to report any peculiarities in previously acquired data.

The *CDDIS Brochure*[36] is also available and provides a brief description of the system, access procedures, and contact information.

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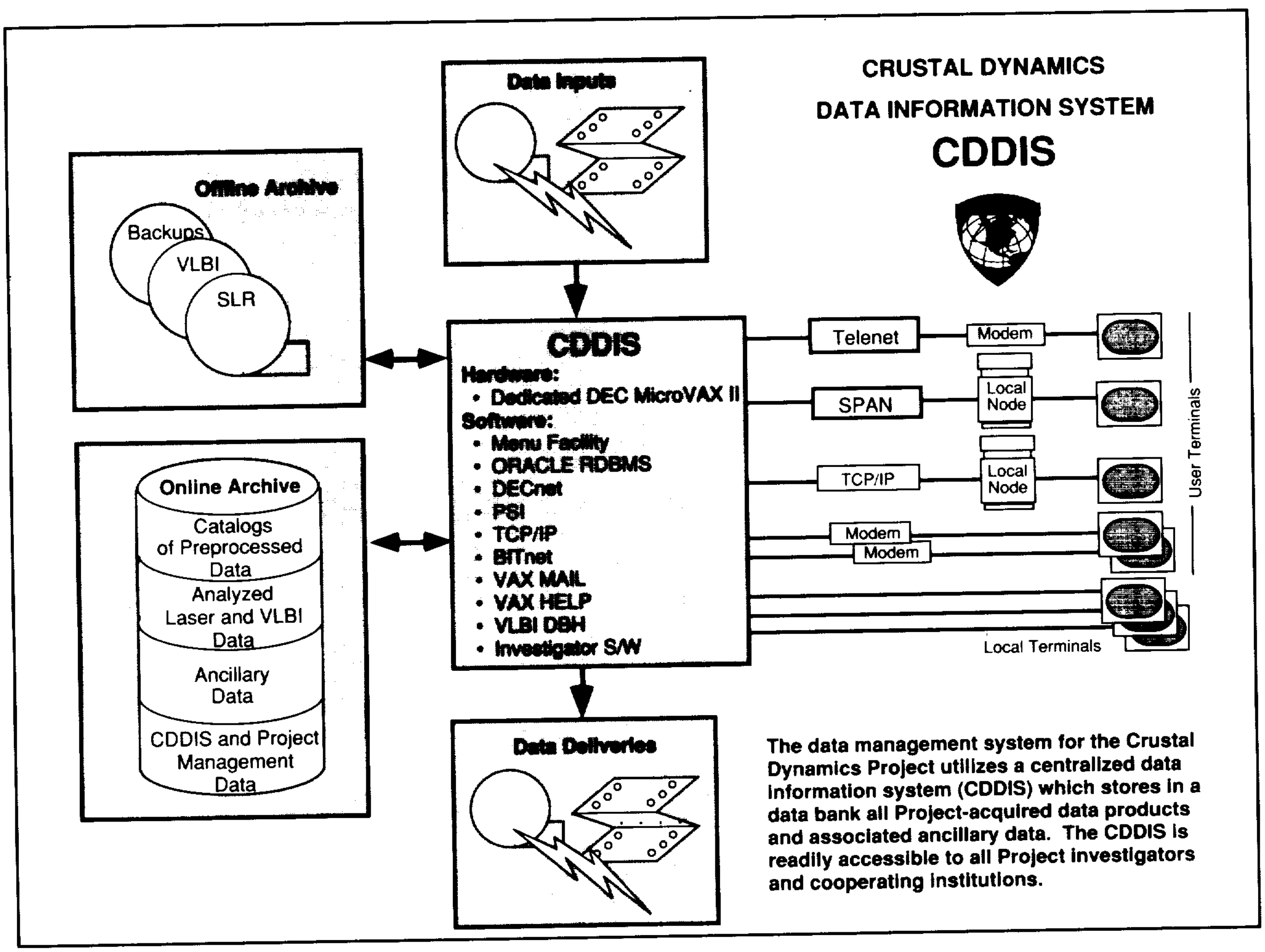

Figure 3: Overview of the CDDIS

COASTAL ZONE COLOR SCANNER

The central archive and distribution facility responsible for providing access to the entire Coastal Zone Color Scanner (CZCS) data set is the National Space Science Data Center. CZCS data products have been produced in collaboration with the Nimbus Project Office, GSFC's Space Data and Computing Division, GSFC's Laboratory for Oceans, and the University of Miami/Rosenstiel School of Marine and Atmospheric Science. The thrust of this effort has been to process all data acquired by the Nimbus-7 CZCS instrument to Earth-gridded geophysical values, and to provide ready access to these data products. The ocean color data products are beginning to provide reliable estimates of marine phytoplankton biomass in the ocean. These are the microscopic plants that grow in the upper sunlit regions of the oceans and form the base of the marine food web. Understanding the distribution of phytoplankton is critical for many branches of marine ecology and fisheries science.

An end-to-end data system utilizing recent advances in data base management and both digital and analog optical disc storage technologies has been developed to handle the processing, analysis, quality control, archiving, and distribution of this valuable data set. The entire Level 1 CZCS data (800 gigabytes) have been copied from magnetic tape to digital optical disc. Levels 2 and 3 data are also available for distribution (see Table 2).

In addition to the NSSDC, a number of academic and research institutions have been established by NASA to serve as regional browse, distribution, and analyses centers for most of the CZCS data sets. These regional distribution centers have resident copies of all data that is Level 1a or higher, and the necessary hardware and software required for browsing, copying, and reformatting the images. One of the most innovative aspects of this project has been the development of an analog optical disc browse and data order capability which is becoming widely available within the research and educational communities.

The CZCS browse capability provides a researcher the ability to quickly search the entire Level 2 CZCS data set and to instantly view pigment fields that meet his search criteria. If the researcher feels that a given scene warrants further investigation, the browse program provides for the generation of an order file which can be sent electronically over SPAN to the NASA archive where the digital data are copied and sent to the requestor. Researchers not on SPAN can use other electronic mailing procedures including Telemail. The browse and order capability is supported through NSSDC Online Data and Information Services (NODIS).

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Data Type	Spatial Resolution (km)	Total Scenes	Presently Available	Individual File Size (mbyte)	Total Volume (gbyte)
Level 1	1	67,789	67,789	12	813
Level 1a	4	66,000	66,000	0.7	48
Level 2	4	60,000	31,000	0.7	44
Level 3					
DAILYPST	20	2,800	960	4	11
DAILYCOMP*	20	2,800		28	78
WEEKLYPST	20	560	192	12	7
WEEKLYCOMP*	20	560		28	16
MONTHLYPST	20	93	32	26	2
MONTHLYCOMP	20	93		28	3

Table 2: Volume of Coastal Zone Color Scanner Data Products

OMNI DATA SET

One of the most accessed value-added data sets that the NSSDC maintains is the composite, hourly resolution, near Earth solar wind magnetic field and plasma data set. Field and plasma data have each been provided by approximately 12 different spacecraft, and extensive cross-calibrations were performed in creating the composite set. In addition, the data set contains selected solar and geomagnetic activity indices (R, C9, Kp, Dst). The data set currently spans 1963 to 1988 and is periodically updated.

The data set presently on line via the NSSDC account spans the 1973-1988 period only. Figure 4 shows the percent coverage of the online OMNI data. In the last few years, the Interplanetary Monitoring Platform 8 (IMP 8) has been the primary source for the magnetic field and plasma data, although some 1985 data from the Soviet/Czechoslovakia Prognoz 10 mission was recently added.

Access to this data set is gained through the NSSDC account. The interface enables the user to choose any subset of the 37 data values per hourly record for any time span, and either to list the selected data to a terminal screen or to create an ASCII or binary file for downloading to a computer.

These data have also been provided on magnetic tape (the "OMNItape"), CD-ROM, and floppy disk, and as both plots and listings in the *NSSDC Interplanetary Medium Data Book*[16] and associated supplements. The latest supplement (No. 4) was issued in September of 1989.

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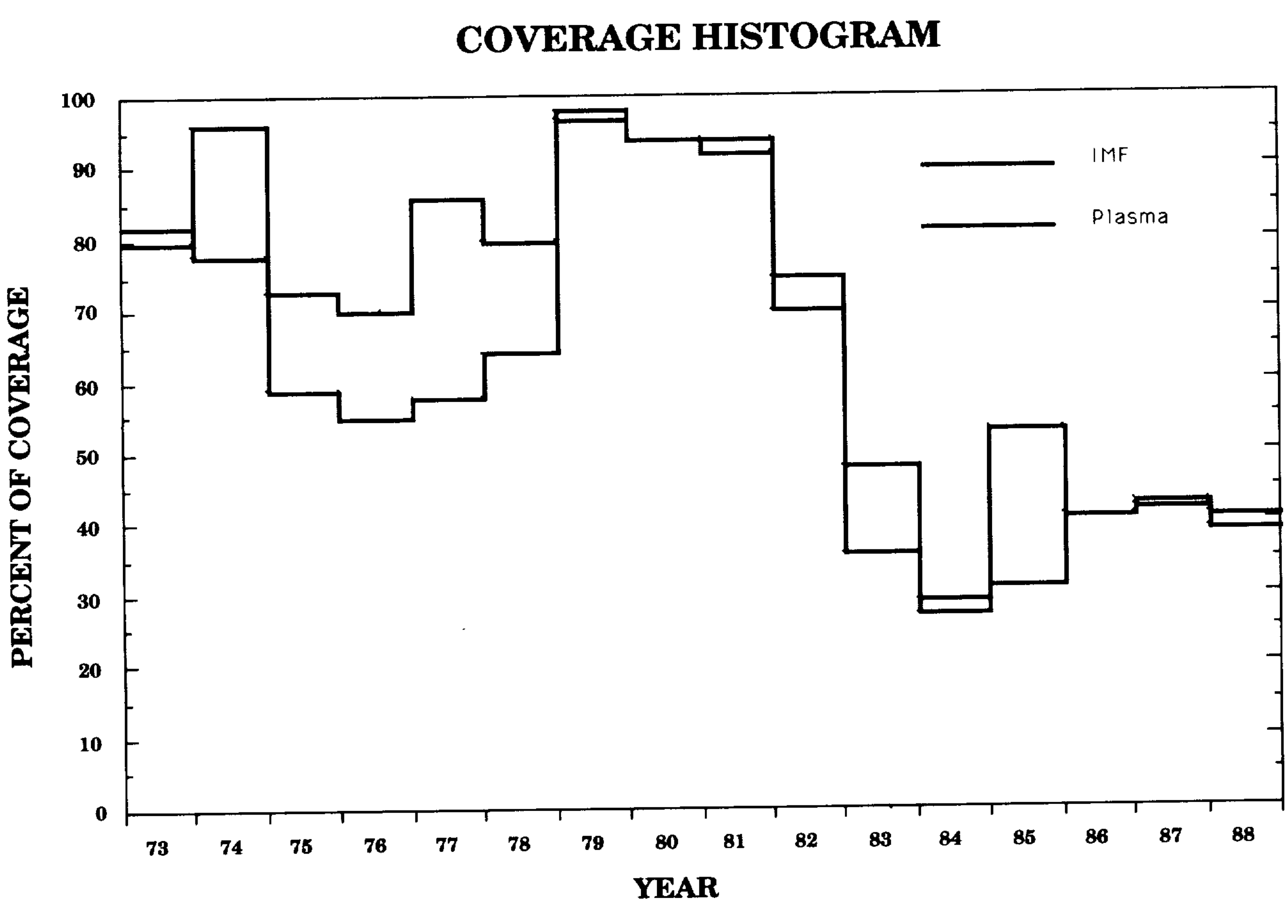
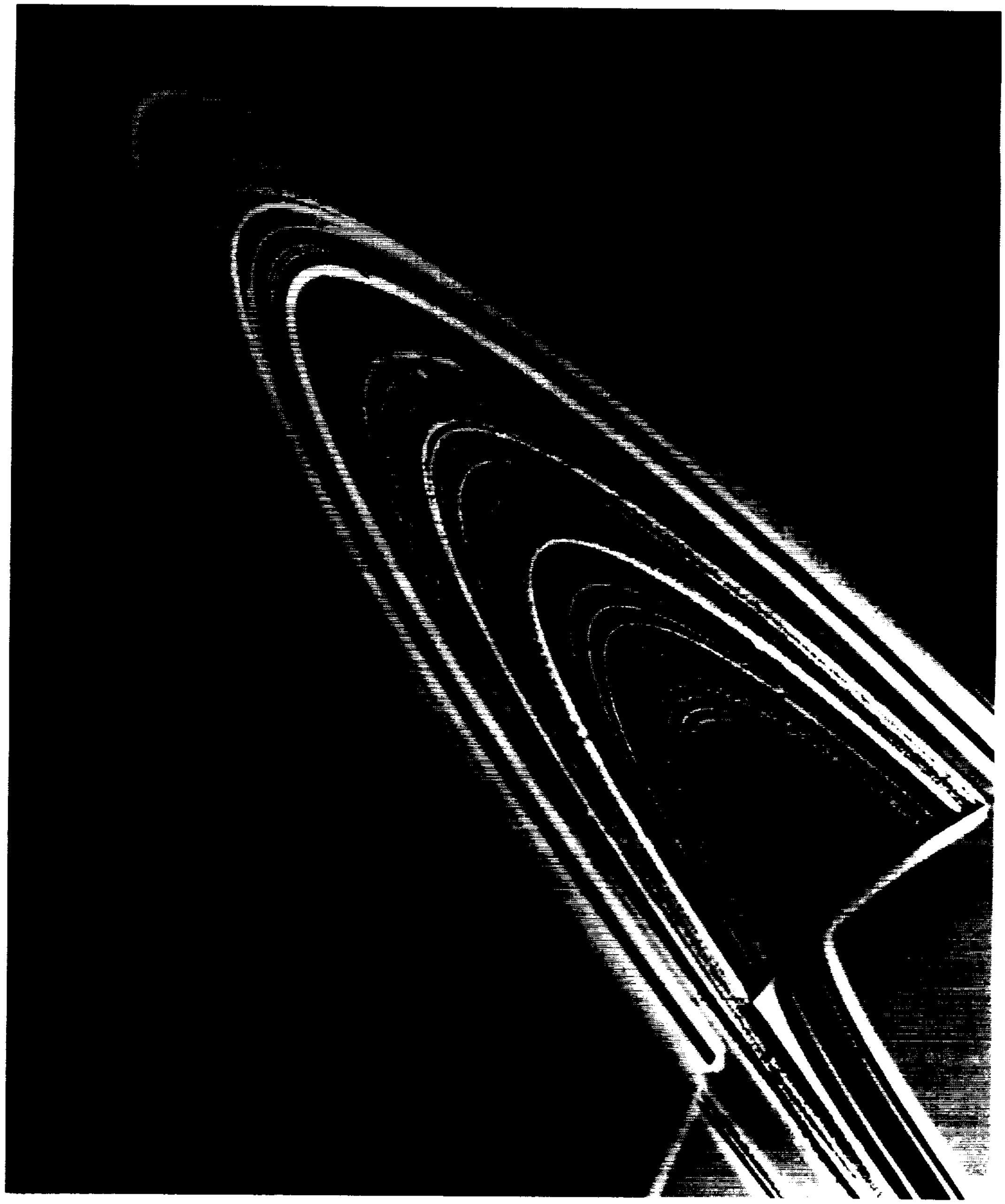


Figure 4: Percent Coverage of the Online OMNI Data



This computer assembled two-image mosaic of Saturn's rings taken by NASA's Voyager 1 on November 6, 1980, at a range of eight million kilometers (five million miles) shows approximately 95 individual concentric features in the rings. The extraordinarily complex structure of the rings is easily seen across the entire span of the ring system. The ring structure, once thought to be produced by the gravitational interaction between Saturn's satellites and the orbit of ring particles, has now been found to be too complex for this explanation alone.

CHAPTER 3

ELECTRONIC ACCESS

SPAN: THE SPACE PHYSICS ANALYSIS NETWORK

The Space Physics Analysis Network (SPAN) is a global DECnet network interconnecting space and Earth science researchers. SPAN is sponsored in the United States by the National Aeronautics and Space Administration and in Europe by the European Space Agency (ESA). Since its inception in 1981 as a project to link researchers at Marshall Space Flight Center, Utah State University, and the University of Texas at Dallas, SPAN has grown steadily (recently, almost exponentially). During this period, the number of tail circuits to SPAN remote facilities has grown considerably, and SPAN host computers now number more than 2700. SPAN is a component of the global DECnet Internet, which currently includes more than 17,000 host computers.

SPAN Network Information Center

The rapid growth of SPAN created the need for users to acquire timely information about the network. Early in SPAN's history, information about the network was spread by word of mouth or through relevant publications; however, it soon became clear that the need for information on SPAN could only be satisfied by developing a central source for dissemination of such knowledge, and the SPAN Network Information Center (SPAN NIC) was established to provide information services for SPAN. SPAN NIC provides a help desk to answer telephone and electronic mail queries concerning SPAN, maintains and distributes the SPAN documentation library, and maintains an online information facility, SPAN_NIC, which is located at the National Space Science Data Center.

SPAN_NIC was developed to meet the need for accurate, up-to-date, SPAN-wide information. It contains a data base of SPAN node information, general SPAN information and history, a list of SPAN documents that can be requested, SPAN internetwork mail address syntaxes, the capability of submission of node information, and important SPAN news briefs. SPAN_NIC can be accessed over SPAN and DECnet Internet, as well as a variety of other networks including the NASA Packet Switch System (NPSS), GTE/Telenet (through NPSS), and TCP/IP Internet. For more information on accessing the online

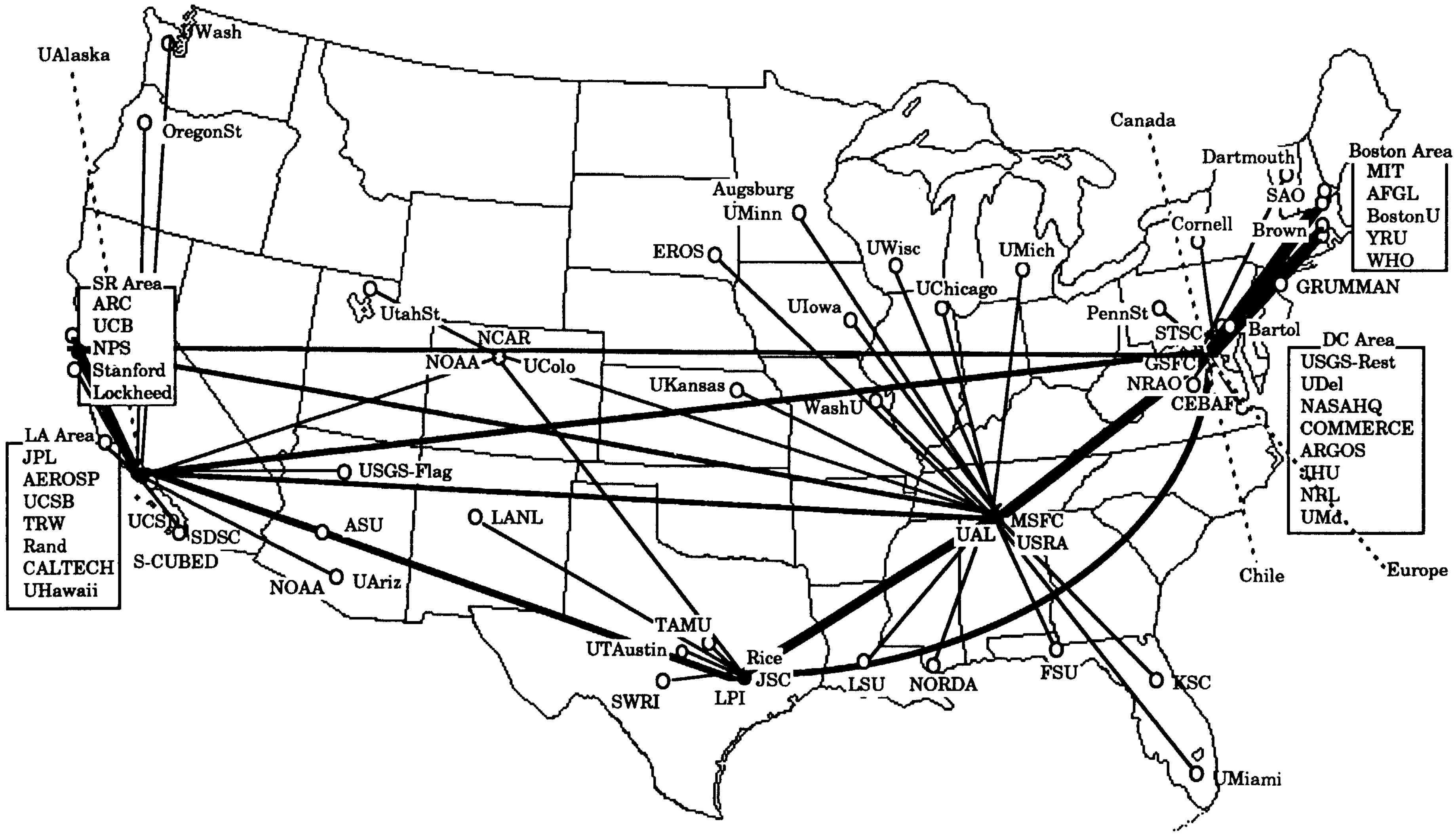


Figure 5: SPAN North American Sites

SPAN_NIC information facility, contact the NSSDC at the address listed below.

SPAN Advisory Group

For the period from 1981 to 1989, the Data Systems Users Working Group (DSUWG) was the major advisory group for SPAN. Through this group, SPAN was run by its users. The DSUWG provided guidance for SPAN's growth and sought standardization for the efficient exchange of information, data, and graphics. The DSUWG was drawn from SPAN's present and potential science user community as well as other interested, active scientists and data system managers. Since there is now a large overlap of users who use both SPAN, a DECnet network, and the NASA Science Network (NSN), a TCP/IP network, the two users working groups combined to form an NSI Networking Users Group. This group now handles the functions previously provided for SPAN by the DSUWG.

Network Topology

SPAN in the United States (US-SPAN) currently features a high speed backbone which connects SPAN Routing Centers located at Goddard Space Flight Center, Marshall Space Flight Center, the Jet Propulsion Laboratory, Johnson Space Center, and Ames Research Center. Each Routing Center is the focus for a star of tail circuits, and they are linked together by a set of redundant 56 kbps backbone circuits. These links are scheduled to be upgraded to speeds ranging from 112 to 224 kbps in 1990. This mesh topology allows medium bandwidth communication as well as backup protection should any single SPAN Routing Center or 56 kbps line fail. The tail circuits (9.6 kbps minimum line speed) link remote institutions into the SPAN backbone.

European SPAN

US-SPAN is connected to European SPAN (E-SPAN) via a 19.2 kbps dedicated line between the GSFC Routing Center and the European Space Operations Center (ESOC) in Darmstadt, West Germany. This transatlantic link is scheduled to be upgraded to 56 kbps in 1990. ESOC is an E-SPAN Routing Center, along with the European Space Research Institute (ESRIN) in Frascati, Italy, and the European Space and Technology Center (ESTEC) in Noordwijk, The Netherlands.

Prior to 1987, the connection between US-SPAN and E-SPAN was established on a scheduled basis using GTE/Telenet and PSI X.25 DLM circuits. X.25 connections from ESOC to the MSFC Routing Center and from ESOC to the GSFC Routing Center are now maintained as backups to the dedicated line, ensuring reliable continuous service between US-SPAN and E-SPAN. Within E-SPAN, the backbone and tail circuits use DECnet over a variety of media including dedicated lines as well as both private and public X.25 packet switch networks. ESOC, ESRIN, and ESTEC all support tail circuits to cooperating institutions within Europe, primarily over public packet switch networks.

The DECnet Internet

SPAN's usefulness to the scientific community has been greatly enhanced by engineering interconnections between wide-area DECnet networks (WANs) and SPAN (e.g., ESnet/DECnet [formerly US-HEPnet], THEnet [formerly TEXnet], USGS GEONET, NASA UARS, etc.). The interconnection of these WANs required careful coordination among the network managements to ensure the technical viability of the resulting "Internetwork." This coordination requires mutual agreements between the various network managers on node and area number assignments, DECnet circuit costs, interconnection gateways, and other characteristics that affect the viability and performance of the DECnet Internet.

In mid-1985, SPAN made its first connection with the US High Energy Physics Network (US-HEPnet) by virtue of having circuits to the same remote institutions. The topology of US-HEPnet (and its successor, the DECnet portion of the Energy Science Network, ESnet) utilizes a routing center approach much like SPAN with Department of Energy-sponsored laboratories functioning as hubs. US-SPAN and ESnet/DECnet interconnect at many tail sites. In June 1989, the first backbone to backbone US-SPAN to ESnet/DECnet link began service. There is also a European counterpart to ESnet/DECnet named European HEPnet (E-HEPnet). E-HEPnet is centered at the European Organization for Nuclear Research (CERN) in Geneva, Switzerland.

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(DECnet Internet) 6277::NETMGR
(TCP/IP Internet) netmgr@nssdca.gsfc.nasa.gov

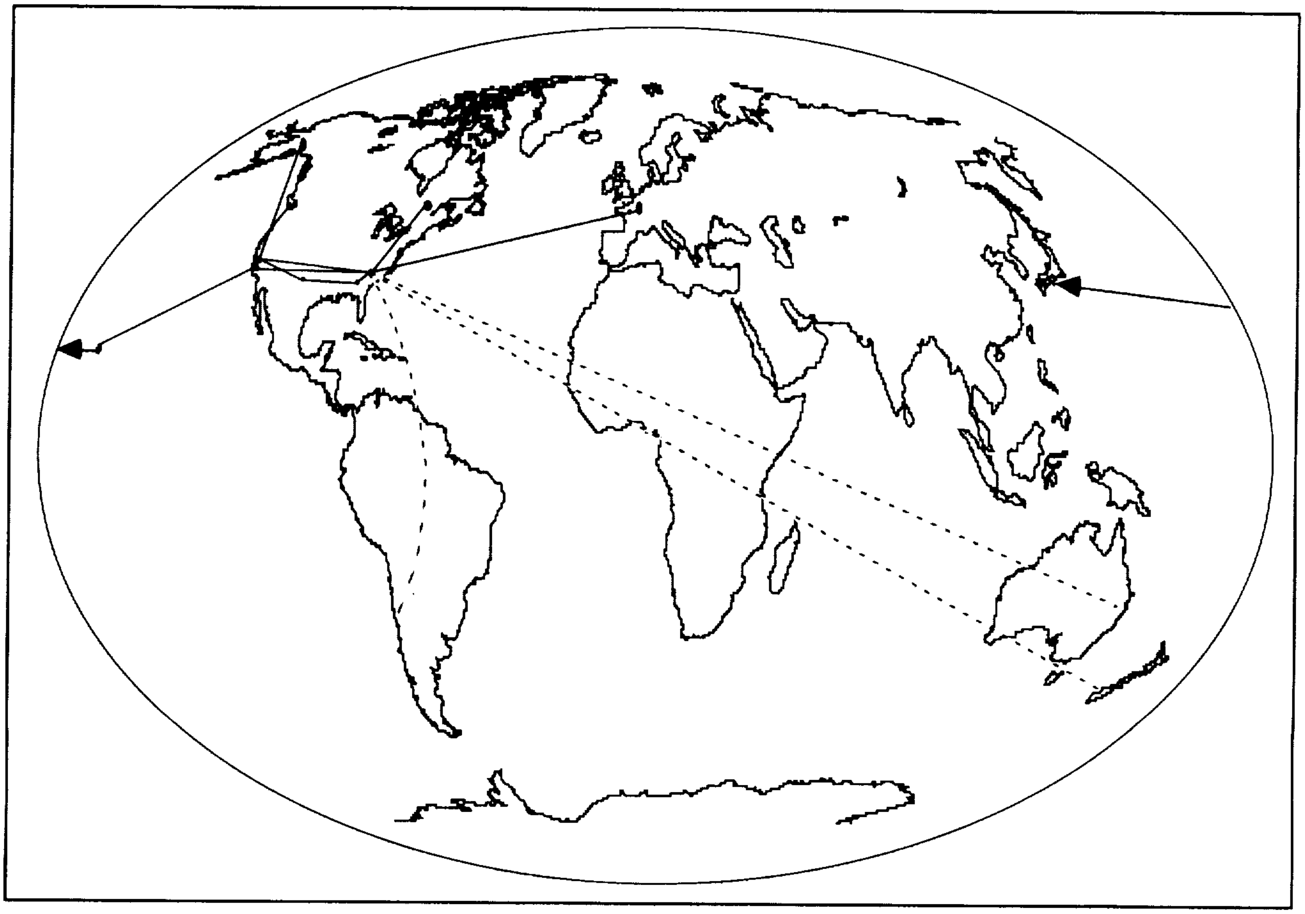

Figure 6: SPAN Long Distance Communication Links

NON-SPAN ACCESS TO THE NSSDC

The NSSDC is active in providing online, remote access to the available systems and resources of the data center. SPAN is a major path into the data center and one that is managed by the NSSDC. Other methods of obtaining access to the NSSDC include:

1. **TCP/IP Internet** - NSSDC VAX/VMS and UNIX systems are members of the NASA Science Network (NSN). This is a TCP/IP- based network that is tied in with NSFnet, NSFnet Regionals, Department of Energy's ESnet, ARPAnet, and other TCP/IP-based networks, which together form the TCP/IP Internet. TCP/IP provides full function, peer-to-peer networking. Applications include TELNET (virtual terminal), FTP (file transfer), SMTP (electronic mail), and others which run over TCP/IP.

2. **BITnet/EARN** - Users of BITnet (U.S.) or EARN (Europe) can access the NSSDC through a gateway located at Goddard. Electronic mail is available, as well as file transfer.

3. **X.25 NPSS/Telenet** - The NSSDCA VAX is a full function X.25 host on the NASA Packet Switch System (NPSS), which is in turn networked into Telenet, a public packet switch network. Remote users can call local X.29 PADs and establish virtual terminal links for interactive sessions. VAX-to-VAX PSImail and PSIcopy utilities can be used to communicate with the NSSDC.

4. **DIAL-UP** - Remote users can dial-up the GSFC ROLM telephone system. From there, users can establish interactive connections into the NSSDC computer systems.

5. **NASAmail/GSFCmail/TELEmail/OMNET** - Users of TELEmail-based electronic mail systems can exchange mail with the NSSDC by using gateways on networks to which the NSSDC is connected.

This list is by no means exhaustive as there are other methods of access. Additional services can provide communications with the NSSDC through available networks.

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SPAN SECURITY

In response to increasing occurrences of computer security incidents in both the public and private sector, SPAN management created a network security office in 1988 for managing the elements of the security program for SPAN. This office provides a central point of contact for incident tracking, as well as a mechanism for coordinating the security concerns of SPAN with other agency networks comprising the worldwide DECnet Internet. It also provides an effective point of coordination between the constituents of SPAN, other networks, and law enforcement agencies.

This office produced a risk analysis and management document for limited distribution that was the first of its kind to address risk analysis in a distributed network environment.

The SPAN security office has also sponsored the development and release of a "Security Toolkit" for SPAN sites. This toolkit consists of programs and procedures which are meant to assist VMS system managers in assessing the security and integrity of their systems with respect to file protection schemes, captive account configuration, and password selection practices.

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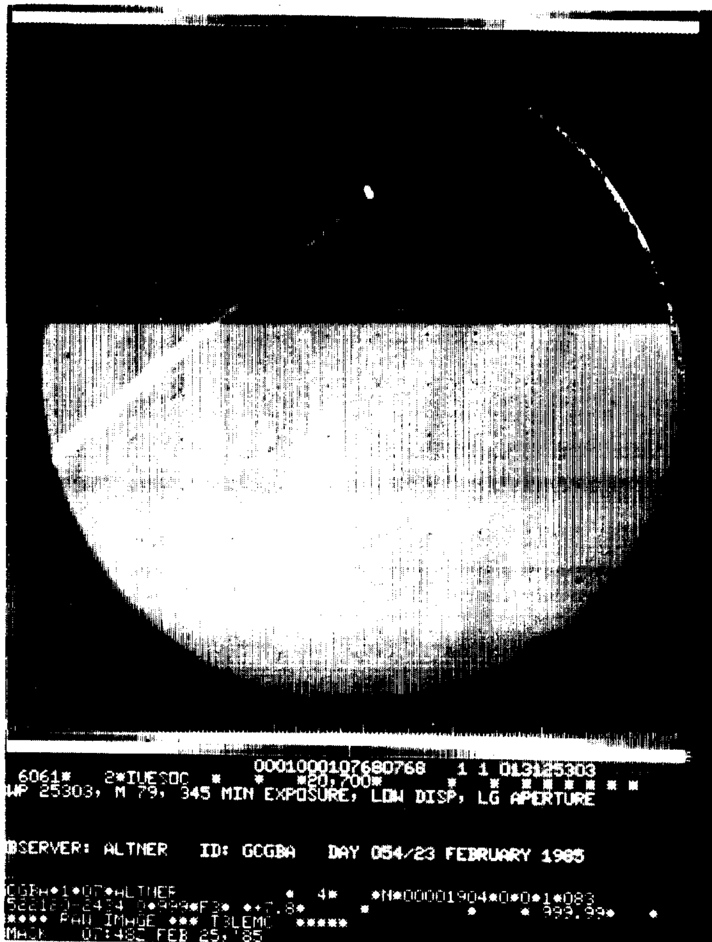

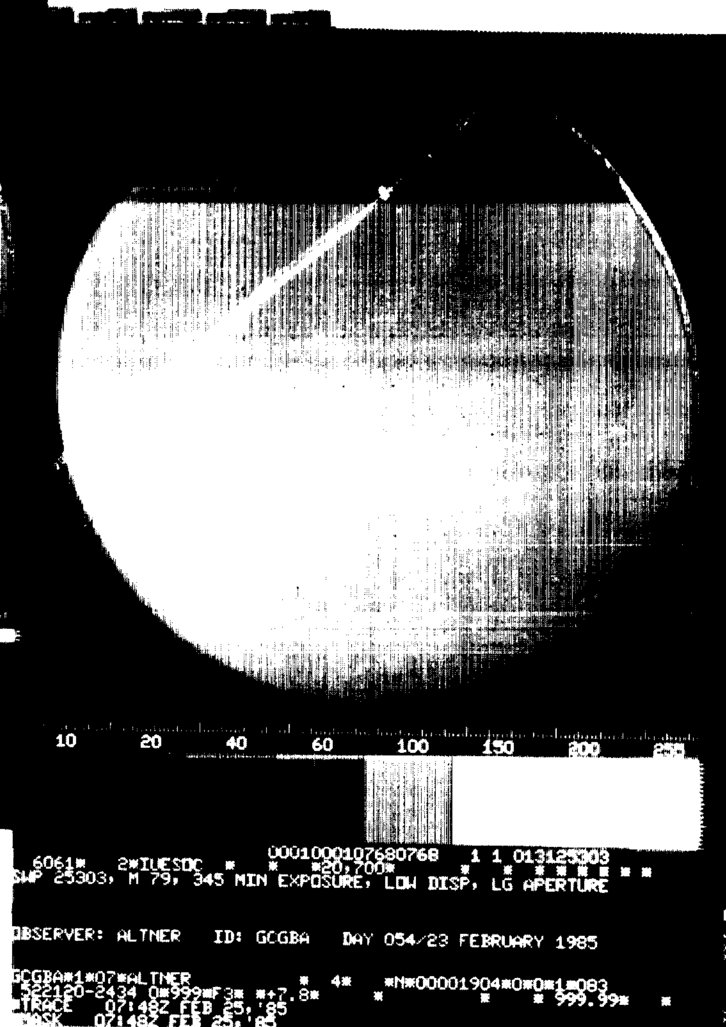

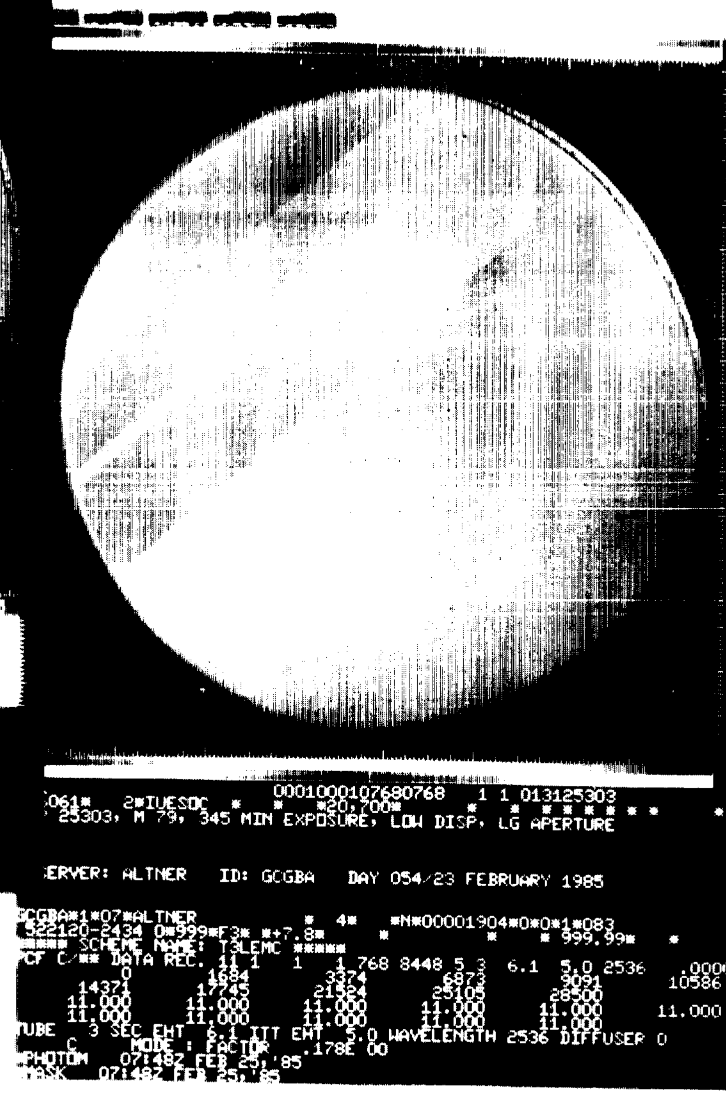

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CHAPTER 4

OFFLINE DATA ARCHIVE

THE NATURE OF THE ARCHIVE

The NSSDC's information system identifies about 4,000 distinct data sets that the NSSDC archives on various media: magnetic tape, optical disk, microfilm, microfiche, and photographic film of various sizes. These data sets come from about 1,000 distinct sensors which have flown on a few hundred spacecraft. The earliest data come from the dawn of the space age in the late 1950s. Most data are from NASA missions, although a few data sets come from other U.S. missions (e. g., Department of Defense) or from non-U.S. missions. The NSSDC holds no classified data.

NSSDC data holdings span the range of scientific disciplines in which NASA is involved. These include astrophysics, lunar and planetary science, solar physics, space plasma physics, and Earth science. Landsat data are specifically excluded by agreement reached years ago. Each year the list of most requested data sets from the NSSDC contains representatives from all disciplines.

The NSSDC currently holds virtually no raw or telemetry data. Many of its holdings were obtained from NASA mission Principal Investigator teams and were generated when those teams processed their raw or telemetry data. Some recent data sets have been obtained from instrument teams whose responsibility has been the production of reliable data sets for wide dissemination (e.g., the Nimbus 7 data sets). Yet other data sets are standard products provided to the NSSDC by a series of Guest Observers. International Ultraviolet Explorer (IUE) data are a prime example of the latter type.

NSSDC digital data are currently stored on 85,000 unique magnetic tapes received between the mid-1960s and the present, and on about 35,000 additional backup magnetic tapes. Approximately 35,000 tapes are physically held at the NSSDC for immediate access; the remainder are held at the nearby Washington National Records Center, where they are retrievable with a delay of about one week. In its classical mode of operation, the NSSDC provides requesters with duplicates of tapes as formatted by the submitting scientist, with data format descriptions and other supporting information to facilitate use of the data. The NSSDC also reformats tapes to satisfy users needing this service.

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REQUEST ACTIVITIES

The NSSDC completes about 2,500 requests for offline data and information each year. In 1988, 39% of these requests were received by mail, 26% via telephone calls to NSSDC personnel, 26% electronically via SPAN or other networks, and 9% from miscellaneous sources.

In 1988, 35% of all requests received were for spacecraft data spanning the range of scientific disciplines; 15% were for offline ADC data; 25% were for various spacecraft and non-spacecraft related documents; 18% were for miscellaneous programs, models, and information; and 7% were referred to other centers or the GSFC Public Affairs Office for processing. These statistics have been approximately the same for the last several years.

During the past five years, the NSSDC has provided data to offline requesters on the following media:

TYPE	AVG. PER YEAR	
Magnetic Tapes	3,114	tapes
Computer Printouts	41,203	pages
Microfilm	229	reels
Microfiche	7,602	fiche
Hard Copy	19,895	pages
Cut Prints	4,131	prints
Cut Film	1,830	each
Roll Film	17,684	feet

Virtually all recipients of data from the NSSDC use these data in scientific research, although a few requests are engineering oriented, and another small segment is commercially oriented.

Among the most frequently requested data in 1988 were Mars imagery data from Viking, ozone data from Nimbus 7, astrophysics data from the IUE and the Infrared Astronomical Satellite (IRAS), and magnetic field and plasma data from IMP 8.

The NSSDC has charged for data on an incremental cost recovery basis; however, modest amounts of data are typically provided free to space and Earth science researchers in lieu of incurring paperwork overheads which would be comparable to the data cost. Other requesters are charged irrespective of the amount of data requested. The NSSDC is currently expanding its charging domain to reflect an increasing use of online services and NSSDC scientific/technical staff involvement.

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DATA RESTORATION/ PRESERVATION PROGRAM

As NASA's long-term archive of space and Earth science data, the NSSDC now holds a large volume of reduced and raw digital data accumulated over the past two decades. Of the roughly 85,000 tapes, many are now over ten years old and slowly deteriorating, and many are written at low densities using seven-track technology that is now obsolete. Although some of these tapes are seldom requested, the data they contain may still be of unique scientific or historic value, for example, in studies of long-term trends.

To guarantee the preservation of the most important of these data, the NSSDC has begun a program of data restoration to copy such data to newer and higher density media. Because resources to actually copy these tapes are limited, one aspect of the effort is to define the relative scientific priorities of different data sets for restoration. To address the prioritization problem, the NSSDC has formed a series of science advisory panels. The initial panel was chosen to focus on the discipline of atmospheric sciences, with some emphasis on the Earth remote-sensing data now held at the NSSDC. Data from spacecraft such as TIROS, Nimbus, and SMS/GOES fall within this definition. This panel generated a priority ranking of the data sets which has been used in the data restoration program.

In parallel with the panel activity, NSSDC has begun tests to define and resolve various technical issues in the copying of large numbers of magnetic tapes that are possibly deteriorating. Tapes from the various data sets under analysis are being sampled to establish typical read error rates and procedures to optimize the data recovery rate with respect to the throughput of restored tapes. Data are currently being copied to high density standard 6250 bpi, nine-track tapes, and to DBM 3480 tape cartridges. The NSSDC is exploring an expanded use of optical disks and various cartridge tape/helical scan technologies as well.

As data restoration evolves from this pilot phase to a more nearly full-scale program, additional science advisory panels in other discipline areas will be formed to review and rank the other data sets within NSSDC's archive. Restoration of these data to high density media will enable the NSSDC to improve the ultimate accessibility of the data to the larger NASA and international scientific community.

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VISUAL REPRODUCTION FACILITY

The Visual Reproduction Facility (VRF) at the NSSDC evolved into a sophisticated capability to support the photographic needs of the scientific research community. Every requested image can be custom printed according to the scientist's special requirements. It not only processes manned and unmanned satellite images, but also scientific research data from other agencies in need of special and very technically demanding visual products.

After formation of the NSSDC in 1966, one of the first tasks performed by the VRF was the reproduction

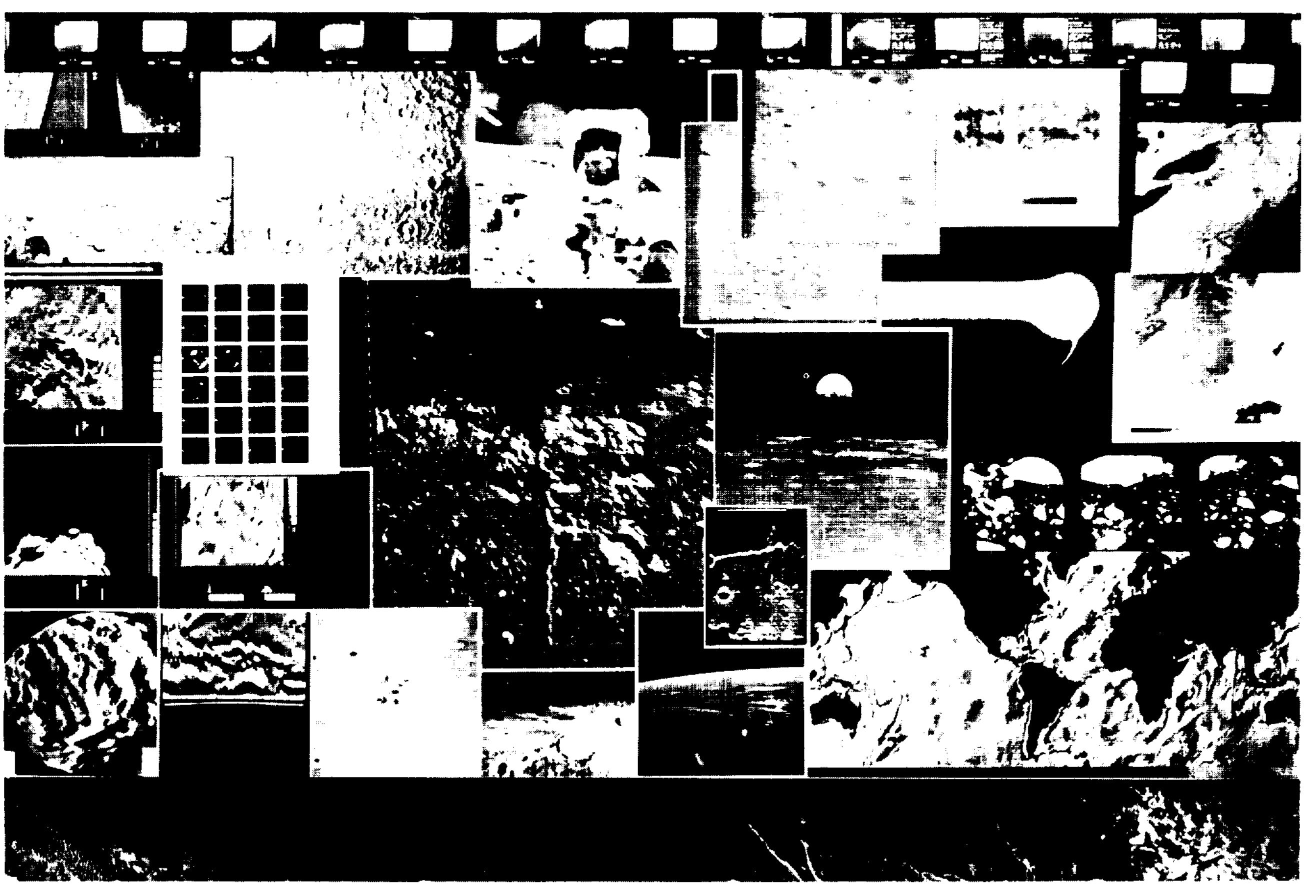

Figure 7: Mosaic of Satellite and Shuttle Imagery

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and archival of the film negatives from the APOLLO and LUNAR orbiters. The NSSDC now has the largest complete set known to date.

The VRF performed a special service for the HRTS telescope project, part of the Space Lab II Mission in 1985, designed to observe ultraviolet light emitted by the solar corona. The shuttle data consisted of black and white film strips between glass plates. The VRF enlarged these on positive film and made paper prints.

Visual data from other missions such as Viking Orbiter and Lander, Voyager I and II, etc., are available from the VRF. The newest data available is from Neptune, and consists of both black and white and color press release photos.

In-House Capability

The VRF has in-house capability ranging from public relations photos for the *NSSDC News*[38] to video taping of scientific conferences such as CDAW, and can duplicate three-fourths inch tape to one-half inch video tape or any combination. It also has the capability to produce poster layouts using such techniques as overlaying line color on black and white photos.

The NSSDC VRF is open to the scientific and educational community in an effort to improve the accessibility of visual data from NASA missions.

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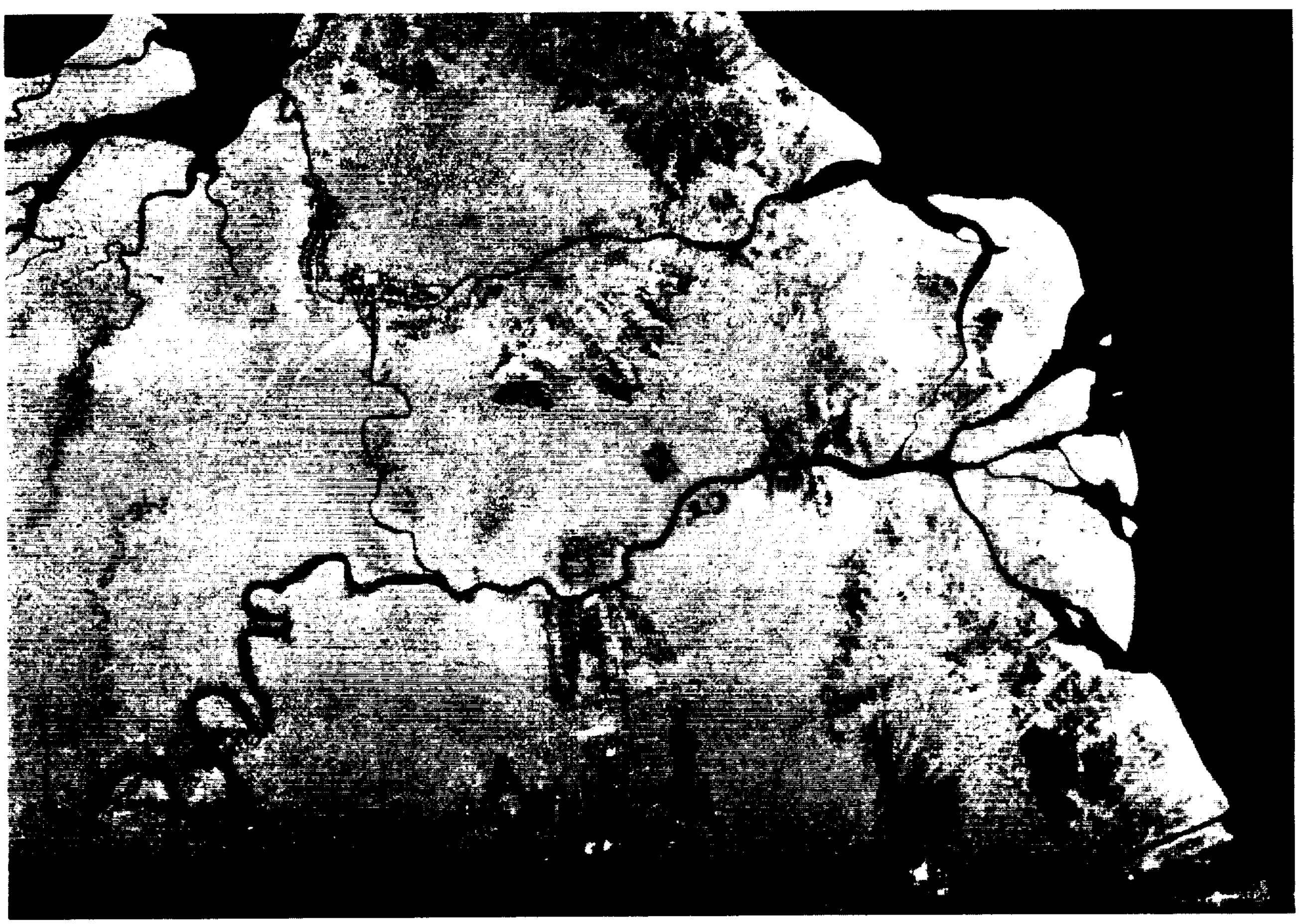

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CHAPTER 5

NEWSLETTERS AND PAPER CATALOGS

NSSDC NEWSLETTER

The NSSDC produces a quarterly newsletter, the *NSSDC News*,[38] which is distributed worldwide to a mailing list of approximately 3,000 recipients. It is available, free of charge, to any interested individual or organization.

The newsletter has been produced by the data center since 1985. Its purpose is to disseminate timely information about the data center and closely related activities that might prove useful to the scientific community. Topics include new data sets available through the NSSDC, technologies being developed within the data center, pilot programs, information about upcoming meetings and results from those meetings, descriptions of data center services with profiles of the personnel that provide the services, and discussions of cooperative programs with other government agencies or academic institutions.

Because the data archive at the NSSDC is multidisciplinary and the data center is also deeply involved in advanced technology development, the newsletter's content is extremely varied. The editorial staff has attempted to make this multifaceted newsletter interesting and readable to a wide range of recipients. Comments from readers about published articles and suggestions for future topics are encouraged.

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SPACEWARN BULLETIN

The International URSIGRAM and World Days Service (IUWDS) is a permanent service of the Council of Scientific Unions (ICSU). One element of IUWDS is the WWAS, which is operated by NSSDC/WDC-A-R&S. The main effort is the SPACEWARN System which alerts the space science community to significant events concerning the status of spacecraft, as recommended by the ICSU's Committee on Space Research (COSPAR). More specifically, NSSDC/WDC-A-R&S collects information on imminent and actual launches and the status of orbiting spacecraft, along with other essential data, and disseminates this information worldwide. The benefit of this role arises from the data center's ability to obtain and assess the numerous inputs it receives from governmental and independent sources around the globe, and to condense them into a concise monthly publication called the *SPACEWARN Bulletin.*[51] The bulletin includes all launch announcements on spacecraft, but only those prelaunch announcements which are submitted directly by the launching agencies; expected re-entry dates of any spacecraft, rocket body, or debris; and actual re-entry dates. Launch announcements are compiled by WDC-A-R&S if they are not provided by the launching agency. These announcements contain brief mission descriptions and orbital parameters. Updates of the orbital/radio beacon data are also included for certain spacecraft, i.e., those with frequencies in the VHF range of interest for ionospheric/atmospheric study. The user community is periodically contacted for confirmation.

In a typical week, NSSDC/WDC-A-R&S receives about 80 telexes, many of them from the U.S. tracking organization, USSPACECOM, and the network of Foreign Broadcast Information Service (FBIS) stations around the world. The latter source is particularly helpful in providing background and pre-launch information gathered from press releases and radio announcements from the Soviet Union, China, Japan, India, and other nations. The FBIS network also supplies information on malfunctions. The USSPACECOM telexes provide the actual launch verification soon after a spacecraft has been launched and its orbit has been determined. This organization suggests the international ID number for the spacecraft, which is then officially assigned by NSSDC/WDC-A-R&S on behalf of COSPAR.

After extracting information from its sources, the NSSDC/WDC-A-R&S staff sends telexes to 12 IUWDS/COSPAR-recommended regional warning centers around the world. They, in turn, forward the information to numerous space science institutions in their jurisdictions. The telexes, usually sent within 48 hours after launch, give the name of the spacecraft, international ID, and date and country of launch.

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PAPER CATALOGS

The current *NSSDC Data Listing*[24] identifies, in a highly summarized way, data available from the NSSDC. More than 4,000 spacecraft/instrument data sets held by NSSDC on magnetic tape or as film/print products of various sizes, as well as several ground-based data sets, models, and computer routines are identified. The *NSSDC Data Listing* provides a very high level index for all NSSDC holdings.

To satisfy the need of the user community for details about the contents of the data sets, the data center provides online information files and various paper catalogs. The *Data Catalog Series for Space Science and Applications Flight Mission*[5,21,22,23,27,29,32,33,43] consists of a series of 11 volumes that describe spacecraft investigations and data sets held by NSSDC and spacecraft investigators. This catalog series consists of the following:

- Five volumes that describe the spacecraft and their associated investigations separated into different categories.
- Five corresponding volumes that describe investigation data sets and available orbital information.
- A master index volume.

The five categories of spacecraft are:

- Planetary and Heliocentric, which includes planetary flybys and probes (Vol. 1A and 1B).
- Geostationary and High-Altitude Scientific (2A,B).
- Low- and Medium-Altitude Scientific (3A,B).
- Meteorology and Terrestrial Applications (4A,B).
- Astronomy, Astrophysics, and Solar Physics (5A,B).

Ten volumes and an index volume have been distributed. There is one major omission from this series: the extensive set of data obtained from the lunar missions conducted by NASA, supplemented by a few small photographic data sets from Soviet missions. These are described in the *Catalog of Lunar Mission Data.*[4]

In addition to this major catalog series, NSSDC distributes other catalogs and special paper reports describing in some detail data holdings in special groups. Examples of these documents include *Catalog of Lunar Mission Data*[4] referenced above; *Data Announcement Bulletin (DAB)*;[18] *Availability of Infrared Astronomical Satellite (IRAS) Data Sets from NSSDC;*[1] *Astronomical Data Center Catalog;*[50] *Coordinated Ionospheric and Magnetospheric Observations from the ISIS 2 Satellite by the ISIS 2 Experimenters;*[31] *User's Note for Alouette and ISIS Ionograms;*[28] *Nimbus (5 and 6) Data Catalogs;*[34]*Catalog of Particles and Fields Data;*[14] *Interplanetary Medium Data Books;*[16] *Catalog of Viking Mission Data;*[48] *Coordinated Data Analysis Workshop (CDAW) Data Catalog,*[15] the *NASA Climate Data Catalog;*[42] *and the Crustal Dynamics Data Information Systems User's Guide.*[30]

Availability of newly distributed paper catalogs and paper data documents is announced in the *NSSDC News.*[38] The NSSDC and WDC-A-R&S *Document Availability and Distribution Services (DADS)*[19] document lists available paper data catalogs and appropriate paper data reports. Copies can be obtained by contacting the NSSDC Request Coordination Group at (301) 286-6695, (SPAN) NCF::REQUEST or (internet) request@nssdca.gsfc.nasa.gov.

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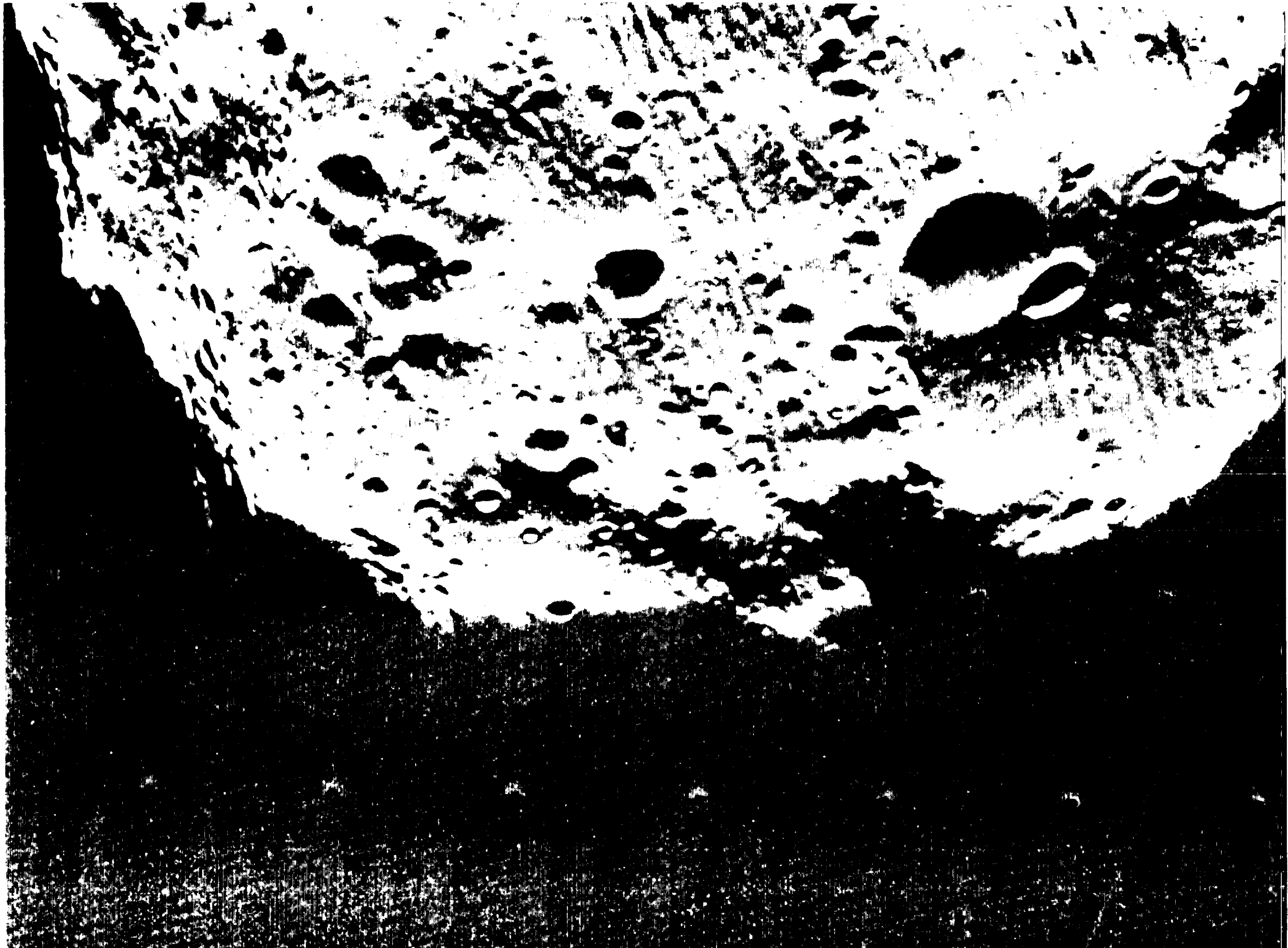

CHAPTER 6

VALUE-ADDED SERVICES

ASTRONOMICAL DATA CENTER

The Astronomical Data Center (ADC) is a group within the NSSDC that specializes in the acquisition, processing, documentation, archiving, and distribution of machine-readable astronomical catalogs and other specialized data sets in various astronomical disciplines. Computerized astronomical catalogs are widely used to support basic research, telescope and spacecraft pointing and tracking, online data reduction, data retrieval, and the analysis of new observations.

The ADC effort is actually a collaboration between the NSSDC and its parent, the Space Data and Computing Division, wherein both groups accept responsibility for the analysis and documenting of catalogs; however, the latter group is more heavily involved with the development of advanced data retrieval systems, while the former maintains the data archive and performs all distribution related activities. Through a cooperative agreement with the CDS in France, the ADC acquires all catalogs deposited with the CDS and supplies all ADC acquired data to the CDS for dissemination from there. Established by the International Astronomical Union, the CDS acts as a central repository of an international network of centers for astronomical data, including facilities at the Goddard Space Flight Center and in Moscow, Potsdam, and Tokyo.

The policies and procedures for the acquisition and preparation of astronomical data for deposit in the ADC archives are primarily determined by the fact that the astronomical data centers are the only permanent archives of data in all disciplines of astronomy, and their primary role is to archive and permanently retain data for use by present and future generations of astronomers. Catalogs acquired from the astronomical community are, therefore, examined, restructured and/or modified if necessary, usually in collaboration with their creators, and archived in the best possible form. This work is done to ensure that the data will be easily processable by other computers, that formats are as simple as possible and conform to standard usage, and that maximum storage efficiency is achieved. The data are then documented in detail with a paper giving historical information, literature citations, and a byte-by-byte format description for each file of the catalog. A draft copy of each document is sent to the author(s) of a machine catalog for comments and suggestions before the document is printed for distribution with the data. The close cooperation of authors and ADC personnel usually results in a better final product, since authors almost always have more expertise with their own data than do data center astronomers. The collaboration can also be a learning experience for authors and compilers of catalogs, and may result in higher quality data preparation for future catalogs.

The ADC maintains a *Status Report on Machine-Readable Catalogs*[45] that gives a more detailed listing of the catalogs given in the *NSSDC Data Listing.*[124] Updated reports are available on request, as well as being published in issues of the *Astronomical Data Center Bulletin.*[49]

The ADC processes more than 500 requests for data per year and answers thousands of questions about data availability, catalog content, and use of the data for various applications. The current archive contains more than 500 catalogs and data sets with approximately 35 GBytes of data.

The ADC also maintains an online information system and network request service that can be accessed via SPAN. Certain data sets (depending upon size) can be transmitted to requesters via SPAN and BITnet. These catalogs are indicated in an information packet that is distributed over the networks. Additional information about how to access the ADC Online Information System can be found in issues of the *NSSDC News*[38] or by contacting the ADC.

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COORDINATED DATA ANALYSIS WORKSHOP PROGRAM

The Coordinated Data Analysis Workshop (CDAW) program is sponsored by the NSSDC to further the conduct and development of new techniques/tools for large-scale collaborative scientific research, using data from many investigators to address significant global-scale physical problems that may not otherwise be addressable. The concept originated in the solar-terrestrial community with a need to analyze simultaneous data from a variety of sources to better understand the structure and dynamics of systems like the Earth's magnetosphere.

The CDAW program is distinguished by its combination of a traditional workshop format with assembly of a data base where the data and relevant models have been cast into a common format, with supporting software and computer access to allow participants direct interactive graphic display and manipulation. Access to the data base between workshop meetings is supported by SPAN links between the NSSDC and the participants. The CDAW program is one model for aspects of how the collaborative work to be included in the Inter-Agency Consultative Group (IACG) solar-terrestrial science initiative and the NASA Global Geospace Science (GGS) program might be carried out.

The most recent activity, CDAW 9, was initiated with a major workshop at the NSSDC in May 1989. This workshop addressed specific events during the 1986 PROMIS (Polar Regions and Outer Magnetosphere International Study) interval. The unique aspect of this interval is concurrent imaging of the north and south hemisphere auroral regions by the Viking and Dynamics Explorer spacecraft, respectively. Several teams of scientists from the U.S., Europe, and Japan participated and addressed such issues as substorm expansion phase and onset mechanisms, and magnetosphere-ionosphere connectivity.

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SATELLITE SITUATION CENTER

The Satellite Situation Center (SSC) is designed to serve the planning needs of investigators for coordination of data acquisition and collaborative efforts. This part of the NSSDC was developed to meet the challenge of the International Magnetospheric Study (IMS).

During the IMS period (1976-1979) and in 1971-1975, the SSC developed a variety of programs to compute and display orbit-related parameters of spacecraft in any of a number of coordinate systems used in space physics. It provides both predicted and after-the-fact trajectory information, utilizing orbital elements. The SSC programs also provide such information as times and locations for which two or more spacecraft are on the same magnetic field line, or when a spacecraft will be on the magnetic field line that connects to a ground station. Models are available to predict times of crossing certain surfaces or regions of interest, such as the magnetopause, the polar cap, or the bow shock. Locations of planets, comets, and spacecraft can be shown in heliocentric coordinates. All of this information can be presented in plot and/or tabular form. The SSC plot capability is augmented by converting any list file to a Common Data Format (CDF) and then utilizing the NSSDC Graphics System. At present, the programs can be run only on the NSSDC's MODCOMP, but efforts are under way to make them compatible with VAX/VMS and Sun/UNIX systems.

The PROMIS project was actively supported by the SSC through identification of predicted opportune times for data acquisition by the numerous spacecraft involved. The SSC service also provides routine ephemeris and related information for use in certain spacecraft science operations planning but does not support routine tracking activities. The NSSDC and its SSC are playing a major role in an international spacecraft coordination program under the auspices of the Inter-Agency Consultative Group (IACG). Computation of mutually favored orbits of Akebono, Active, DE1, and CRRES spacecraft are now well under way. Efforts are now in progress to make the results of these computations available to the science community through online files that may be accessed through SPAN.

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MODELS OF THE SOLAR-TERRESTRIAL ENVIRONMENT

Models are ideally the synthesis of the accumulated experimental evidence. They allow us to advance from monitoring the environment to forecasting it. A modeler's task is to combine past data records from different experimental techniques and to extract the dominant variation patterns.

In the different subregions of the Earth-Sun system, different parameters are of interest and different dependencies have to be considered. The solar-terrestrial environment encompasses the Earth's ionosphere, atmosphere, and magnetosphere, and the solar wind, the interplanetary magnetic field, and the Sun.

The NSSDC contributes expertise and resources to several aspects of the long-term goal of establishing reliable models for the entire solar-terrestrial environment. Figure 8 schematically illustrates the broad spectrum of activities at NSSDC related to models. It is actively involved in international efforts to improve the existing models and develop models for regions and parameters not yet described. Several international scientific organizations (e.g., COSPAR, URSI, IAGA) supervise and guide the modeling efforts. The models selected and recommended by these organizations are distributed by the World Data Centers. Besides these officially designated models, the NSSDC maintains a large archive of models (see Table 3) and related software for the ionosphere,[2] atmosphere, and magnetosphere. The model software packages are distributed on magnetic tape or floppy disk, and are networked to remote users over SPAN.

User-friendly interfaces and special versions for personal computers have been developed for the most frequently requested models (shown in bold print in Table 3). The most important models can also be accessed on line in the NSSDC account. Menu options include: (1) read documentation, (2) transfer software, and (3) run program. Many of the models are integrated into other value-added services at the NSSDC such as the SSC and the CDAW.

The NSSDC is well equipped for modeling work. Its assets include a science team with experts on the different areas of solar-terrestrial science, a large archive of spacecraft measurements, and a group of computer hardware and software specialists.

Ionosphere

The ionosphere is the partially ionized, gaseous

IONOSPHERE:	
	IRI-86 (COSPAR/URSI)
	Ching-Chiu (1975), Rush-Miller (1973)
ATMOSPHERE:	
	CIRA/MSIS-86 (COSPAR)
	Jacchia Reference Atmospheres 70, 71, 77
	US Standard Atmosphere 62, 66, 76
MAGNETIC FIELD (MAIN):	
	IGRF 45, 50, 55, ... 85, 85-90
	GSFC (9/65, 12/66, 9/80)
	POGO (3/68, 10/68, 8/69, 8/71)
	MAGSAT (3/80, 4/81)
MAGNETIC FIELD (INCLUDING EXTERNAL SOURCES):	
	Tsyganenko et al. (1982, 1987)
	Beard (1979), Mead-Fairfield (1975)
	Olson-Pfitzer (1974)
TRAPPED PARTICLES:	
	AE-8, AP-8
	AE-2 to AEI-7, AP-1 to AP-7
SOLAR PARTICLES:	
	SOLPRO, Solar Proton Fluences, Stassinopoulos-King (1974)

Table 3: Models at the NSSDC

envelope that surrounds the Earth from about 50 km to 2000 km. Radio waves undergo a change in direction and phase when transmitted through the ionospheric plasma; therefore, reliable ionospheric models are needed for a wide variety of applications including telecommunications, satellite orbit determination, and radio astronomy.

In need for an international standard, URSI and COSPAR established working groups in the early 1970s to produce an International Reference Ionosphere (IRI). The NSSDC is represented in both panels, and the master copy of IRI is held and updated at the NSSDC. The IRI model describes the variation of electron and ion densities and temperatures with latitude, longitude, altitude, local time, season, and solar activity. The IRI function system includes spherical harmonics (global variation), Fourier functions (time), and Epstein functions (altitude). Data analysis and comparisons resulted in several improvements of the IRI model. The next major step is the development of a reliable model for auroral and polar latitudes. In this region, the close coupling with the magnetosphere and the precipitation of energetic particles have to be considered.

Geomagnetic Field

Description of the Earth's magnetic field is one of the most important tasks of magnetospheric modeling. The NSSDC has collected a large archive of geomagnetic field models and related software. For the main Earth field, this includes the IGRF models (1945, 1950, ...1985), the GSFC models (September 1965, December 1966, September 1980), the POGO models (March 1968, October 1968, August 1969, August 1971), and the MAGSAT models (March 1980, April 1981). Each model provides the geomagnetic field vector for any latitude, longitude, and altitude, and the epoch for which the model was built. The epoch is important because the geomagnetic field exhibits a small secular variation. All of the models use spherical harmonics to represent the potential of the geomagnetic field, whose gradient determines the magnetic vector field. The expansion includes the dominant dipole term and the higher multipole terms.

These models are good representations of the Earth's magnetic field in the inner magnetosphere out to several Earth radii. Farther out, the interaction with the solar wind distorts the Earth magnetic field. On the day side, the solar wind pressure compresses the terrestrial field; on the night side, the field is stretched out like the tail of a comet. Several groups have attempted to model the whole field, including the contributions from magnetospheric current systems. The NSSDC archives software packages for the following models: Olson-Pfitzer - 1974, Mead-Fairfield-1975, and Tsyganenko - 1987.

Magnetospheric Trapped Particles

The Earth is surrounded by a belt of trapped electrons and protons. These particles gyrate rapidly around the geomagnetic field line, bounce back and forth less rapidly along magnetic field lines, and drift slowly around the Earth. At the magnetic equator, the belt begins at about one Earth radius (above approximately 200 km) and is more than five Earth radii thick.

The NSSDC has been the major force behind the modeling of the trapped particle fluxes since the first comprehensive satellite measurements were undertaken. The models have been continuously updated at the NSSDC as new measurements became available. This is documented in several NSSDC reports covering the model editions from 1 to 8. Further improvements are envisioned with the results of the upcoming Combined Release and Radiation Effects Satellite (CRRES).

NSSDC's trapped radiation models provide the electron and proton fluxes (integral or differential) for given energy, L value, and B/B_0 (magnetic field strength normalized to the equatorial value), either for solar maximum or for solar minimum. They have been used for a wide array of applications and have proven especially helpful for determining the radiation exposure for satellite missions.

The NSSDC is continuously updating and expanding its model collection to enhance its service to the

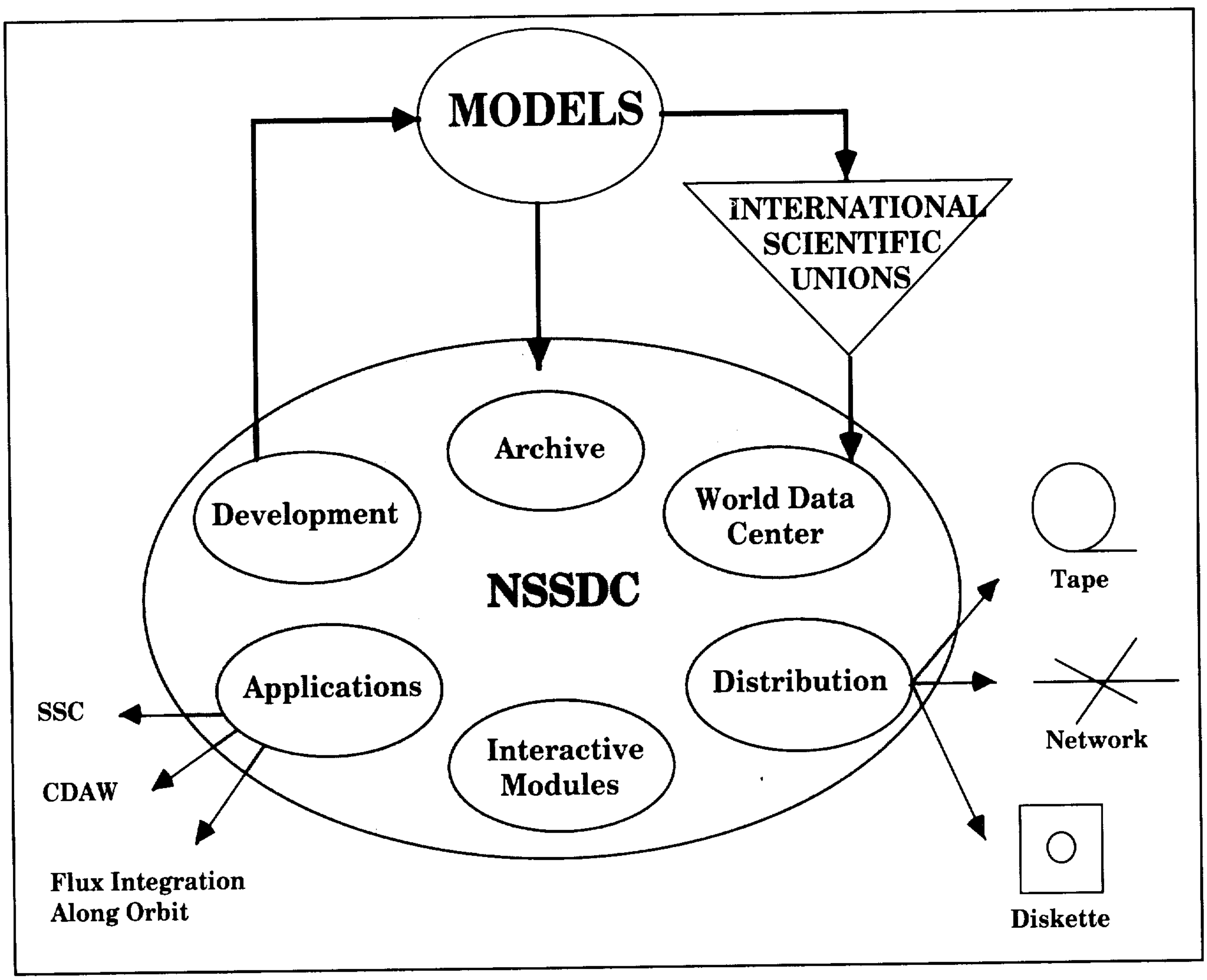

Figure 8: NSSDC Archiving and Distribution of Geophysical Computer Models

scientific community and to large-scale projects like the International Solar Terrestrial Program (ISTP). Future plans include a catalog of models (online and in hard copy).

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NASA SCIENCE DATA SYSTEMS STANDARDS OFFICE

The NASA Science Data Systems Standards Office (NSDSSO) at the NSSDC has been established to serve the space and Earth science communities in evolving cost-effective, interoperable data systems. It has been recognized that research organizations that promote the use of cost-effective standards for their operations will have relatively more resources available to devote to the generation of truly unique and significant advances in science and technology. To this end, the NSDSSO performs a number of functions designed to facilitate the recognition, development, adoption, and use of standards by the space and Earth science communities.

The NSDSSO is organized into four distinct functional areas, all operating under the guidance of its Executive Board. These areas are known as NSDSSO Administration, Standards Library, Standards Accreditation, and Standards Conformance and Support (see Figure 9). The Administration operation is concerned with managing the activities of the other three NSDSSO areas, administering the office's policies and procedures, and providing an active interface to other standards organizations within and outside NASA to foster both the exchange of standards information and the development of new standards.

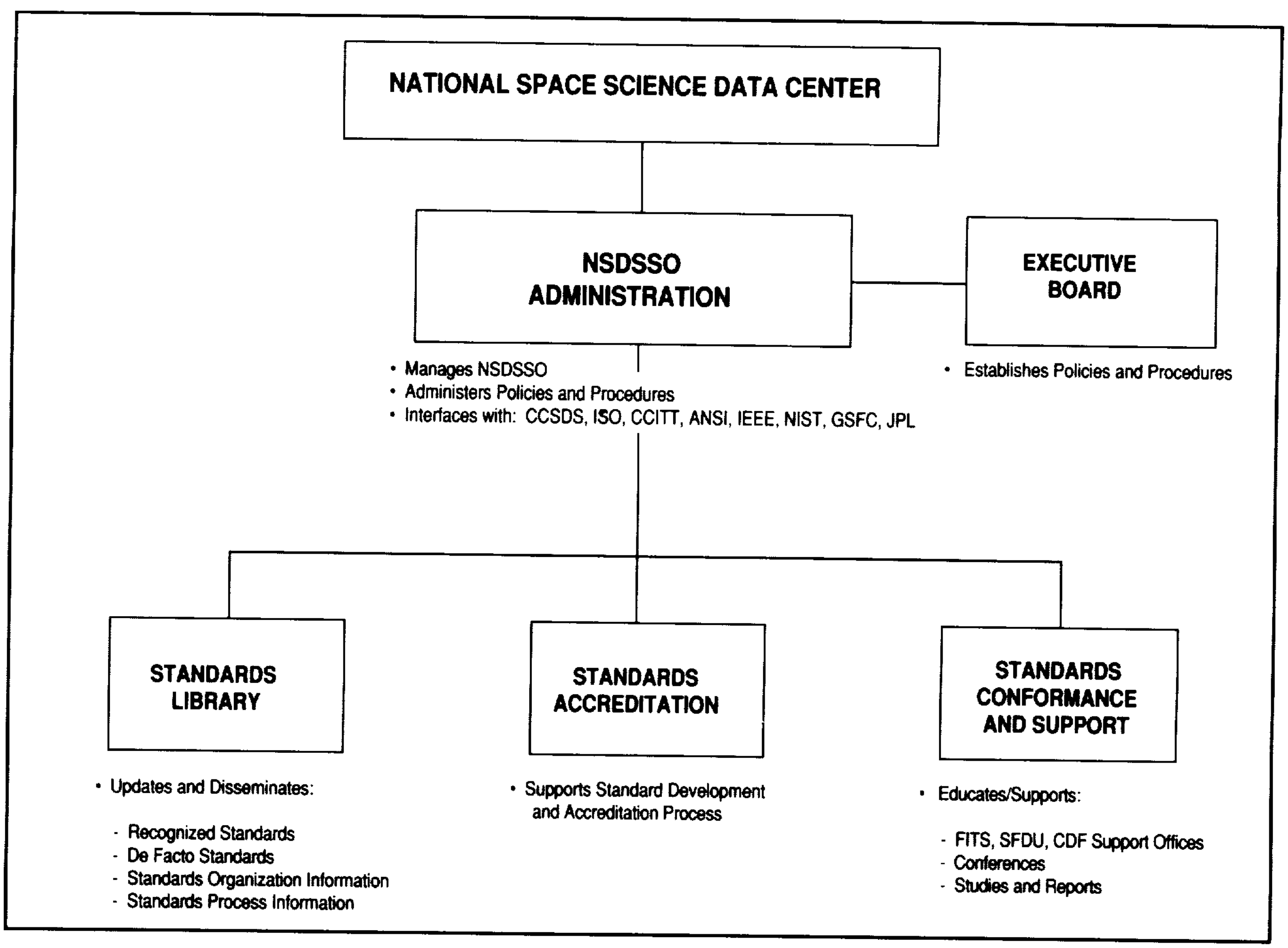

Figure 9: NASA Science Data Systems Standards Office Administration

The Library is concerned with collecting, updating, and disseminating information about existing and emerging standards of relevance to NASA and NASA-related data systems. Information on recognized standards (i.e., standards documented by recognized standards organization such as the International Standards Organization [ISO], American National Standards Institute [ANSI], and Consultative Committee for Space Data Systems [CCSDS]), and de facto standards (i.e., specifications/systems in wide and stable use) are the primary categories maintained in the Library, with each broken into a number of subcategories to facilitate searching and identification. Other categories include information on the various standards organizations and on the standards creation process. Some standards specifications are available on request, while others must be obtained from commercial organizations. Requests for standards information may be satisfied through the online information service, electronic mail to the SPAN account known as NCF::NSDSSO, or by mail request to the NSSDC. The overall Library operation provides an educational service to the space science community.

The Standards Accreditation operation is concerned with the establishment, maintenance, and use of policies and procedures for the development of new standards, and the adoption of existing standards as NSDSSO standards. These policies and procedures cover the establishment of technical groups to develop standards, the review processes through which draft standards must pass, and the logistical support available from the NSDSSO. The overall Standards Accreditation operation provides a mechanism for the development and accreditation of standards by the space and Earth science communities.

The Standards Conformance and Support operation is concerned with support for existing and emerging standards. This support ranges from providing information to potential users on experience with commercial standards, to a full support office for the use of a particular standard. Where a commercial vendor is not available to support a particular standard, testing and validation of an implementation of the standard may be provided by this operation. The actual operations at any one time will depend on the needs of the community and availability of resources. The overall Standards Conformance and Support operation provides a broad range of educational and supportive services to the space science community.

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GENERIC DATA STORAGE STRUCTURES

The NSSDC's Common Data Format (CDF) is a self-describing data abstraction for the storage and manipulation of multidimensional data in a discipline-independent fashion. The development of CDF arose out of the NSSDC's recognition of a need for a class of data models matched to the structure of scientific data, as well as to use of such data. Applications that need to be served by an appropriate data model include analysis by statistical and numerical methods, visualization and management.

Traditional methods of handling scientific data such as flat sequential files are generally inefficient in storage, access or ease-of-use for large complex data sets, particularly for applications like visualization. Modern, commercial relational data management systems do not offer an effective solution because they are more oriented toward business applications. The relational model does not accommodate multidimensional or hierarchical structures often found in scientific data sets. In addition, relational systems do not provide adequate performance for the size, complexity, and type of access dictated by current and future data sets and their potential usage. In contrast, these data base management systems have been quite viable for a large class of non-spatial metadata (i.e., information about data) within a number of NSSDC data systems.

Therefore, there is a need for some type of data (base) model that possesses elements of a modern data base management system, but is oriented toward scientific data sets and applications. This intermediate approach should be easy to use, support large disk-based data sets, and accommodate scientific data structures. CDF is one implementation of such a data model. It is based upon the concept of providing abstract support for a class of scientific data that can be described by a multidimensional block structure. Although all data do not fit within this framework, a large variety of scientific data do. For example, the type of data utilized in the NASA space and Earth science research community can be easily characterized by its dimensionality (e.g., 0 for point data, 1 for vector data, 2 for imagery). Since CDF is designed to support many scientific applications in a discipline-independent fashion, it is a powerful tool for the development of systems that can archive, manage, manipulate, display, or analyze data. This abstraction, which consists of a software package and a self-describing data structure, is a result of some of the NSSDC's applied computer science work.

CDF version 1 was completed in early 1986 and is described by L. Treinish and M. Gough, in *A Software Package for the Data-Independent Management of Multidimensional Data*, **EOS**, **68**, pp. 633-635, 1987[46]. CDF version 1 consists of FORTRAN language bindings and is operational on Digital Equipment Corporation's VAX/VMS systems. More than 100 organizations outside of the NSSDC representing various NASA laboratories, research groups, current and future flight projects, as well as other government agencies, universities, corporations, and foreign institutions are currently using or have requested this CDF software package. As a result, the CDF development efforts have become a standard method for storing space and Earth science data for a variety of applications. Language bindings for IDL (Interactive Data Language, a commercial data analysis software package developed by Research Systems, Inc.) on VMS systems are also available.

CDF version 1 has been critical to the success of the NSSDC's CDAW 8 and 9 workshops and NCDS activities. CDF has enabled the CDAW participants to produce scientific results via data interpretation and analysis at an unprecedented rate. CDF was used to manage a diverse solar-terrestrial physics data base (more than 50 different data sets for each workshop) that was a driver for various generic (i.e., CDF-based) data analysis and display tools. CDF is a key element in the NCDS by providing a mechanism for climate researchers to easily work with data online, in association with information about climate data (i.e., catalogs and inventories) and an extensive data archive. In addition, a CDF Support Office has been established in conjunction with the NSSDC Science Data Systems Standards Office, to help dis-

Operations of the CDF Software Package

(Language Bindings for the CDF Data Abstraction)

Name/Operation	**Function**
Global	The Entire CDF
• CDF_create	Create a CDF
• CDF_open	Open a CDF
• CDF_close	Close a CDF
• CDF_delete	Delete a CDF
• CDF_inquire	Inquire about a CDF
Attribute	Global or Variable-Specific Information
• CDF_attr_create	Create a CDF attribute
• CDF_attr_inquire	Inquire about a CDF attribute
• CDF_attr_put	Enter a value for a CDF attribute
• CDF_attr_get	Extract a value for a CDF attribute
Variable	The Actual Data
• CDF_var_create	Create a CDF variable
• CDF_var_inquire	Inquire about a CDF variable
• CDF_var_put	Enter a value for a CDF variable
• CDF_var_get	Extract a value for a CDF variable
• CDF_hyper_put	Enter a multidimensional block for a CDF variable
• CDF_hyper_get	Extract a multidimensional block for a CDF variable

Table 4: Summary of Bindings in Version 2 of CDF

seminate information about CDF and to distribute CDF software and documentation.

The NSSDC has recently completed version 2 of CDF. A summary of the bindings are listed in Table 4. This version 2 software is a completely new implementation in C with separate C bindings. It will offer significantly enhanced performance and flexibility over version 1 while being upward compatible with it. The FORTRAN bindings will be maintained as a veneer on top of C, which provides a transparent interface for current CDF users to the new software, as well as handling incompatibilities between the C and FORTRAN programming languages. A key feature of version 2 is its ability to operate on a wide range of different computer systems (e.g., DEC VMS, Sun and Silicon Graphics UNIX, Apple Macintosh, IBM MVS and VM). Currently, the FORTRAN veneer layer will only be supported on a subset of those systems where FORTRAN bindings will continue to be required (e.g., VMS, Sun). Version 2 language bindings for IDL will also be implemented. (IDL currently operates only on DEC VAX/VMS and Sun/UNIX systems.)

The performance improvements in CDF version 2 come from the inherently greater efficiency of C versus FORTRAN, including restructuring of the software to take advantage of C functionality, optimization of internal disk caching, and new access methods. In addition to version 1's capability to provide random access to all elements within a data set stored as a CDF, version 2 extends the bindings to provide hyperplane access. The hyperplane technique provides random, aggregate access to subdimensional blocks within a multidimensional variable. In other words, a vector, plane, parallelepiped, etc., out of an equal or higher-dimensional structure can be accessed through a single call. The subdimensional structure can span the full extent of the multidimensional block or be smaller in size.

In addition to the portability of the software, another advantage of version 2 is that a CDF user/programmer will have the ability to select a run-time binding to a physical data format layer. The physical layer may be either the native format of the computer system being used or a machine-independent layer, which is built upon the IEEE standard via the eXternal Data Representation (XDR) protocol developed by Sun Microsystems and placed in the public domain. Many computer manufacturers (typically of UNIX-based systems) have adopted XDR as their native protocol. On other systems (e.g., VMS) XDR services are available via software services. However, for applications where data portability is not critical and absolute performance is of greater importance, the optional run-time binding to the native physical format offers significant flexibility. In addition, the upward compatibility of the software with version 1 will apply to the data as well - version 2 will provide read access to extant version 1 (VMS) CDFs.

NSSDC has started planning CDF version 3, which will enhance version 2 with machine and media-independent distribution and network services. Part of this activity is currently focusing on testing of the Network Computing System (NCS) developed by Apollo Computer and adopted by a number of other computer manufacturers (e.g., IBM and DEC). Initially, NCS could be used to provide a network shell to provide transparent access to CDF data bases distributed over a network. In this scenario, an application running on a Sun workstation could have transparent access to a large data set stored in CDF on a VMS system via an optical disk, for example at the applications programmer's level. For environments where task-to-task networking is neither available nor feasible, transport distribution services would be developed to provide computer-independent mechanisms for "shipping" CDFs through a variety of media. This truly interoperable CDF over heterogeneous environments is expected to become available in 1990.

Other future work will concentrate on additional access methods and alternative (e.g., hierarchical) data structures, which will be particularly relevant for large volumes of spatial data. Since the implementation of the CDF data abstraction really implies an extension of a conventional programming language for the support of multidimensional data objects, a recasting of CDF into an object-oriented environment such as C++ will be pursued.

The CDF effort involves the integration of various physical science disciplines and the computational sciences with an emphasis on developing capabilities for researchers to concentrate on doing science, freeing them from the mechanism of working with specialized data structures or formats. What is important is not the details of the technology, but what that technology can easily and inexpensively provide to promote science. Such activities will further the use of heterogeneous computer systems to support the management, analysis, and display of any scientific data of interest separately from a centralized computer system.

Figure 10 illustrates the role of CDF in the data systems that support two of the NSSDC programs mentioned above, CDAW and NCDS. In addition, the sample plots show the diversity of the data sets that can be supported by CDF.

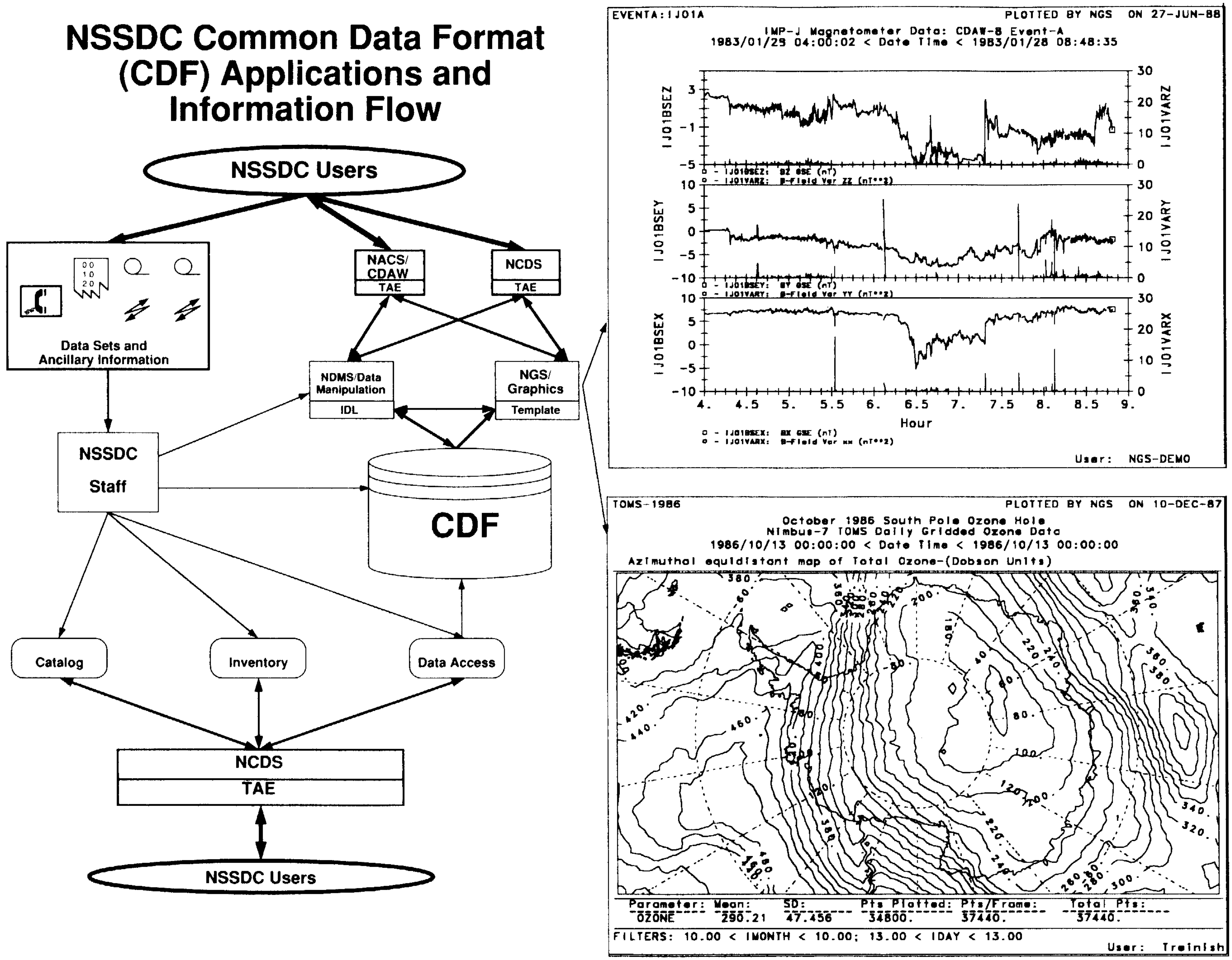

Figure 10: Common Data Format (CDF) Structure and Examples

The top plot on the right illustrates data concerning the Earth's magnetic field derived from the Interplanetary Monitoring Platform (IMP-J) spacecraft. These data were among the ensemble of data sets that formed the CDAW 8 data base. This plot is divided into three panels, one each for the x, y and z components of the magnetic field. Each of the traces are for some five hours of in situ observations by the IMP-J magnetometer on January 28, 1983. The righthand series of three traces is for the magnetic field components in GSE coordinates in units of 10^{-9} Teslas, which are marked by a circle. The lefthand traces are for the variance of the components in units of 10^{-18} Teslas^2.

The bottom plot on the right illustrates data from the Total Ozone Mapping Spectrometer on board the Nimbus 7 spacecraft. The data are available as daily world grids (37,440 cells per grid) from late 1978 through the present at the NSSDC, and are supported by the NCDS. These data have become increasingly valuable as they indicate the presence of the so-called ozone hole over the south pole. This plot shows the internal structure of the ozone hole for October 13, 1986, projected in an azimuthal equidistant map centered over the south pole so that Antarctica fills the viewing window. The contour lines of total ozone are incremented every 20 Dobson Units.

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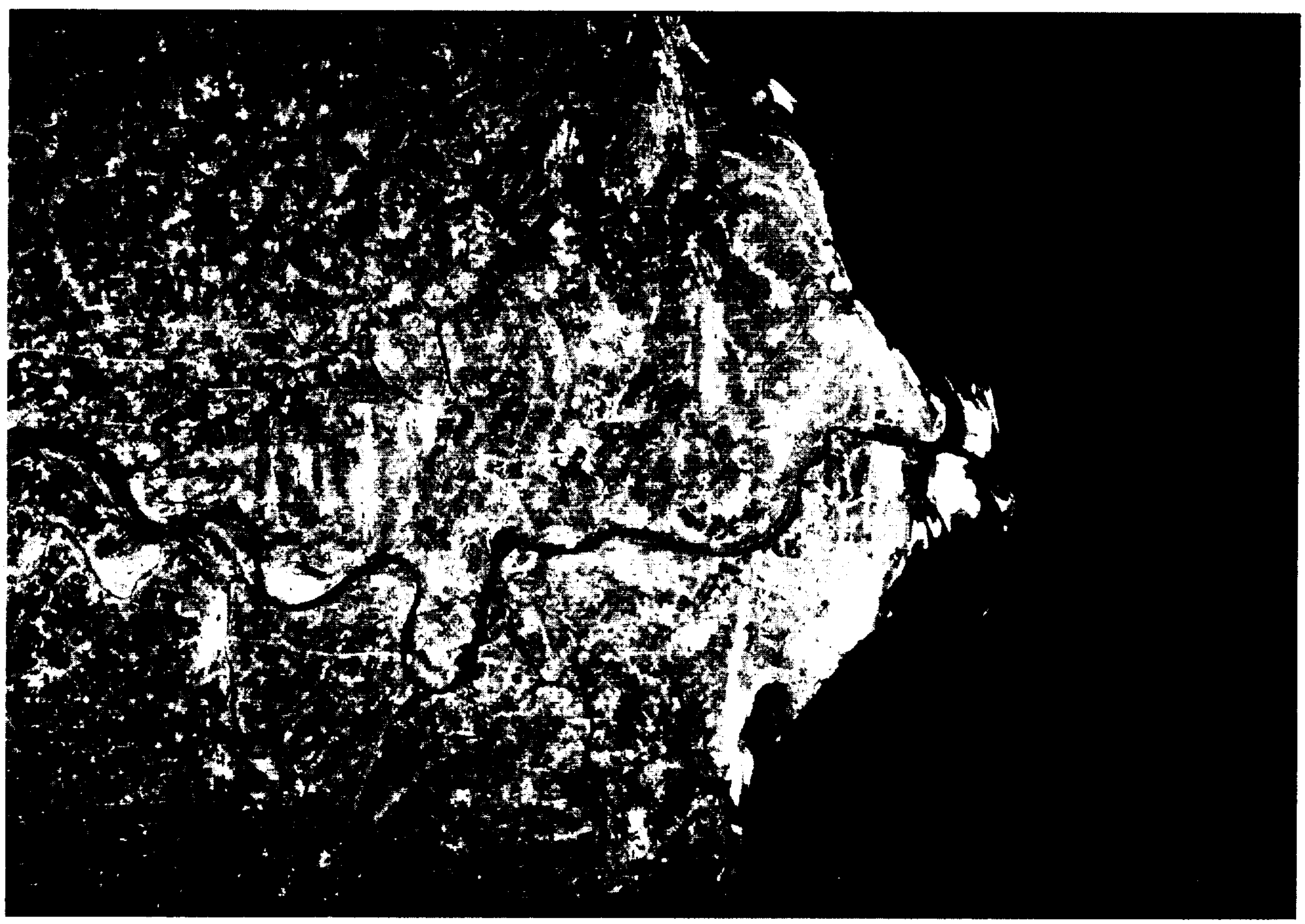

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CHAPTER 7

MASS STORAGE ACTIVITIES

WORM OPTICAL DISK SYSTEMS

In order to better preserve current data for future accessibility, to deal with physical storage space constraints, and to prepare for the future ingest of very large data volumes, the NSSDC has been actively pursuing a mix of research and operational activities with optical disk technologies. Most of these activities have dealt with Write Once Read Many (WORM) and Compact Disk Read Only Memory (CD-ROM) technology.

WORM technology enables users, like the NSSDC and its "customers," to write data from their tapes or other media to optical disks. There are two common form factors, 5 1/4-inch and 12-inch. Most NSSDC activity has been with 12-inch WORMs, which are capable of holding 1 GB of data on each side of a two-sided disk. Capacities are gradually increasing with time. Lack of widely accepted standards continues to be a problem.

The NSSDC has developed the SOAR (System for Optical Archival and Retrieval) software package for reading from and writing to WORM disks with VAX/VMS (Files-11) via Unibus, and Q-bus interfaces. In Read mode, the WORM disk appears just as if it were a magnetic disk, but in Write mode, SOAR diverts directory information to a magnetic disk where it may be overwritten by VMS until it is moved to the optical disk upon filling and closing the optical disk. The current version of SOAR permits the writing of the directory to a specially allocated optical disk region on dismounted, not-yet-closed disks.

The NSSDC is currently developing a software package (Virtual Optical Disk or VOD) to enable a disk written with certain file structures (e.g., Files-11) and under certain operating systems (e.g., VMS) to be read from and used by computer systems running operating systems other than the one used in the disk's creation.

To help deal with the lack of standards in the WORM environment, the NSSDC has coordinated a competitive mass buy of 12-inch WORM disk drives to be compatible with VAX computers and the SOAR software package. Forty units were purchased under this procurement, with the great majority being repurchased by groups throughout the NSSDC customer community. Disk drive recipients will write data to their disks for archiving at the NSSDC and will be able to receive from NSSDC WORM disks archived by their colleagues.

As a separate application of WORM technology, the NSSDC has recently taken delivery of a stand-alone system consisting of a WORM drive, a standard 1/2-inch tape drive, a smart controller, and a user terminal. With this system, images of tape files may be moved to optical disks and back again to tape. This enables the archiving of data on space-conserving optical disks, yet allows the easy dissemination of user-requested data files on tapes to users having no optical disk reading capability.

The NSSDC has begun migrating data from its tape archives onto WORM disks. Such data include zodiacial light data from Helios, spectral data from the International Ultraviolet Explorer, and Nimbus 7 SMMR and TOMS data.

WORM technology is the technology of choice when only a small number of copies of archival data will be created and when local write capability is required.

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CD-ROM ACTIVITIES

CD-ROM is the technology of choice when a central organization must create many copies of a given data set for wide dissemination. Each CD-ROM disk may hold about 600 MB of digital data.

The NSSDC has purchased a CD-ROM premastering system for use by NASA groups in the creation of CD-ROMs. During the first half of 1989, CD-ROMs were created containing 30 of the most popular Astronomical Data Center source catalogs, and comet Giacobini-Zinner data taken in situ by the ICE spacecraft and remotely by various International Halley Watch ground observatories. A major workshop for users of these disks and potential users of the NSSDC premastering workstation was held at the NSSDC in mid-1989. The definition of standards and recommendations to layer on top of ISO-9660 is being developed.

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NSSDC DATA ARCHIVE AND DISTRIBUTION SYSTEM (DADS)

Many projects have been supported at the NSSDC to implement data archive systems. None, however, have the potential and scope of the NSSDC Data Archive and Distribution System (DADS) which is currently being developed.

There are four major software components in the system: the archiver subsystem, catalog subsystem, data ingest subsystem, and host/user interface subsystem. It uses a VAXCluster configuration with almost 1.2 terabytes of online optical disk storage. The hub of the system is two VAX 8250s and one VAX 6410. A crucial part of the system is the mass storage component of two Cygnet optical disk jukeboxes, models 1802 and 1803. The jukeboxes are each configured with two 6.5 gigabyte optical disk drives. The Cygnet 1802 holds 51 platters and the 1803 holds 131 platters for a total of 1.2 terabytes of online disk space.

Other components of the cluster include magnetic tape drives, stand-alone optical disk drives, staging disks, multiple network access, and a MicroVAX 3300. The jukebox robotics are operated by Cygnet's Jukebox Interface Management System (JIMS) software. Information about the actual data in the archive is managed by the Data Base Management System. DADS will support a data ingest of 300 kb/second into the optical jukebox.

DADS is being designed to support user data requests through online interactive sessions. When DADS becomes operational in late 1990, the system will automatically satisfy user requests by having operators mount removable media, do the copying from the jukeboxes, and mail the disks and tapes to the user. In addition, DADS will support network services which are likely to be the main data distribution method. Following the test of the hardware and software systems, DADS will become the focal point for a number of future NSSDC active project archives.

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As mid-summer approaches in the northern hemisphere on Mars, the melting north polar cap has receded to its smallest size. These overlapping pictures were taken by the Viking Orbiter 2 television cameras on August 30, 1976, from a range of about 4,000 kilometers (2,480 miles). The solid white area toward the top (north) is ice, probably both frozen CO_2 and water ice. The dark bands, which are regions devoid of ice, spiral in toward the cap's center. The reason so little ice occurs in these bands is uncertain but may be related to winds blowing away from the center of the cap. The southern edge of the cap is at about 82 degrees north latitude. The north pole itself is approximately on the planet's limb (the horizon at top of photo on right).

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NSSDC NATIONAL SPACE SCIENCE DATA CENTER

CHAPTER 8

COMPUTER SCIENCE RESEARCH

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE

There is a tremendous diversity of computers, operating systems, data base management systems, communications alternatives and computer center protocols, which makes it necessary that NASA space scientists learn many different access methods in order to obtain data for their research. A solution to that problem is being developed through the Distributed Access View Integrated Database (DAVID) Project using an approach called "uniformization." This approach places a uniform layer on top of each existing system so the user has to learn only two systems, his own and the uniform system. The DAVID solution entails the following approach:

Libraries

Local area networks will be represented as *libraries* and wide area networks as *consortiums of libraries*. The library paradigm (see Figure 11) provides a uniform and well known model for helping users identify and locate objects that are resident on heterogeneous systems. Each computer in a local area network will be modeled as a room of the library. The *main room* will be the gateway into the library and will contain the major administrative functions (administration, reference, circulation, reproduction, union library, and remote library desks); the *tutorial room* will contain the tutorials on using the library; the *catalogue room* will contain a catalog data base of all the items in the library; the *reading room* will contain online items of the library; the *personal library room* will contain the user's personal online items; and the *management room* will provide online items for managing the local library. In addition, a *union library* will contain the *union catalogue* which will identify the items over a consortium of libraries.

Online/Offline Holdings

Both online and offline library holdings will be managed. *Online holdings* will include items immediately accessible to the user via terminal access. *Offline holdings* will contain items that are not immediately accessible and generally require human intervention for acquisition and/or reproduction. These online and offline holdings will be further divided into *type classes* such as data bases, spread-

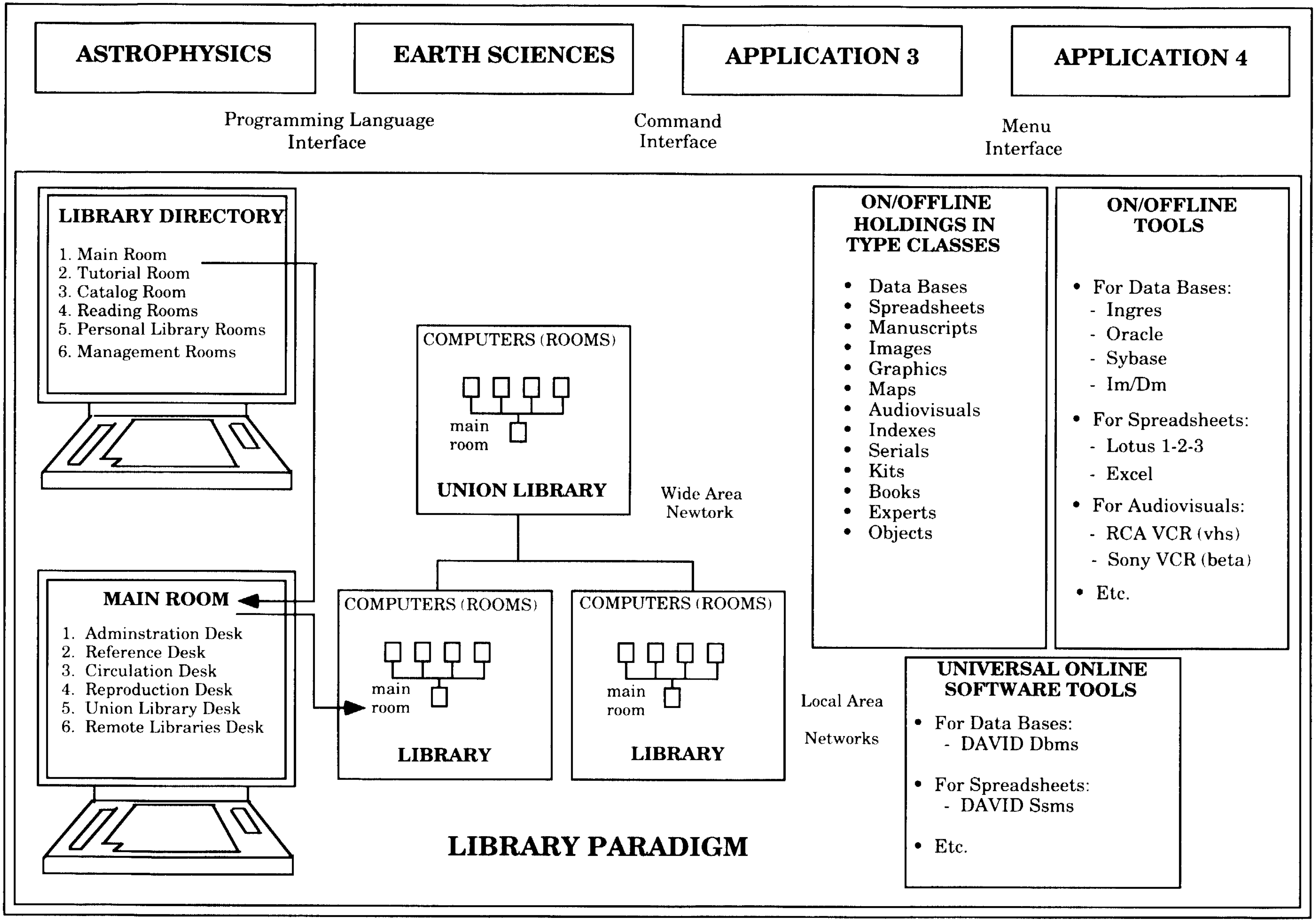

Figure 11: DAVID Approach to the Heterogeneous Systems Problem

sheets, manuscripts, graphic material, images, maps, sound recordings, audiovisual media, microforms, etc. Each type class will include types which vary depending on the particular type class, that is online types will include DAVID, Ingres, Oracle, etc., and offline will include VHS cassette video tapes, 35mm film, etc.

Online/Offline Tools

DAVID will include tools for accessing and manipulating holdings of a particular type within a particular type class. *Online tools* will include computer programs immediately accessible to the user via terminal access or through a batch process. The data base type class will include Oracle, Ingres, and Sybase data base management software programs as online tools for holdings of types Oracle, Ingres, and IMS, respectively. *Offline tools* will not be immediately accessible to the user via terminal or batch process, and generally will require the user to be at the location of the tool.

Universal Software Tools for Online Holdings

The DAVID system will have universal software tools for uniformly accessing and manipulating online all holdings within a particular type class. For example, the DAVID Universal Database Management System has universal creating/dropping, reading/modifying, reproduction, user/data base administration, and system administration tools for different online data base types. As a result, the user will be able to read, update and query data in Oracle, Ingres, and IMS data bases, correlate the results, and store the end product as a Sybase data base, all using the same query language. Other DAVID Universal Object Type Management Systems will correspond to the type classes manuscript, graphics, spreadsheets, etc.

Menu, Command, and Host Language Access

The DAVID system will support three levels of user access. *Menu level* access will enable the unsophisticated user to access the DAVID library system at a terminal through a user-friendly menu driven interface. *Command level* access will allow the more sophisticated user to access it through a command driven interface, and the *host language level* will enable the very sophisticated user to access it through subprogram calls within a program within some programming language.

The DAVID Project is in the latter stages of development. When complete, DAVID will allow users to communicate with disparate data bases, finding and accessing data as if they were finding and accessing literature in their local library.

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INTELLIGENT DATA MANAGEMENT PROJECT

The objective of the Intelligent Data Management Project is the development of Intelligent Information Fusion (IIF) systems that integrate emerging software technologies using 3-D graphics, communications, object-oriented data bases, natural language query processing, connectionist models, artificial neural networks, artificial intelligence techniques, and expert systems. The research into the utilization of these technologies will provide the basic information environment for NASA's planned space missions through the foreseeable future. The technical areas being addressed in our research are as follows:

- Intelligent user interface development
- Automatic data labeling, characterization, and cataloging
- Knowledge-based geographic information systems
- Object-oriented data base development
- Knowledge acquisition tools
- Intelligent domain specific resource planning and scheduling

The concept of this end-to-end information fusion system will remove from the user the burden of learning the system architecture, data content, available resources, and system language. Users can easily input domain-specific information into the system which automatically encodes it into a knowledge base.[9]

The intelligent user interface work has created a large scale, domain-independent, spatial data management expert system that serves as a front-end to data bases containing spatial data. This system uses spatial search techniques to generate a list of all the primary keys that fall within a user's spatial constraints prior to invoking the data base management system, which substantially decreases the amount of time required to answer a user's query. Using a domain-independent query expert system, it also preprocesses the user's English query, mapping a broad class of queries into a smaller subset that can be handled by a commercial natural language processing system. This system was applied to data from the IUE satellite as proof of concept. This work was presented at the 1989 GSFC Conference on Space Applications of Artificial Intelligence and received an "Honorable Mention Award."[11,12,17,44] Figure 12 illustrates this prototype.

The concept of using artificial neural networks for automatic labeling and characterization of data objects stems from the enormous data generating capabilities in the next generation of satellite remote sensors. Current data management technologies cannot effectively cope with the complexity and magnitude of data. What is needed is an innovative approach that creates object-oriented data bases that characterize, label, and catalog remotely sensed data "on-the-fly" that are manageable in a domain-specific context and whose contents are available interactively and in near-real-time to the user community. The IDM team recently completed a prototype system using a back propagation, supervised, learning procedure for training layered networks of neuron-like nodes to recognize objects or features within a satellite data stream.

The IDM team used values of four spectral bands from Landsat 4 Thematic Mapper imagery as input to the network. It was concluded from the results that information is available in raw spectral values concerning the ground truth classes into which individual pixels can be categorized. The limited training set precludes any conclusions about how accurate a neural network could become with this data; however, the results look very promising. In the future, this paradigm will be extended to work on multiple images taken of different locations and from different instruments. The decisions concerning application of different kinds of networks could eventually be implemented by an expert system, which could also procedurally pass along the appropriate meta information into an object-oriented data base for interaction by the user in near-real-time with an intelligent interface described above. This work was also presented at the 1989 GSFC Conference on Space Applications of Artificial Intelligence and received the "Best Paper Award."[6,8,10] Figure 13 illustrates this work.

In the area of knowledge-based Geographic Information Systems (GIS), the IDM team is working on the development of an intelligent interface for adding spatial objects into a GIS. It is being built on a prototype GIS currently being developed by the University of California at Santa Barbara called KBGIS. This system can accommodate high-level expert system rules and heuristics as well as efficient spatial data search techniques through the use of new data structures, and develops a learning capability by interaction with the user. The basic difference between this and traditional GISs is that a knowledge-based GIS embodies the user's point of view about the data layers and the manipulation procedures that can be implemented on those layers, as well as provides standard GIS capabilities. The immediate goal is to transform this system into a portable system by converting the VAX dependencies to a standard UNIX system.

The IDM staff is also adding the capability to import Land Analysis System (LAS) imagery easily into its prototype. Once this work is completed, it will evaluate the feasibility of linking and customizing a natural language query processor (NLQP), and a high-level expert system that will deal with the pragmatic translation between the NLQP and the KBGIS.[7] Figure 14 illustrates the current progress.

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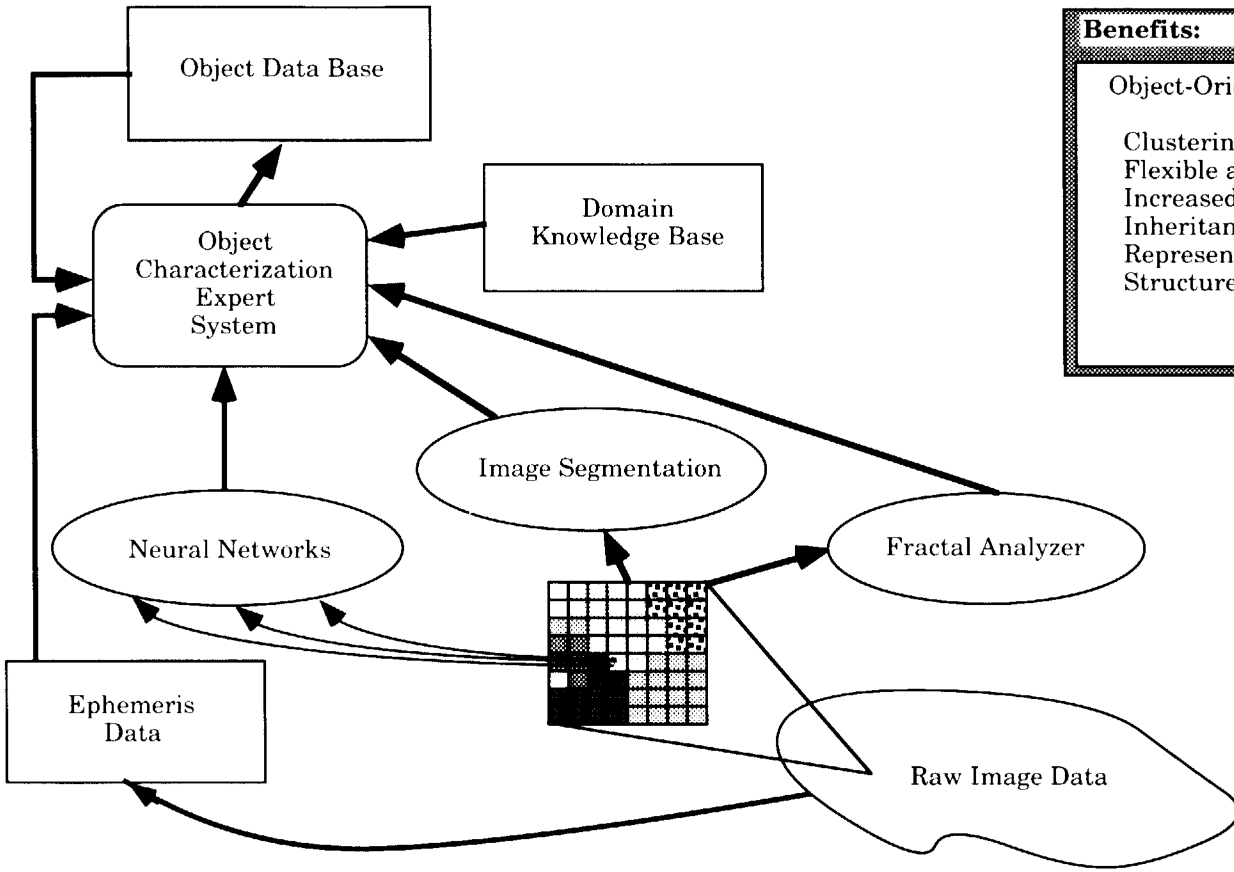


Benefits:

Object-Oriented Data Bases:

- Clustering of related objects
- Flexible abstract data-typing facilities
- Increased modeling power
- Inheritance hierarchy
- Representation of complex data structures
- Structure and behavior of objects

Benefits:

High-Level Processing:

- Addition of semantics
- Temporal analysis
- Guided by previous results
- Reasoning with uncertainty

Benefits:

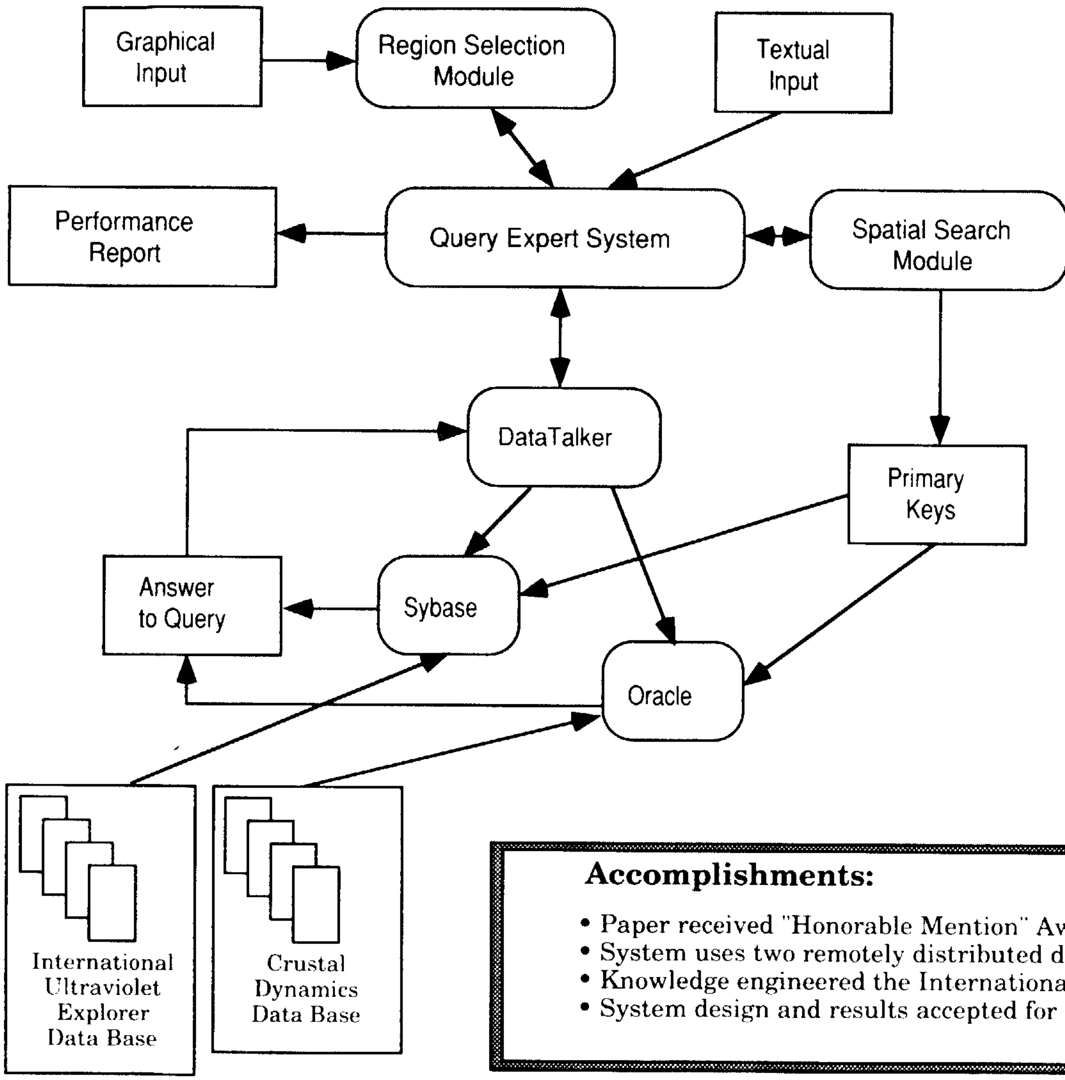
Low-Level Processing:

- Fast computations
- Variety of "experts"
- Measure on quality of output

Accomplishments:

- Received "Best Paper" Award at 1989 Goddard AI Conference
- Applied Neural Networks to two distinct domains
- Evaluated and submitted Purchase Request for GemStone, a commercial object-oriented data base package
- Results accepted for publication in refereed journal

Figure 12: Intelligent Data Management Processes - Automatic Data Characterization and Cataloging System Architecture



Benefits:

Queries are formulated in subset of English, using domain-specific vocabulary. User is not required to learn data base specific language.

Context of query is defined by textual and spatial input.

System architecture is compatible with heterogeneous data bases that reside on different machines.

Specialized spatial search structures increase the speed for answering a query from O(N) to O(log N).

Capabilities of system improve over time as knowledge engineer implements changes reflected by performance report.

Accomplishments:

- Paper received "Honorable Mention" Award at the 1989 Goddard AI Conference.
- System uses two remotely distributed data bases residing on different machines.
- Knowledge engineered the International Ultraviolet Explorer Satellite Domain.
- System design and results accepted for publication in a refereed journal.

Figure 13: Intelligent Data Management Processes - Intelligent User Interface

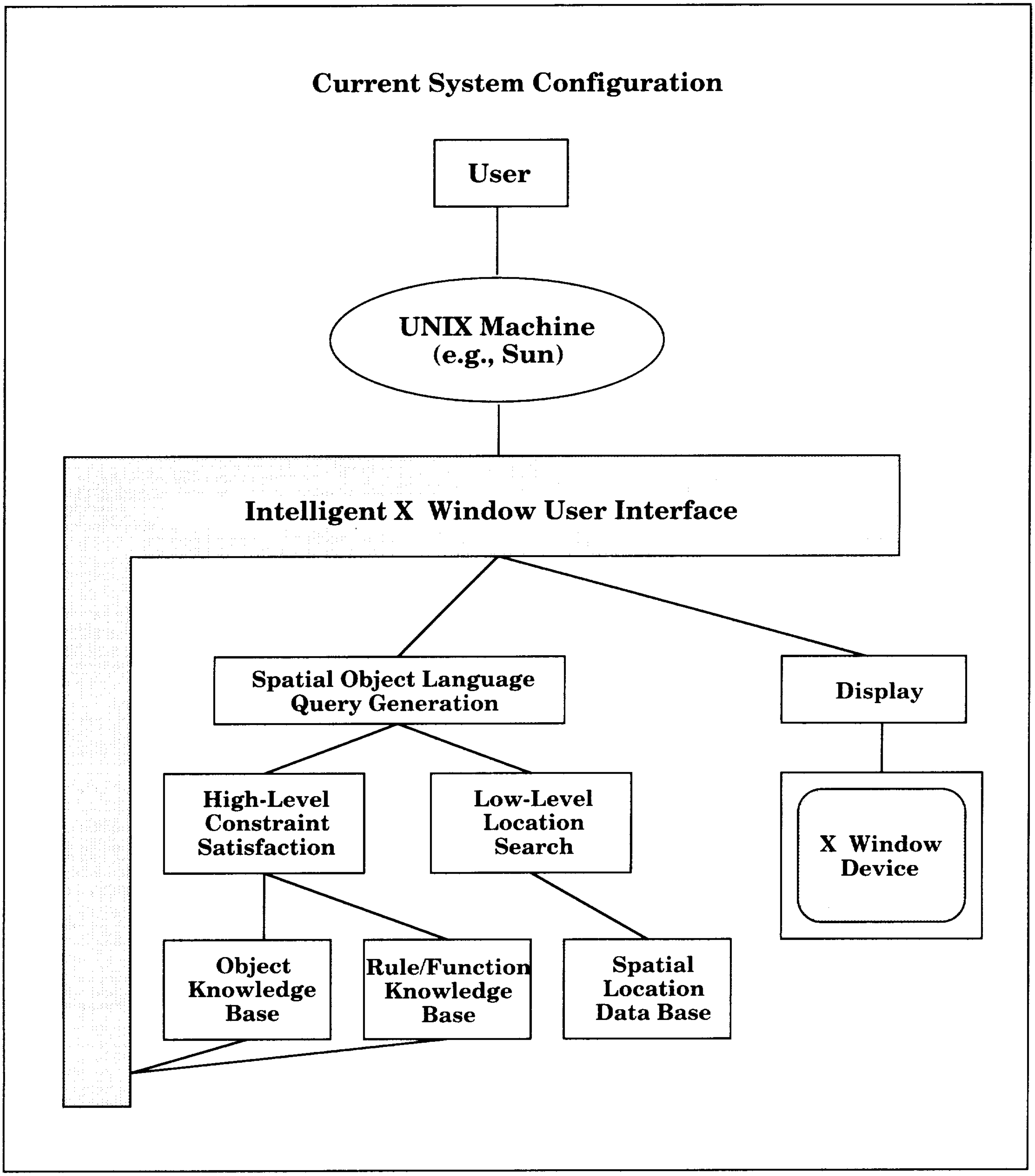


Figure 14: Knowledge-Based Geographic Information System (KBGIS)

DISCIPLINE-INDEPENDENT DATA VISUALIZATION

Critical to the understanding of data is the ability to provide pictorial or visual representations of those data, particularly in support of correlative data analysis. Hence, a researcher must employ tools to visualize data as one important mechanism in the exploratory data analysis/interpretation process. There has been an explosion of technology over the last few years in methods of computing that take advantage of the huge bandwidth and processing power of the human visual system to help comprehend large volumes of complex data by giving visual form utilizing graphics and imaging technology. This concept of data visualization has the power to bring an unprecedented capability to the scientific community.

Despite the advancement of this visualization technology, there are still significant problems in bringing today's hardware and software into the hands of the typical scientist. For example, there are other computer science domains outside computer graphics that are required to make visualization effective. Data management and intuitive human computer ergonomics are needed to build systems that have appropriate, easy-to-use interfaces for use with data of interest. In addition, there are specific rendering algorithms, data transformations, etc., that can be cast into a generic framework when part of a visualization pipeline.

The National Space Science Data Center has an ongoing research and development program to implement such effective visualization tools using generic (i.e., data-independent) techniques for the display of multidimensional data. These efforts are designed to bring visualization to the space and Earth science research community in a discipline-independent fashion. The results of this research are available to the scientific user community for browsing of data sets as an adjunct to metadata management, as well as for data analysis. This research will be of critical importance for the interpretation of information from current and planned large-scale data generators, such as supercomputer-based models and simulations, and spacecraft-based instruments like those of NASA's Earth Observing System.

Visualization of scientific data in a discipline-independent fashion implies two basic tenets. First, to support correlative data analysis, it is necessary to be able to look at multiple sets of data in exactly the same fashion (i.e., visual correlation within a common framework). This may be as simple as placing two different parameters from different data sets in an x-y plot along a common time line. On the other hand, displaying different sets of point data, mapped grids or images in some arbitrary geographic window that is independent of the specific data sets in question must also be accommodated. Second, a variety of different visualization techniques must be available to either examine a single set of parameters from one source or a number of different parameters from disparate sources. Specific representation techniques illustrate different aspects of data. By utilizing a variety of tools, a visual understanding of data at appropriate levels of qualitative and quantitative detail as well as at appropriate microscopic and macroscopic levels can be achieved. Of course, not all techniques for representing data are useful for all data sets. Hence, a wide variety of representation schemes are necessary to accommodate a disparate collection of data.

Therefore, discipline-independent visualization implies the development of software that manages arbitrary data sets and possesses different tools for displaying data. In other words, data management is as important a component of a data visualization system as underlying graphics and imaging technology. To implement a system that can provide these features in a practical fashion, the management of and access to the data must be decoupled from the actual visualization software. Within such a system, there must be a clean interface between the data and display of the data so that arbitrary data can be accessed by the visualization software. Hence, the visualization software only needs some basic descriptions of the data that it will display, which must be supported by a uniform data storage format. In addition, a common user interface for the selection of the techniques for representing data and associated options as well as a common design for the actual displays are required. As a consequence of such an approach, a software system of this design has an open framework. It can ingest arbitrary data objects for visualization, and other visualization techniques can be added independent of the application. This implies that a significant reduction in long-term software development costs can be realized because new data sets do not require new display software, and new display techniques do not require new data access software.

To implement these concepts for the space and Earth science research community, the NSSDC has developed the NSSDC Graphics System (NGS), an interactive discipline-independent toolbox for non-programmers to support the visualization of data on the NSSDC Computer Facility (NCF) DEC VAXCluster.[47] Parts of the NGS are being recast or ported to powerful UNIX workstations such as a Sun 4 or a

Silicon Graphics IRIS to provide highly interactive visualization tools. The NGS can access arbitrary data through the NSSDC Common Data Format (CDF), which serves as a uniform interface between the visualization tools and the actual data. The NGS supports displays of any arbitrary multidimensional subset of any CDF-based data set by providing a large variety of different representation schemes, all of which are supported by implicit animation (i.e., slicing of a data set into sequences).

The design of the NGS provides an open-ended framework for discipline-independent data visualization so that new capabilities can be added. New tools have been implemented as a result of NSSDC's research in several areas of computer science, including novel computer graphics rendering techniques and data structures. These include rendering and manipulation algorithms with portable implementations that can operate on any data object for n-dimensional gridding, geometric (spherical and cartesian) data modelling, and ray-tracing via recursive spherical triangle subdivision.

The NGS is designed to be portable so that it eventually can be made available on computer systems outside of the NCF to promote the exchange of both software and data. The NGS is already being ß-tested at several VAX/VMS sites on the Space Physics Analysis Network (SPAN) to evaluate it for potential use in future flight projects, as well as to support specific scientific investigations. It is expected that the NGS implementation for UNIX workstations will be made widely accessible in the future. In addition, the NGS is currently available operationally on SPAN to the users of NSSDC's Network Assisted Coordinated Science System in support of its CDAW activities, and to users of NSSDC's NCDS.

The NSSDC is currently helping a number of scientists in a variety of disciplines solve their problems in scientific data visualization through the tools available in the NGS. This research support is in addition to the ß-testing and evaluation of the NGS for future NASA flight missions, etc. Unfortunately, the forum of this article prevents the full power of the tools embodied in the NGS to be shown; neither does it allow a display of the breadth and depth of these applications of visualization technology. Therefore, Figure 15 is offered as a basic sample of the capabilities of the NGS and, hence, as proof of the concepts outlined above. Keep in mind that this example only illustrates one basic visualization technique and that it as well as those not shown, can be applied to *any* data.

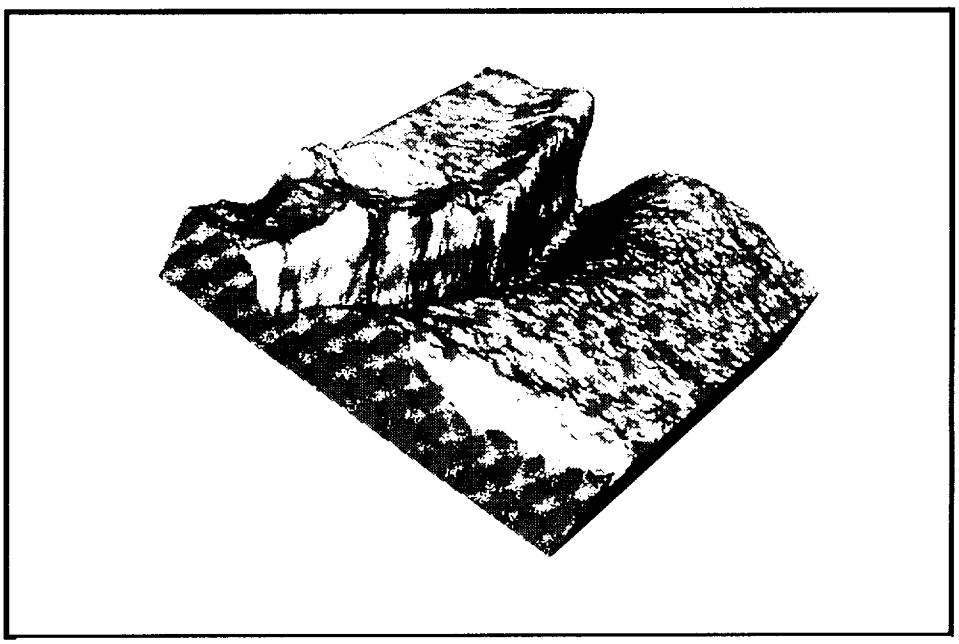


Figure 15: Mean Sea Surface of the Bering Sea Showing the Aleutian Trench

The figure visualizes the mean sea surface over the Aleutian Trench, which reflects changes in the local bathymetry. In this picture an estimate of the mean sea surface derived from altimeter data from NASA's SEASAT and the GOES 3 satellites has been viewed from the southwest. The data are prepared as a world grid at one-eighth degree resolution. This three-dimensional image has been tilted in the horizontal by 73°, and it is viewed at an inclination of 36°. The image has been illuminated from the southwest with an artificial light source that has been placed at the same location as the eyepoint of the viewer. Over this small region, the mean sea surface reflects the shape of the ocean bottom rather than subsurface changes in the composition of the Earth. The large depression of the sea surface over the trench amounts to 20 meters of height change, whereas the depth of the sea floor changes by more than 3000 meters across the trench. Conventional visualization methods cannot show all of the subtle structure apparent in high-resolution data such as these sea surface heights derived from altimeter data. A generic ray-tracing algorithm available in the NGS permits a solid, light-shaded object to be generated from any data, as in this picture, to bring out such details.

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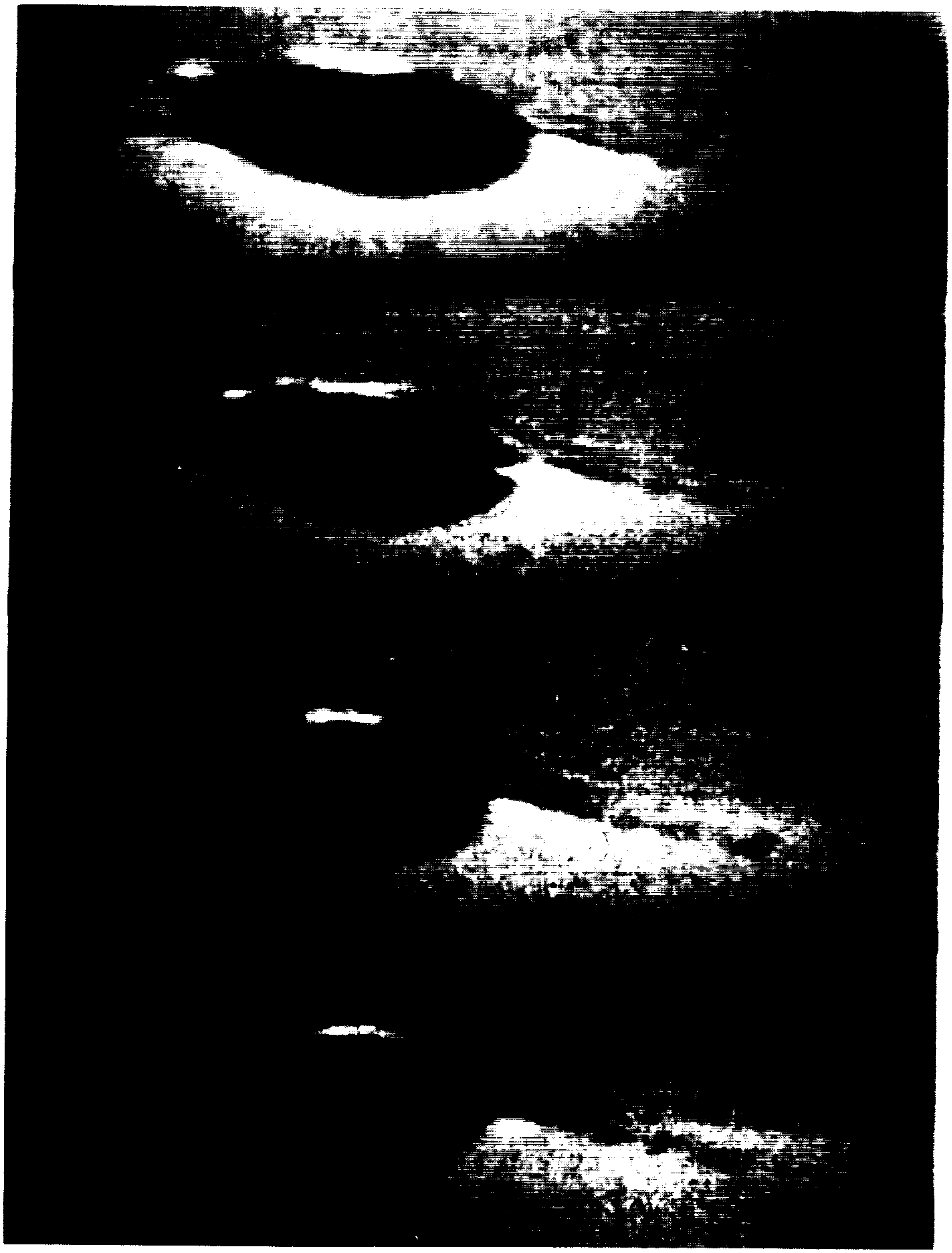

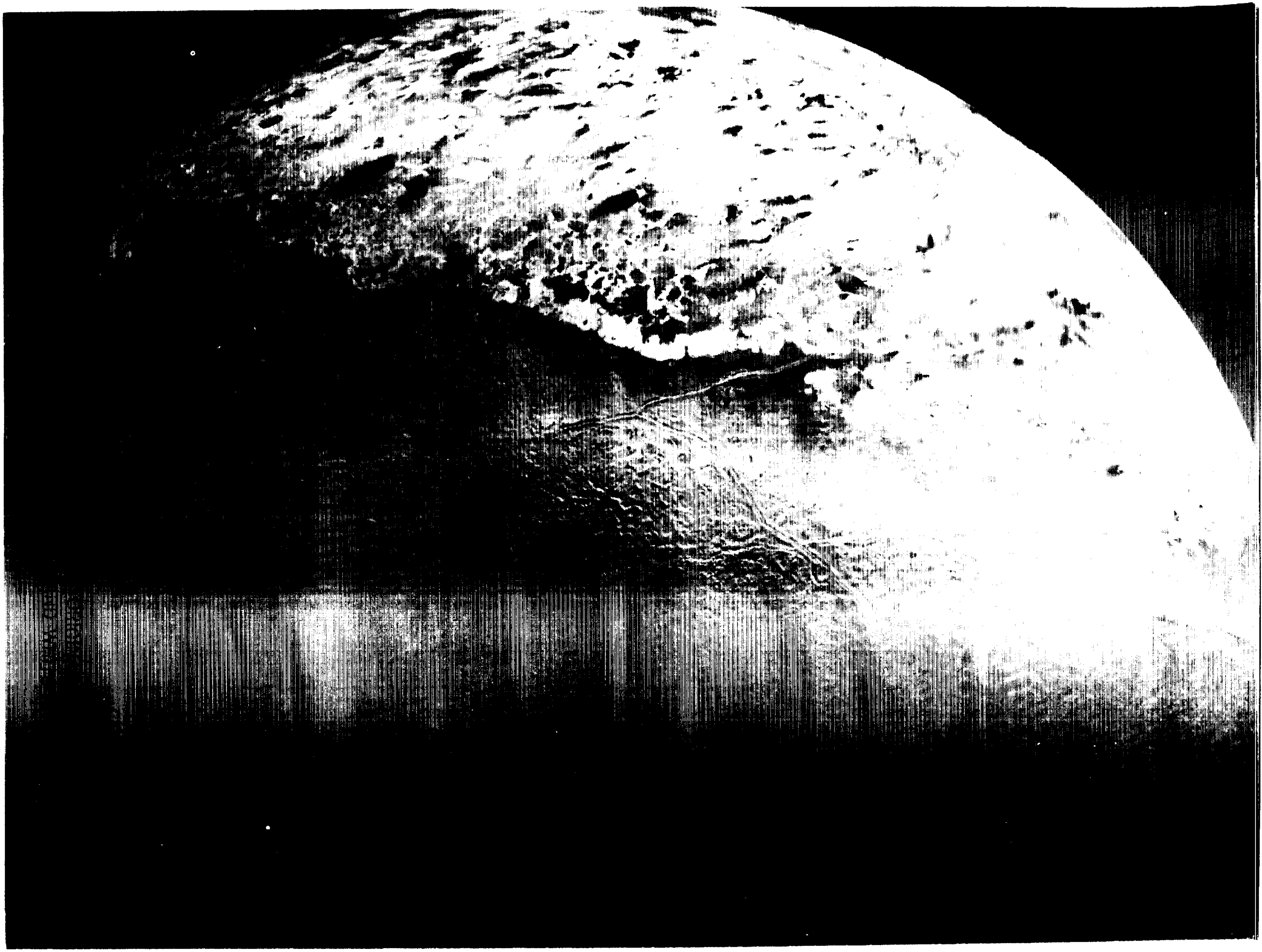

NIMBUS 7

TEMPERATURE/HUMIDITY INFRARED RADIOMETER 6·7 MICROMETER CHANNEL

DAILY MONTAGE OF DAYTIME DATA FOR 20AUG79

ORBIT	04157	04156	04155	04154	04153	04152	04151	04150	04149	04148	04147	04146	04145	04144
AN LON	172·1E	161·8W	135·8W	109·7W	083·7W	057·6W	031·6W	005·5W	020·5E	046·6E	072·6E	098·7E	124·7E	150·8E
AN GMT	002251	223839	205426	191014	172601	154149	135736	121324	102912	084459	070047	051634	033222	014809

160 213 229 239 247 254 260 265 269 KELVIN

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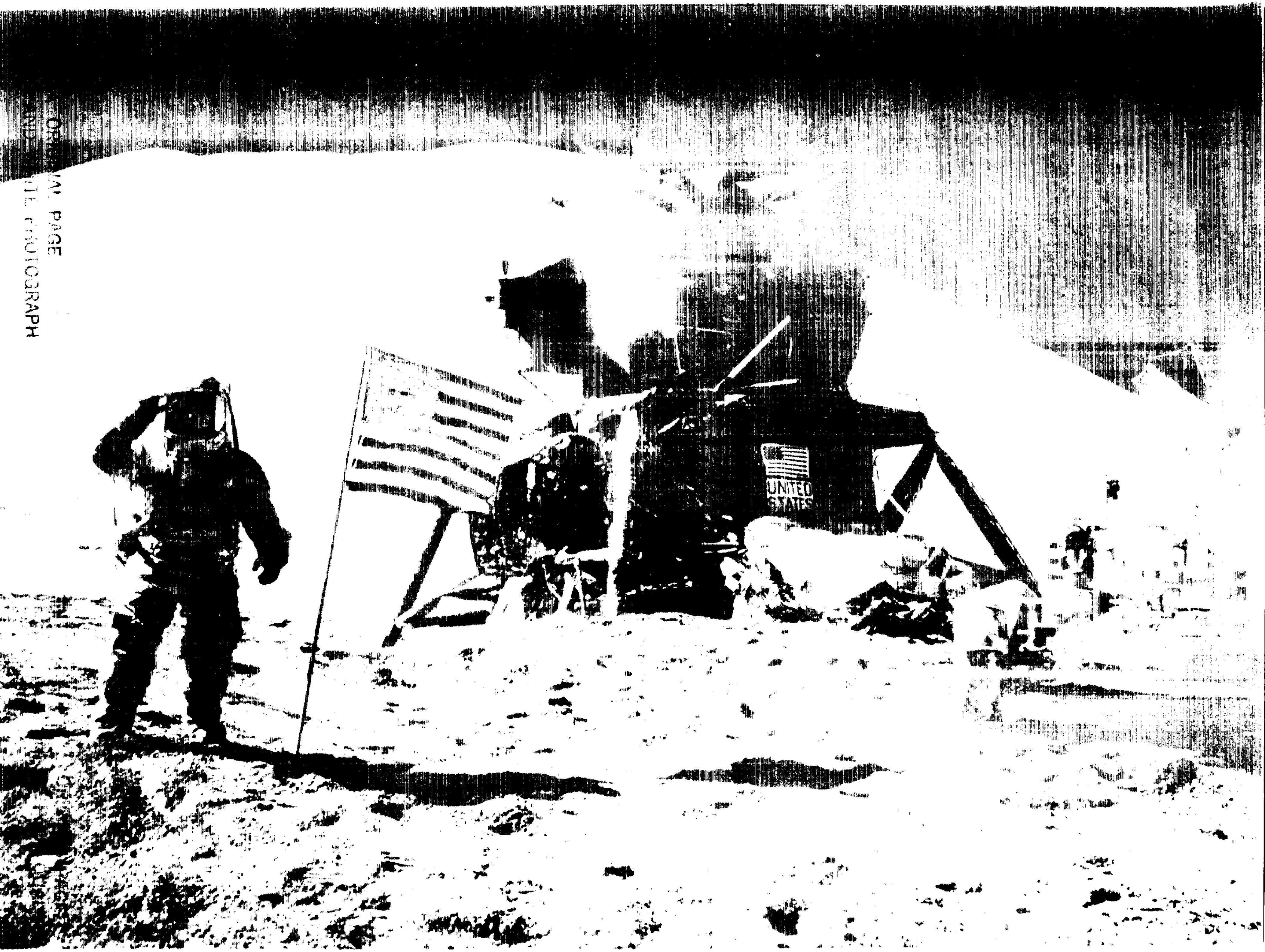
NSSDC ACRONYM AND ABBREVIATION LIST

ADC	Astronomical Data Center
AEM	Atmospheric Explorer Mission
AIAA	American Institute for Aeronautics and Astronautics
ANSI	American National Standards Institute
ARC	Ames Research Center (NASA)
ARPAnet	Advanced Research Projects Agency Network
BITnet	Because It's Time (or There) Network
BMFT	Bundes Ministerium Forschung und Technologie
CCSDS	Consultative Committee for Space Data Systems
CDAW	Coordinated Data Analysis Workshop
CDDIS	Crustal Dynamics Data Information System
CDF	Common Data Format
CD-ROM	Compact Disk-Read Only Memory
CDS	Centre de Donnees de Strasbourg
CFA	Harvard Smithsonian Center for Astrophysics
CFC	Chlorofluorocarbons
CIRA	COSPAR International Reference Atmosphere
COADS	Comprehensive Ocean Atmosphere Data Set
CODD	Central Online Data Directory
COSPAR	Committee on Space Research
CRRES	Combined Release and Radiation Effects Satellite (joint NASA/USAF mission)
CTIO	Cerro Tololo Inter-American Observatory
CZCS	Coastal Zone Color Scanner
DAB	*Data Announcement Bulletin*
DADS	Data Archive and Distribution System
DADS	*Document Availability and Distribution Services*
DAN	Data Analysis Network (Canada)
DAVID	Distributed Access View Integrated Database
DBMS	Data Base Management System
DEC	Digital Equipment Corporation
DECnet	DEC Networking Products (generic family name)
DLR	Deutsches Forschungs Anstalt fuer Luft und Raumfahrt
DSUWG	Data Systems Users Working Group
ECMWF	European Center for Midrange Weather Forecasting
E-HEPnet	European High Energy Physics Network
ELSET	Element Set
EOS	Earth Observing System
ERB	Nimbus 7 Earth Radiation Budget Instrument
ERBE	Nimbus 7 Earth Radiation Budget Satellite
ERBS	Nimbus 7 Earth Radiation Budget Satellite
EROS	Earth Resources Observation System
ESA	European Space Agency
ESO	European Southern Observatory
ESOC	European Space Operations Centre
E-SPAN	SPAN in Europe
EUROHEPnet	European High Energy Physics Network
EXOSAT	European X-Ray Observation Satellite (ESA)

FBIS	Foreign Broadcast Information Service
FGGE	First GARP Global Experiment
FIFE	First ISLSCP Field Experiment
FIRE	First ISCCP Regional Experiment
FNOC	U.S. Navy's First Numerical Oceanography Center
FRG	Federal Republic of Germany
GGS	Global Geospace Science
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellite (NASA-NOAA)
GPS	Global Positioning System
GSFC	Goddard Space Flight Center (NASA)
HEPnet	High Energy Physics Network (also known as PHYSnet)
HRI	High Resolution Interferometer
IACG	Inter-Agency Consultative Group
IAGA	International Association of Geomagnetism and Aeronomy
ICE	International Cometary Explorer
ICSU	International Council of Scientific Unions
IDL	Interactive Data Language
IDM	Intelligent Data Management
IGRF	International Geomagnetic Reference Field
IIFS	Intelligent Information Fusion System
IMP	Interplanetary Monitoring Platform
IMS	International Magnetospheric Study; Ion Mass Spectrometer
IRAP	ISLSCP Retrospective Analysis Project
IRAS	Infrared Astronomical Satellite (The Netherlands-NASA-U.K.)
IRI	International Reference Ionosphere
ISCCP	International Satellite Cloud Climatology Project
ISLSCP	International Satellite Land Surface Climatology Program
ISO	Information Systems Office
ISO	International Standards Organization
ISTP	International Solar-Terrestrial Program
IUE	International Ultraviolet Explorer (satellite, NASA-U.K.-ESA)
IUESIPS	IUE Spectral Image Processing System
IUI	Intelligent User Interface
IUWDS	International URSIGRAM and World Days Service
JIMS	Cygnet's Jukebox Interface Management System
JPL	Jet Propulsion Laboratory (NASA)
JSC	Johnson Space Center (NASA)
KSC	Kennedy Space Center (NASA)
LAS	Land Analysis Software
LAS	Land Analysis System
LLR	Lunar Laser Ranging
Magsat	Magnetic Field Satellite
MIDAS	Munich Image Data Analysis System
MIPS	Mission and Information Planning System
MIT	Massachusetts Institute of Technology
MPE	Max Planck Institute (Federal Republic of Germany)
MPP	Massively Parallel Processor
MSFC	Marshall Space Flight Center (NASA)
MSIS	Mass Spectrometer Incoherent Scatter (atmosphere model)

NACS	Network Assisted Coordinated Science
NASA	National Aeronautics and Space Administration
NCDS	NASA's Climate Data System (formerly PCDS)
NCF	NSSDC Computer Facility
NCS	Network Computing System
NGS	NSSDC Graphics System
NIC	Network Information Center
NLQP	Natural Language Query Processor
NOAA	National Oceanographic and Atmospheric Administration (formerly ESSA)
NODIS	NSSDC Online Data and Information Services
NODS	NASA Ocean Data Systems
NORAD	North American Air Defense Command
NPSS	NASA Packet Switched System
NRAO	National Radio Astronomy Observatory
NSDSSO	NASA Science Data Systems Standards Office
NSF	National Science Foundation
NSN	NASA Science Network
NSSDC	National Space Science Data Center (NASA)
ORACLE	Relational Data Base Management System
PDS	Planetary Data System
PHYSnet	High Energy Physics Network (also known as HEPnet)
PI	Principal Investigator
PLDS	Pilot Land Data System
PRA	Planetary Radio Astronomy
PROMIS	Polar Regions Outer Magnetosphere International Study
PSCN	Program Support Communications Network
PSN	Packet Switched Network
PSPC	Position Sensitive Proportional Counter
RAND	Request Activity and Name Directory
RAPSE	*Report on Active and Planned Spacecraft and Experiments*
ROR	ROSAT Observation Request
ROSAT	Roentgen Satellite (German x-ray research satellite)
SAO	Smithsonian Astrophysical Observatory (Smithsonian Institution)
SBP	Sedimentary Basins Project
SDSD	NOAA's Satellite Data Services Division
SEASAT	Sea Satellite (NASA)
SERC	Science and Engineering Research Council
SIMBAD	Set of Identifications, Measurements, and Bibliography for Astronomical Data
SLR	Satellite Laser Ranging
SMM	Solar Maximum Mission
SOAR	Software for Optical Archival and Retrieval
SPACEWARN	World Warning Agency for Satellites
SPAN	Space Physics Analysis Network
SPAN_NIC	SPAN Network Information Center
SQL	Standard Query Language
SSC	Satellite Situation Center
SSL	Space Science Laboratory
STARCAT	Space Telescope Archive and Catalog
ST/ECF	Space Telescope/European Coordinating Facility
STP	Solar-Terrestrial Physics

TAE	Transportable Applications Executive
TCP/IP	Transmission Control Protocol/Internet Protocol
Telenet	Public packet switched network owned by GTE
THEnet	Texas Higher Education Network
TMO	Table Mountain Observatory
TOMS	Total Ozone Mapping Spectrometer
UARS	Upper Atmosphere Research Satellite (NASA)
U.K.	United Kingdom
ULDA	Uniform Low Dispersion Archive
URSI	International Union of Radio Science
USGS	United States Geological Survey
US-HEPnet	U.S. High Energy Physics Network
USRSDC	U.S. ROSAT Science Data Center
US-SPAN	SPAN in the U.S.
VAX	Virtual Address Extension (DEC minicomputer)
VICAR	Video Image Communication and Retrieval
VLBI	Very Long Baseline Interferometry
VOD	Virtual Optical Disk
VRF	Visual Reproduction Facility
WAN	Wide Area Network
WDC-A-R&S	World Data Center A for Rockets and Satellites
WFC	Wide Field Camera
WORM	Write Once-Read Many
WWAS	World Warning Agency for Satellites
XDR	eXternal Data Representation



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