PREFACE

The purpose of this document is to acquaint space and Earth research scientists with an overview of the services offered by the National Space Science Data Center (NSSDC). 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 is far more than an organization that manages a large body of space data for distribution. As this document illustrates, it provides many, many valuable services for scientists throughout the world. The brief discussions in this document provide only the starting point. At the end of each section is the name of a contact person who will provide detailed information and help on request.

NSSDC personnel are highly talented individuals, skilled in a variety of scientific and technological disciplines. Together they strive for a common goal: to provide the research community with data and attendant services in the most efficient, economical, and useful manner possible now and in the future. The organization is dedicated to get the most scientific value out of NASA's initial investment in its missions.

I would like to thank those who contributed articles for this document. A special thanks goes to Lloyd Treinish and Dr. James Vette for their technical assistance. Special thanks also goes to Karen Satin and Bob Richards (Science Applications Research), and Rhonda Scholl (McDonnell Douglas Astronautics Company) for their editorial assistance. And finally, I would like to thank Charlotte Griner (McDonnell Douglas Astronautics Company) for her untiring efforts in the compilation and preparation of this document for publication.

Dr. James Lauer Green, Director
National Space Science Data Center
January 1989

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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 reduced 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 and analysis 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 and tens of thousands of film products, and optical, video, and magnetic disks. The NSSDC 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, 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 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 hundreds of computers supporting a full range of scientific disciplines. The NSSDC is continually investigating and applying new communications technology to increase the reliability 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.

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.

Thousands of spacecraft belonging to more than a dozen countries have been launched. More than 300 are now in operation. 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.*[32] A periodic *Report on Active and Planned Spacecraft and Experiments*[14] is published for scientific spacecraft; it presents more frequently needed information about spacecraft currently operating or planned.

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 ADC has a cooperative agreement with the Centre de Donnees Stellaires at Strasbourg, France, which encourages a wide-ranging exchange of data and information.

The NSSDC distributes the *NSSDC News*[27] 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*[15]).

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 of 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)*,[14] 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*[32] 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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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 discussed in detail elsewhere are funded out of specific NASA discipline organizations for the benefit of scientists supported by those offices. These cases, including NCDS, the PLDS, and the CDDIS, require that users have individual accounts on the NSSDC VAXs.

Other services are offered through the "NSSDC Account" on the NSSDC VAX cluster. This account is available nearly 24 hours per day, 7 days a week to anyone who can reach the NSSDC VAX via dial-up or via networks (see section 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 Total Ozone Mapping Spectrometer (TOMS) 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, 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 is available for downloading or executing. Further, 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 require 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 data information systems. More importantly, in many cases the directory offers automatic network connections to catalogs or information systems where more detailed information about data of interest may be obtained. Often, the data may be ordered through the catalogs or information systems. The directory is easily accessed via network or dial-in line (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 overall 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) and the United States Geological Survey (USGS) 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. 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 has been developed that will allow IUE archival data to be requested and transmitted by 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 send a replacement tape.

To acquire IUE data over SPAN, a requester must first log onto the NSSDC account and then 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 his or her node. If the requested spectra are not available from the mass storage, a message will be sent describing the current status of the request.

Publications concerning the IUE request service include: *Requesting IUE Data Via SPAN,*[25] November 1987, and *Accessing SPAN from Non-SPAN Nodes,*[24] April 1988 (tape requests only).

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ROSAT MISSION INFORMATION AND PLANNING SYSTEM

The Roentgen Satellite (ROSAT) Project is a cooperative venture between the Max Planck Institute for Extraterrestrial Physics (MPE) in the Federal Republic of Germany (FRG), NASA in the United States, and SERC in the United Kingdom (U.K.). The satellite mission is the study of stellar X-ray sources. The ROSAT spacecraft, designed and operated by the West Germans, is managed by the MPE and flies 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 NSSDC was selected as the U.S. ROSAT Science Data Center (USRSDC) by NASA Headquarters, and has been chosen to design the mission planning software to create, maintain, and track ROSAT Observation Requests (RORs). As a result, the Mission and Information Planning System (MIPS) has been developed (see Figure 1). This system will assist NASA Headquarters and the ROSAT Users Committee with the evaluation, selection, and scheduling of U.S. proposals for observing X-ray sources by the ROSAT satellite. It will provide necessary schedules and reports to NASA Headquarters, the GSFC ROSAT Science Team, the MPE, and general observers, and will directly interface with the West German mission planning software at the MPE. 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.

MIPS will support 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 will also provide 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 is being 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 and the ARPANET/Internet network.

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U.S. ROSAT SCIENCE DATA CENTER

Mission Information and Planning System (MIPS)

ROSAT

MIPS

MicroVAX II
16 MB Memory
500 MB Disk Storage
INGRES DBMS

U.S. Mission Planning Operations
-ROSAT Observations Requests
-Long Mission Timelines
-Short Mission Timelines

General Observers
at Home Facilities
or DDAC's

Networking to MPE.
SAO, DDAC's, NASA
Headquarters

Mission
Planning
Programs:

-OBSTIME
-VIEWING

Data Base of
Technical
Specifi-
cations for
PSPC and HRI
Instruments

Observation
Catalogs:

-ROSAT
-EINSTEIN
-EXOSAT

Status of
Observations
and of
Processed
ROSAT Data

ROSAT
Bulletin
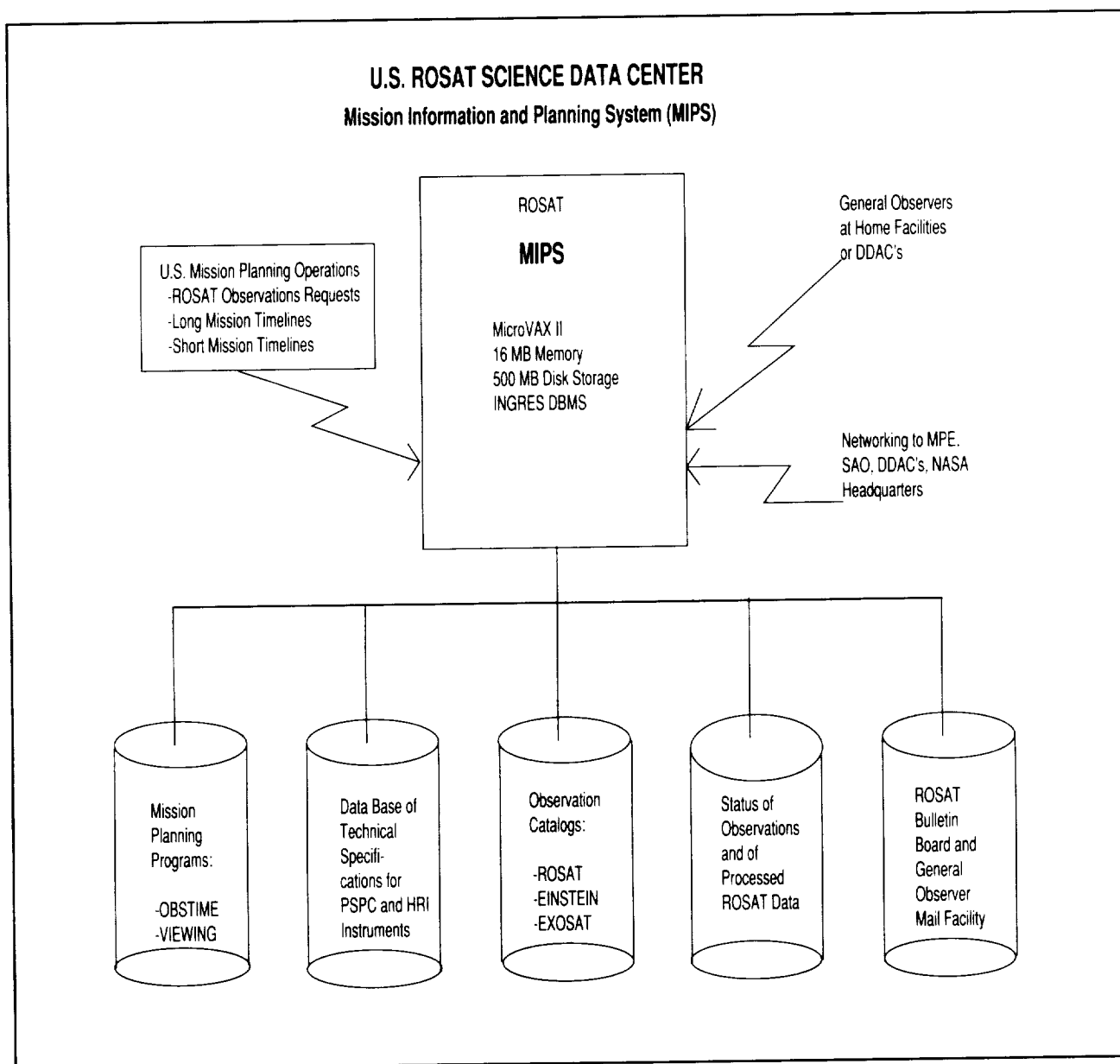Board and
General
Observer
Mail Facility

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 is integrated with the NSSDC Request Activity and Name Directory (RAND), which contains name and address information for all users of NSSDC facilities. When a user logs into the ADC account and gives his/her name, the corresponding RAND information is displayed if the user is located in the RAND data base. The user is then asked to verify the information displayed. Changes to this information can then be made, and they are saved for examination by NSSDC personnel before being entered into the RAND system permanently. A new user is prompted for full name and address entry. This procedure precludes the necessity for users to enter their full names and addresses each time they log into the account.

The system has three options to search for catalogs. (1) Catalogs are listed by the ADC or Centre de Donnees de Strasbourg (CDS) number. They are 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 cata-

log, the 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 the 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 TCP/IP 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). Access to the SIMBAD (Set of Identifications, Measurements and Bibliography for Astronomical Data) data bank in France is achieved through STARCAT and by a direct connection to the French packet switched network TRANSPAC via GTE Telenet.

The STARCAT system is a collection of software and associated astronomical data, the latter consisting of full catalogs and various observing logs from space-borne astronomy missions. These data are resident on a Britton Lee 700 data base machine at the NSSDC so that they can be accessed quickly and efficiently using Omnibase. 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 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 600,000 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 85 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 stellar 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.

Since access to SIMBAD is rather expensive because of required Telenet usage, the ADC provides a request service to assist the astronomical community in research activities. SIMBAD output can be printed and mailed to requesters or can be sent via the various computer networks. The NSSDC is also currently providing full access to STARCAT and SIMBAD for 11 individual and small groups of astronomers on a trial basis. These users were selected through a proposal submission and approval pro-

gram initiated by the NSSDC. This pilot program may be extended if support can be obtained for its further development.

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NASA'S CLIMATE DATA SYSTEM

NASA's Climate Data System (NCDS) is an advanced scientific 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 locate data of interest by accessing a catalog of data descriptions and an inventory of temporal and volume information, to preview data using graphical and statistical methods, and to create subsets for further analysis at their own sites.

The system provides access to over 30 valuable research data sets from both satellite and conventional sources. Included are data sets from six Nimbus 7 instruments and several correlative data sets, such as those produced by the First Global Atmospheric Research Program Global Experiment and the World Monthly Surface Station Climatology data set. Access is also provided to several data sets generated by the International Satellite Cloud Climatology Project (ISCCP). NCDS also supports the research program for validating and improving the ISCCP products - the First ISCCP Regional Experiment (FIRE).

NCDS functions are provided by integrating the capabilities of several general purpose software packages with specialized software for reading data sets in a variety of formats (see Figure 2). These packages include a relational data base management system for storing information about the data, a user interface package providing uniform access to these tools, graphics and statistical packages for previewing the data, and a software package produced by the NSSDC for storing and accessing data

duced by the NSSDC for storing and accessing data in a self-describing data independent format (the Common Data Format). The capabilities provided are integrated into a flexible system that can be easily modified, either to provide additional functional capability or to take advantage of new technology as it becomes available.

NCDS provides extensive data management and analysis support to climate researchers at several universities and government agencies. These researchers are able to access the system remotely via dial-up lines and over SPAN. Its capabilities are packaged into a system freeing users from the need to understand data formats or programming languages. NCDS serves as a prototype for future information management in all disciplines.

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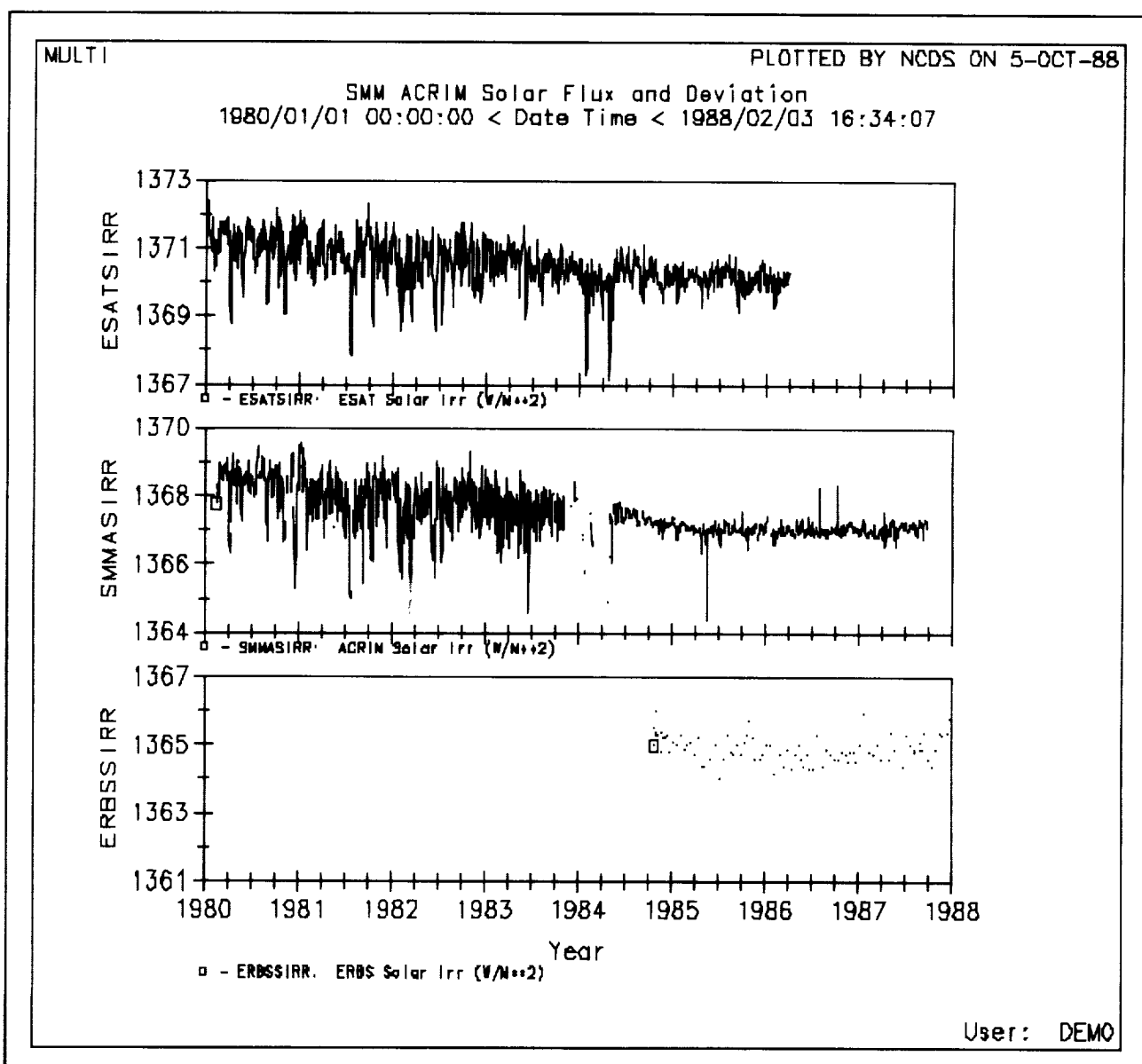   (internet)olsen@nssdc.gsfc.nasa.gov

Figure 2: Sample Plot of NCDS Data Sets

10

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 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 with 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.

In anticipation of the need for the ozone data by atmospheric research scientists, the NSSDC has put approximately 120 days of TOMS ozone data on line. These data were taken during the most recent Antarctic ozone hole episode lasting from September through November, 1987. Scientists using SPAN can download TOMS data from NSSDC's computers to their own computers for further analysis. New features to be added include convenient remote access to these data using a personal computer such as the IBM PC. To reduce the transmission time, users will be able to select subsets of TOMS data based on time or geographic location.

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PILOT LAND DATA SYSTEM

The Pilot Land Data System (PLDS) will provide a distributed information system to support research by land scientists. The PLDS will aid land scientists in their research by helping them identify data of use to them, acquiring those data no matter where they are located, and providing them a mechanism to access remote computer facilities using electronic communications.

The PLDS is a multicenter cooperative data system currently under development, with the NSSDC serving 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 geared toward support of three land science projects, the International Satellite Land Surface Climatology Project (ISLSCP), the ISLSCP Retrospective Analysis Project (IRAP), the First ISLSCP Field Experiment (FIFE), and the Sedimentary Basins Project (SBP). However, in the future there will be more emphasis on the needs of the broader land science community.

The long-term objectives of the Pilot Land Data System are as follows:

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

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

- Provide access to existing scientific data once a scientist has identified which pieces should be acquired.

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

- 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.

This prototype system was made available to members of the science projects in August 1987. It has very limited functionality and differs widely between the nodes. This difference is a reflection of the specific needs of the different science projects and the recognition that a broader perspective was necessary. To aid members of the three science projects with use of this prototype system, a User Support Office was established at each of the nodes.

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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 three types of space-age techniques in this study: laser ranging to an artificial satellite or the moon, Very Long Baseline Interferometry (VLBI), and the Global Positioning System (GPS). 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 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, 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, raw, correlated VLBI, and GPS data is retained off line in the CDDIS
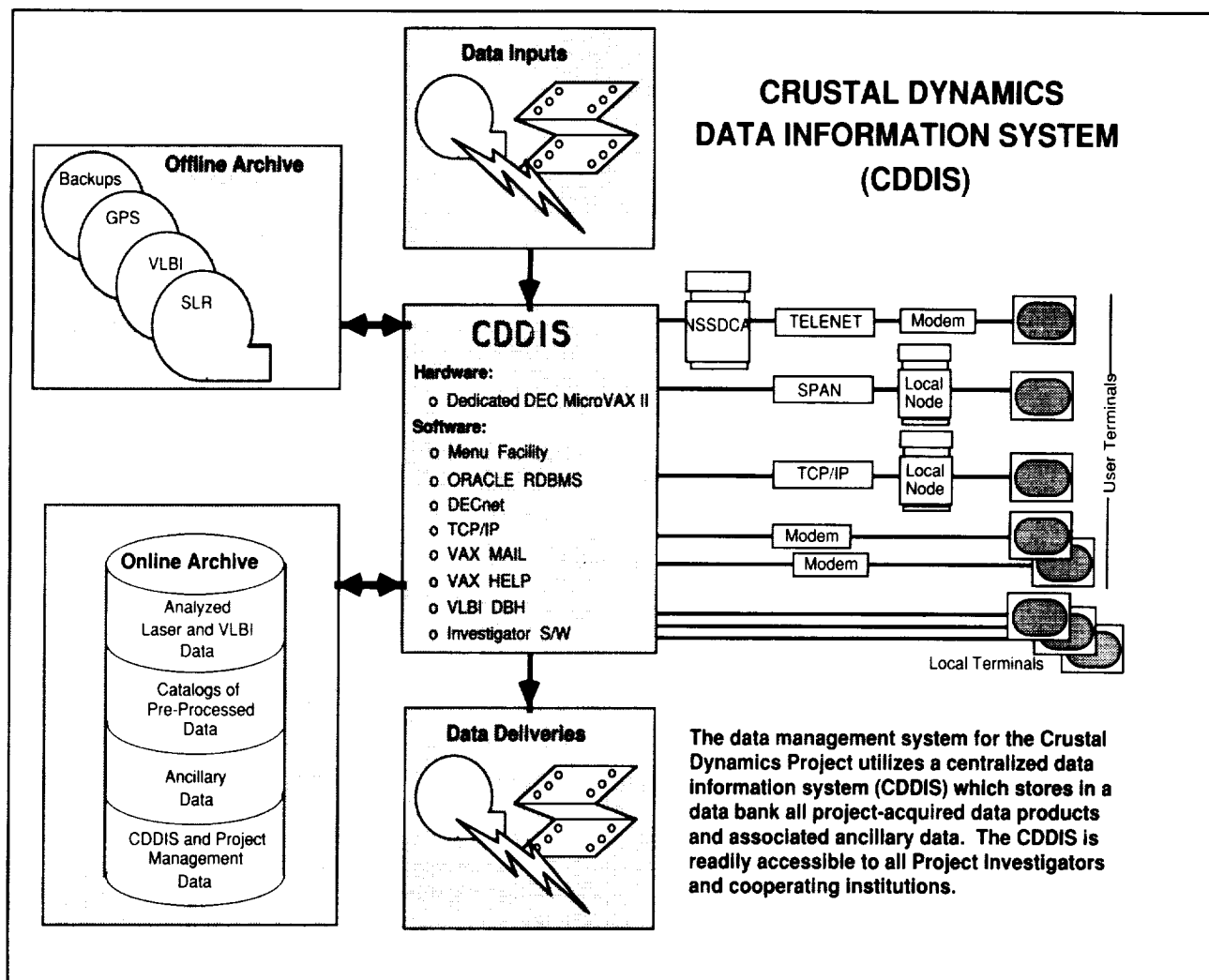

Figure 3: Overview of the CDDIS

tape library. All other information can be accessed through a data base utilizing the ORACLE data base management system (DBMS). The laser, VLBI, and 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, VLBI data from 1976 through the present, and GPS data for 1985 through the present. Summaries of 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. Listings of available GPS data are also contained in the online data base.

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 global institutions. 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,*[22] provides brief descriptions of the DIS and its menu items, as well as detailed instructions on how to access the system and who to contact when problems occur. A regular bimonthly publication, the *DIS Bulletin,*[23] 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 report any peculiarities in previously acquired data.

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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 1987 and is periodically updated.
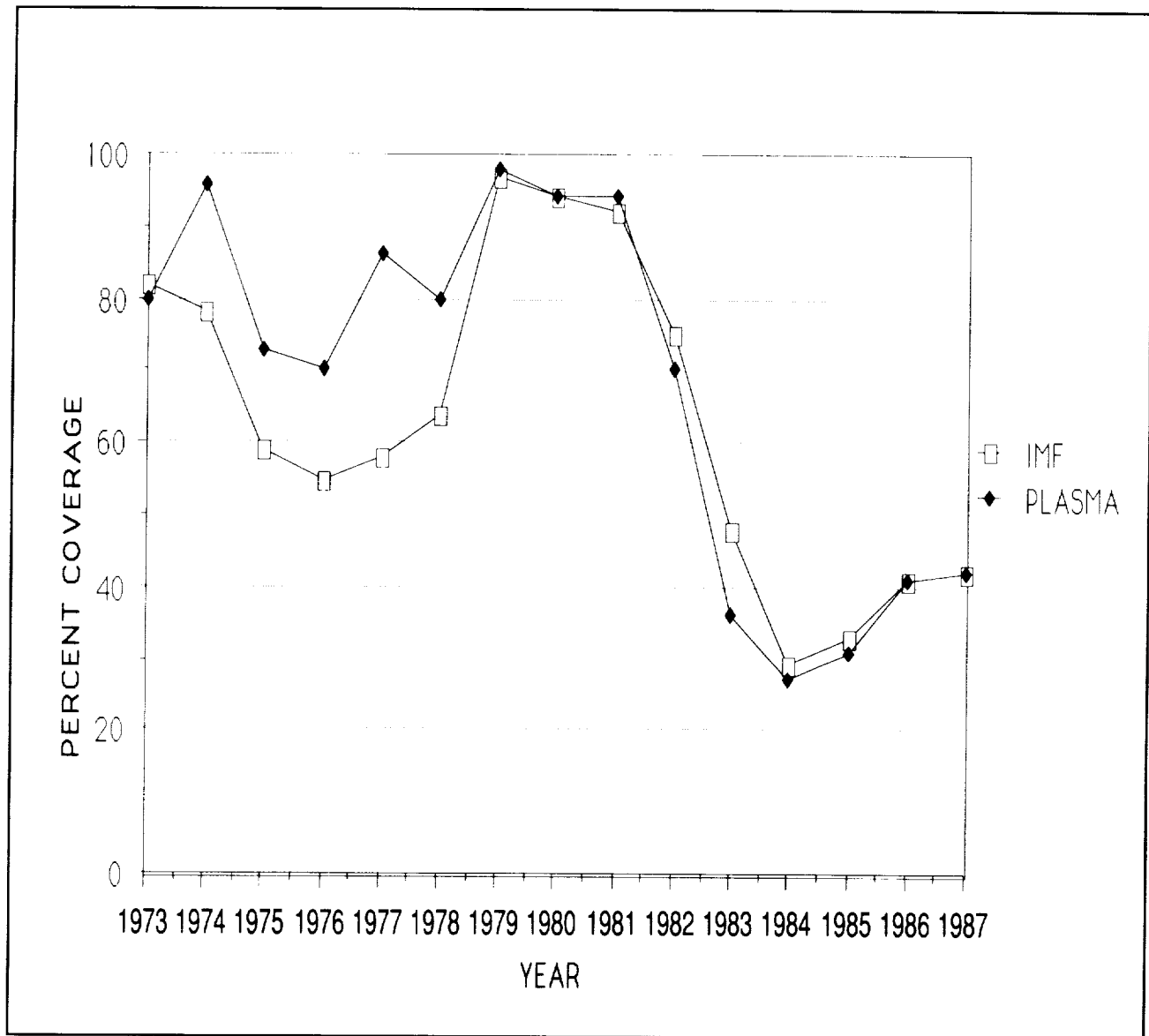
Figure 4: Percent Coverage of NSSDC Composite Interplanetary Medium Data Sets

The data set presently on line via the NSSDC account spans the 1973-87 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.

Access to this data set is gained through the NSSDC account. The interface enables the user to choose any subset of the 37 words per hourly record for any time span, and to either list the selected data to a terminal screen or 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*[6] and associated supplements.

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ELECTRONIC ACCESS

SPACE PHYSICS ANALYSIS NETWORK

The Space Physics Analysis Network (SPAN) links DECnet-based computers doing space and Earth science research and data analysis in the United States, Canada, Europe, Japan, Australia, New Zealand, and South America. It provides a common working environment for sharing computer resources and computer peripherals, and providing the potential for significant time and cost savings for correlative data analysis.[9]

At the present time, SPAN uses four central routing nodes connected with six 56-kilobit per second (kbps) links. The routing centers are located at the GSFC, Marshall Space Flight Center (MSFC), JPL, and Johnson Space Center (JSC). Additional SPAN routing nodes are planned for ARC and Kennedy Space Flight Center (KSC). Remote SPAN nodes are typically linked to the closest of these four routing centers using 9.6-kbps circuits (called tail circuits).
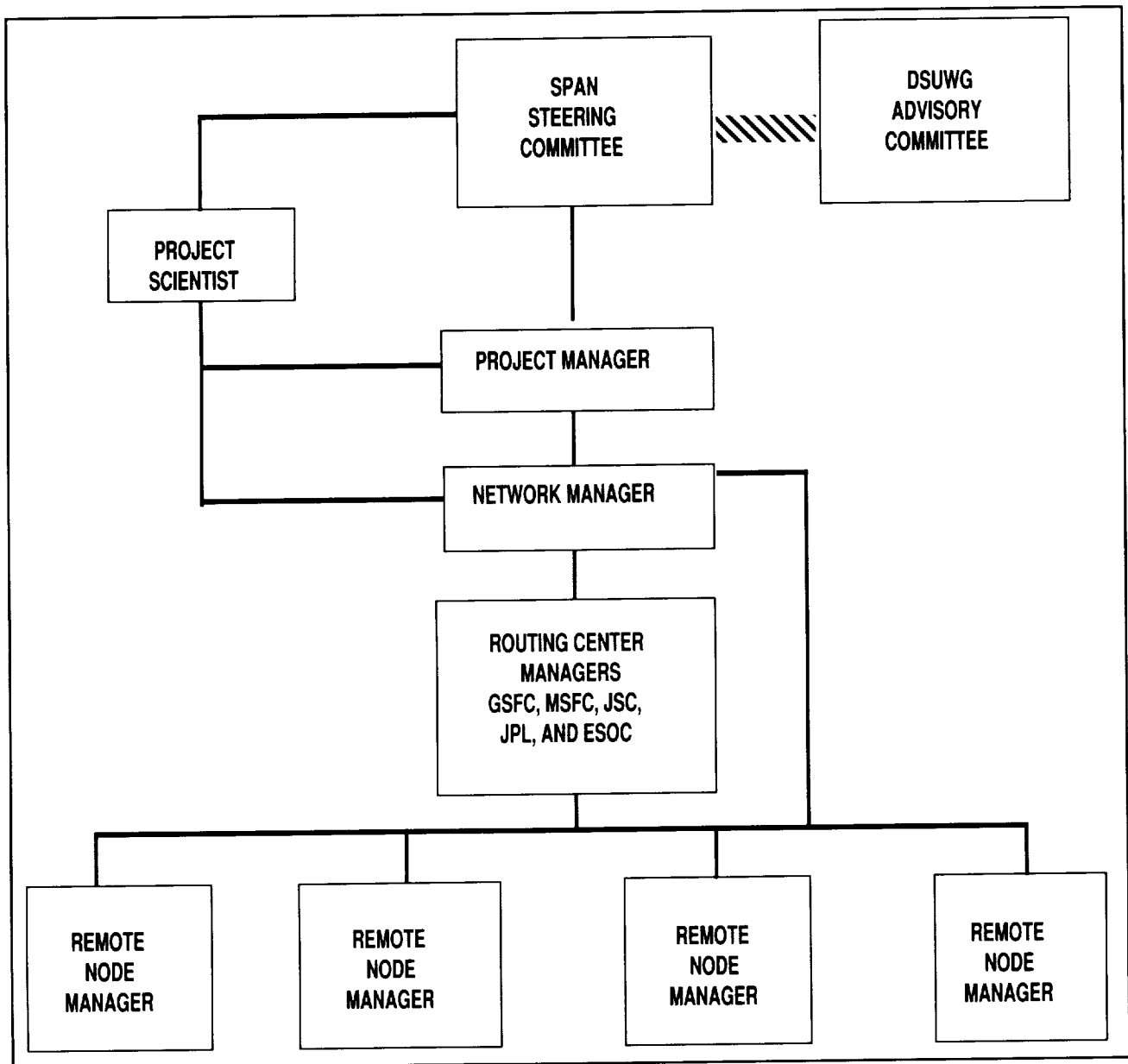

Figure 5: Management Structure of the Space Physics Analysis Network

Several wide-area networks (WANs) have connected to SPAN. The High Energy Physics Network (HEPnet, also known as PHYSnet), including EUROHEPnet; the Canadian Data Analysis Network (DAN) which supports CANOPUS; THEnet, consisting of Texas universities; and Astronet, an Italian network, have connected to SPAN. WANs for flight projects such as the Upper Atmosphere Research Satellite (UARS) have also connected to SPAN. Because the existing wide-area networks already contain a large number of nodes, some coordination has been done to resolve conflicts in node numbers between SPAN and these networks throughout the world. After joining with SPAN, these WANs continue to maintain their separate identities. SPAN has approximately 2,000 registered nodes and is part of an internet of about 6,000 nodes.

The Data Systems Users Working Group (DSUWG) is the major advisory body for SPAN. Through this group, SPAN is run by its users. The DSUWG provides guidance for SPAN growth and seeks standardization for the efficient exchange of information, space data, and graphics. The DSUWG is drawn from SPAN's present and potential science user community as well as other interested, active scientists and data system managers.

A SPAN project management team has been developed and approved by the DSUWG. The team provides a management structure that includes the DSUWG Advisory Committee, a steering committee, a project scientist, a project manager, an internetwork manager, a network operations manager, routing center managers, and remote node managers, as shown in Figure 5.

With the extremely rapid growth in the number of SPAN nodes and users, concern was focused on how researchers can easily identify computers and locate other users on SPAN. The NSSDC developed an online SPAN data base that contains information about the SPAN nodes (e.g., type of computer, location, contact person, discipline supported, node address), and will implement a data base containing SPAN user information that will provide the basis for a directory of SPAN users. The online system is called the SPAN-Network Information Center (SPAN-NIC). In addition to the SPAN data base, SPAN-NIC contains general SPAN information and history, a list of SPAN documents that can be requested, SPAN inter-mail address syntaxes, and important SPAN news briefs. A network information coordinator is available to help users with network problems.

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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** - All nodes of the NSSDC VAX cluster are a part of the NASA Science Network (NSN). This is a TCP/IP-based network that is tied in with NSFnet and the ARPANET based 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. Typing TELNET 128.183.10.4 will connect you to the NSSDCA computer.

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. Simple VAX-to-VAX PSI-mail can also be exchanged 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 VAX cluster.

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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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 a series of Guest Observers. International Ultraviolet Explorer (IUE) data are a prime example of those.

NSSDC digital data are currently held 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 Federal 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 format statements 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 1987, 50% of these requests were received by mail, 25% via telephone calls to NSSDC personnel, 18% electronically via SPAN or other networks, and 7% from miscellaneous sources.

In 1987, 35% of all requests received were for spacecraft data spanning the range of scientific disciplines; 14% were for ADC data; 20% were for various spacecraft and non-spacecraft related documents; 21% were for miscellaneous programs, models, and information; and 10% were referred to other centers or the GSFC Public Affairs Office for processing.

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 1987 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.

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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 more than 80,000 tapes, many are now over 10 years old and slowly deteriorating, and many are written at low densities using 7-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 is forming 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 held its first full meeting at GSFC on April 13-14, 1988. A preliminary ranking of the data sets under review has been generated. It is expected that a more complete and final prioritization will be generated over the next several months with an accompanying summary report.

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, 9-track tapes. 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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NEWSLETTERS AND PAPER CATALOGS

NSSDC NEWSLETTER

The NSSDC produces a quarterly newsletter, the *NSSDC News*,[27] 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 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*.[32] The bulletin includes pre- and post-launch announcements on spacecraft; 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.

In a typical week, NSSDC/WDC-A-R&S receives about 80 telexes, many of them from the U.S. tracking organization 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, and dates of predicted and actual re-entries. The tracking organization telexes provide the actual launch verification soon after a spacecraft has been launched and its orbit has been determined. This organization suggests an 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* [13] identifies, in a highly summarized way, data available from the NSSDC. More than 3,000 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 to 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 Missions* [3,10,11,12,16,20] 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).

About half of the volumes have been distributed and the others are in the process. 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.* [2]

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* [2] referenced above; *Data Announcement Bulletin (DAB);* [7] *Availability of Infrared Astronomical Satellite (IRAS) Data Sets from NSSDC;* [1] *Astronomical Data Center Catalog;* [31] *Coordinated Ionospheric and Magnetospheric Observations from the ISIS 2 Satellite by the ISIS 2 Experimenters;* [19] *User's Note for Alouette and ISIS Ionograms;* [17] *Nimbus (5 and 6) Data Catalogs;* [21] *Catalog of Particles and Fields Data;* [4] *Interplanetary Medium Data Books;* [6] *Catalog of Viking Mission Data;* [33] *Coordinated Data Analysis Workshop (CDAW) Data Catalog;* [5] the *NASA Climate Data Catalog;* [26] and the *Crustal Dynamics Data Information Systems User's Guide.* [18]

Availability of newly distributed paper catalogs and paper data documents is announced in the *NSSDC News.* [27] The NSSDC and WDC-A-R&S *Document Availability and Distribution Services (DADS)* [8] 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 or (SPAN) NCF::REQUEST.

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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. The CDS acts as a central repository, established by the International Astronomical Union, of an international network of centers for astronomical data, including facilities at the Goddard Space Flight Center, and in Moscow, Potsdam, and Kanazawa, Japan.

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*[28] that gives a more detailed listing of the catalogs given in the *NSSDC Data Listing*.[13] Updated reports are available on request, as well as being published in issues of the *Astronomical Data Center Bulletin*.[30]

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*[27] 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 other-

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wise 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 allowed 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 CDAW-8 program, just concluding, was focused on identification and interpretation of observations relating to the formation of plasmoids in the Earth's magnetotail, as well as larger questions of overall magnetotail dynamics and energy flow. CDAW-8 is expected to produce more than 10 manuscripts for journal publication.

The next solar-terrestrial CDAW will be concerned with data from the Polar Regions Outer Magnetosphere International Study (PROMIS), and is expected to be held in February 1989. Additional CDAWs in the areas of global cloud cover and the ozone hole phenomena are also being planned.

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SATELLITE SITUATION CENTER

The Satellite Situation Center (SSC) is designed to serve the planning needs of diverse investigators for coordination of data acquisition for collaborative efforts both large and small. This part of the NSSDC

was developed to meet the challenge of the International Magnetospheric Study (IMS).

During the IMS period (1976-79), and in 1971-75, 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 form as well as in tabular form. The SSC plot capability is augmented by converting any list file to a Common Data Format, and then utilizing the NSSDC Graphics System.

The SSC provides auxiliary trajectory-related parameters to the San Marco satellite project (launched in March 1988) to accompany the investigators' data. 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 expect to play a major role during the upcoming International Solar-Terrestrial Physics era, when a number of new spacecraft will be added to the current fleet of solar-terrestrial research spacecraft.

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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 6 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 1) and related software for the ionosphere, 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 1). 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 experts.

IONOSPHERE

The ionosphere is the partially ionized, gaseous envelope that surrounds our 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 '70s 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 at the NSSDC resulted in several improvements of the IRI model. The next major step is the development of a reliable model for auroral latitudes. In the auroral region, unlike the other regions in the polar ionosphere, the close coupling with the magnetosphere and the precipitation of energetic electrons 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 (9/65, 12/66, 9/80), the POGO models (3/68, 10/68, 8/69, 8/71), and the MAGSAT models (3/80, 4/81). 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. The NSSDC's geomagnetic field collection includes several models that attempt to describe the whole field; they in-

IONOSPHERE:

IRI-86 (COSPAR/URSI)
Ching-Chiu (1975), Rush-Miller (1973)

ATMOSPHERE:

CIRA/MSIS-86 (COSPAR)
Jacchia Reference Atmospheres 70, 71, 77
U.S. Standard Atmosphere 62, 66, 76

MAGNETIC FIELD (MAIN):

IGRF 45, 50, 55, ... 85, 85-90 (IAGA)
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 1: Models at NSSDC

clude the models by Olson-Pfitzer (1974), Mead-Fairfield (1975), and the most recent Tsyganenko et al, (1982, 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 scientific community and to large-scale projects like the International Solar Terrestrial Program (ISTP). Future plans include a catalog of models (on line and in hard copy).

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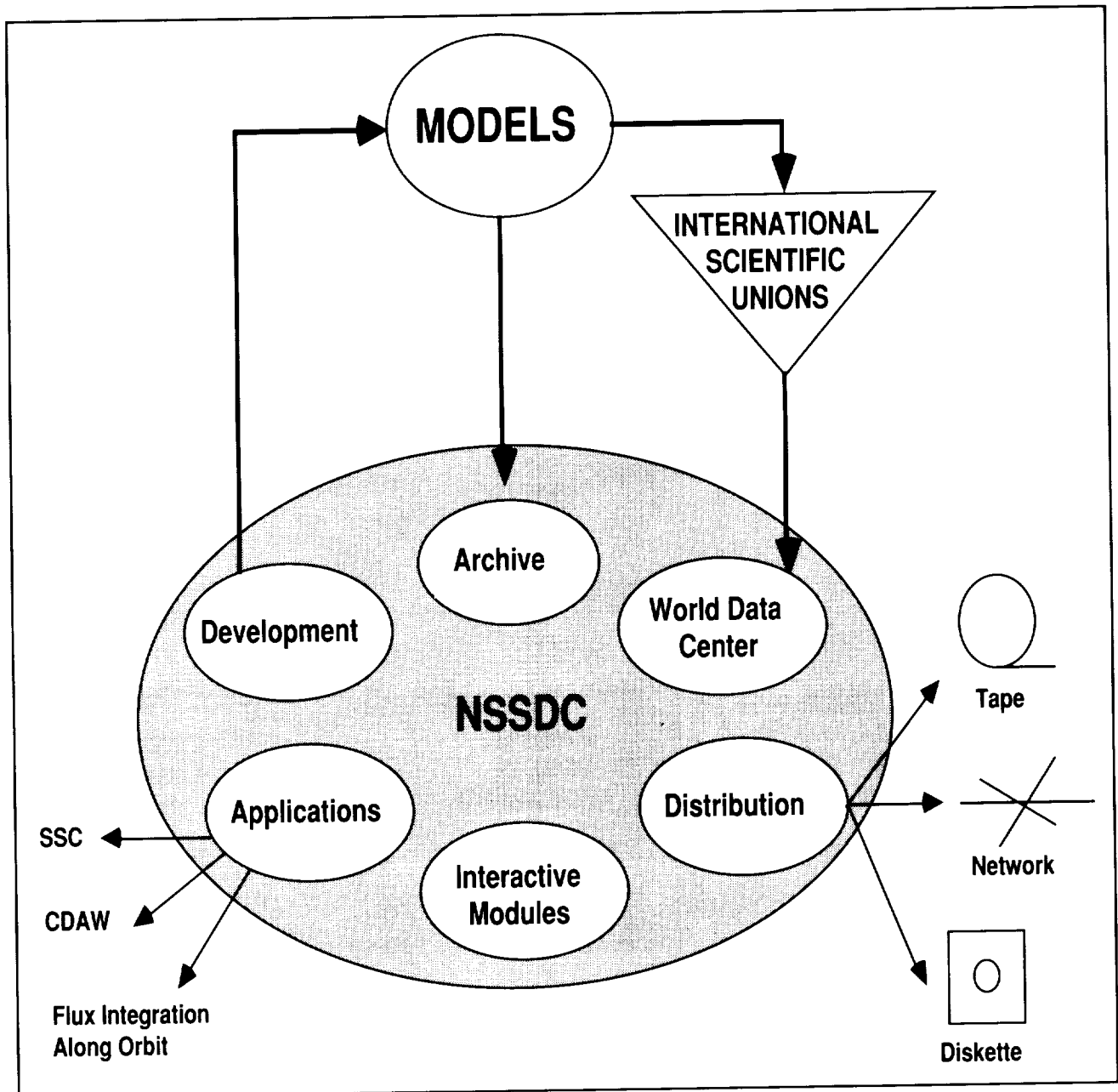   (internet) bilitza@nssdc.gsfc.nasa.gov

Figure 6: NSSDC Archiving and Distribution of Geophysical Computer Models

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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 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 science communities.

The NSDSSO is organized into three distinct functional areas known as Standards Information Dissemination, Standards Process Administration and Standards Validation and Testing (see Figure 7). The information dissemination operation 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 organizations 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, with each broken
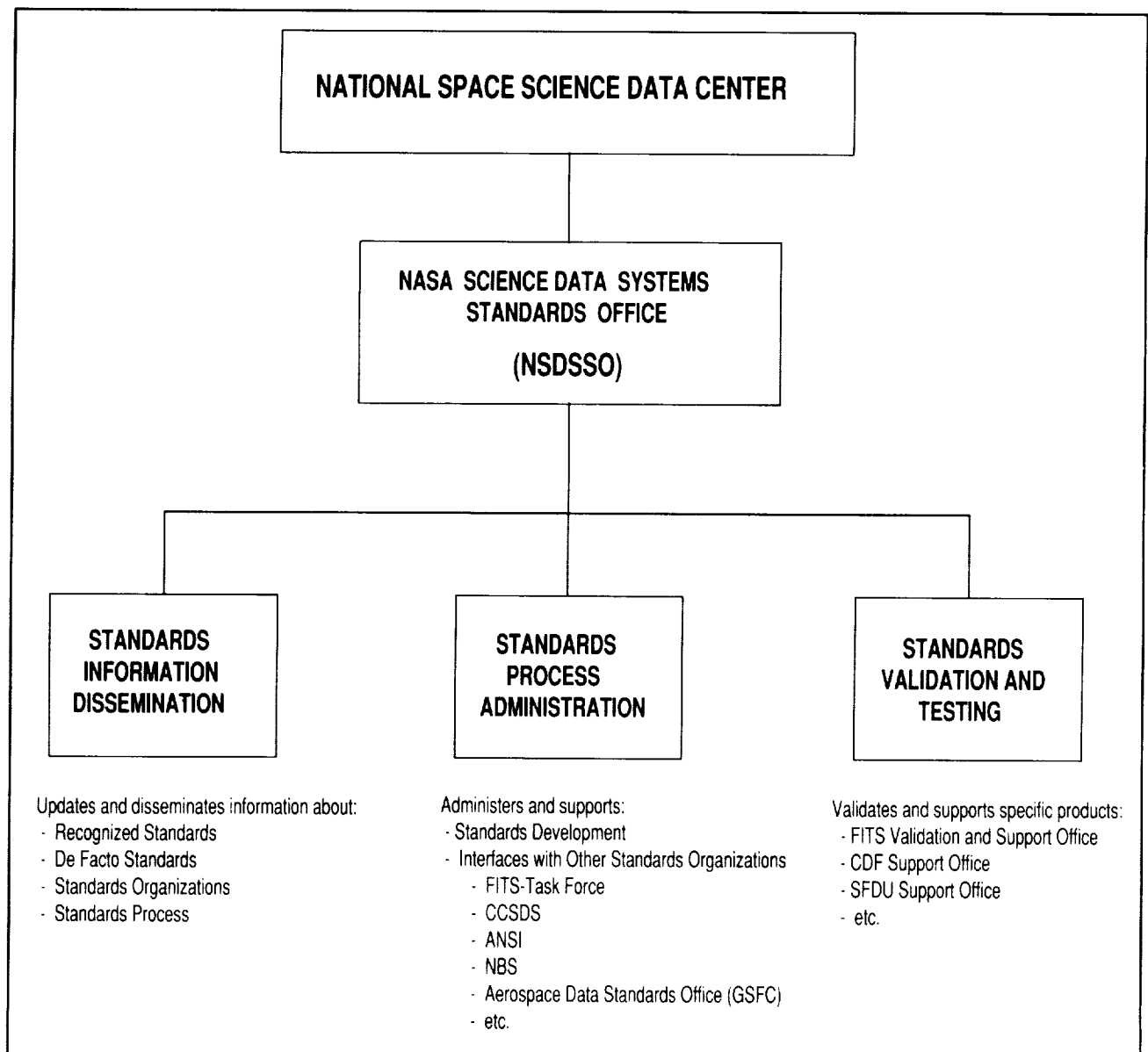

Figure 7: NASA Science Data Systems Standards Office Organization at the NSSDC

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 upon 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::REQUEST, or by mail request to NSSDC. The overall Standards Information Dissemination operation provides an educational service to the space science community.

The Standards Process Administration operation is concerned with the establishment, maintenance, and use of standards-process policies and procedures for the development of new standards by members of the space science community. 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. Interfaces with other standards organizations are defined, and policies on the adoption of existing standards, as NSDSSO standards, are created. The overall Standards Process Administration operation provides a mechanism for the development of standards by the space science communities.

The Standards Validation and Testing 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 the availability of resources.

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GENERIC DATA STORAGE STRUCTURES

The NSSDC has developed the first self-describing data abstraction for storing and manipulating multidimensional data to support discipline-independent scientific applications. This abstraction, which consists of a software package and a self-describing data structure, is called the Common Data Format (CDF) (see Figure 8). CDF provides true data independence for applications software that has been developed at the NSSDC.[29] Scientific software systems at the NSSDC use this construct so that they do not need specific knowledge of the data with which they are working. This permits users of such systems to apply the same functions to different sets of data.

In addition, CDF provides a simple means for the transport of data among different research groups in a format-independent fashion. The users of data-independent NSSDC systems rely on their own knowledge of different sets of data to interpret the results, a critical feature for the multidisciplinary studies inherent in the Earth and space sciences. Such CDF-based software can use the information available through the CDF software package to inform a user about contents, history, and structure of data supported in a given CDF, and it allows such a user to concentrate on the scientific nature of the data of interest rather than its format.

CDF has been used to develop a number of generic data management, display, and analysis tools for a wide variety of disciplines at the NSSDC. The CDF development efforts are evolving into a standard method for storing space and Earth science data for a variety of applications. For example, over 80 organizations outside the NSSDC representing various NASA laboratories, research groups, current and future flight projects, etc., as well as other government agencies, universities, corporations, and foreign institutions have become beta-test sites for the CDF software package for their individual development of software to archive, manage, manipulate, display, or analyze data in a variety of disciplines.

Through its software package, CDF provides the applications programmer a mechanism for uniformly viewing data of interest via a data structure oriented to the user of the data (i.e., a scientist). It is a conceptually simple framework for the creation of generic applications (e.g., graphical displays, statistical analysis) and transparent, discipline-oriented

or user views of data. It is a uniform structure for the distribution of self-descriptive data that can be supported by analysis software. This mechanism for the flexible organization of interdisciplinary data into generic, multidimensional structures consistent with potential scientific interpretation provides a simple abstract conceptual environment for the scientific applications programmer who works with data, but it also encourages the decoupling of data analysis considerations from those of data storage. The developer of CDF-based applications can easily create software that permits a user to slice data across multidimensional subspaces. However, CDF is not a standard format for programmers to "grovel" in the bits. Neither is it a mechanism for programmers to write messy FORTRAN formats, nor a structure for storing and translating obscurely packed data formats between strange operating systems. Finally, it is not a format with which programmers have to consider low-level input/output tasks.

The CDF software package is a toolbox of high-performance programming primitives for managing multidimensional data ensembles; it provides a simple abstract view for random access to arbitrary blocks of data. Any analysis or other applications capabilities must be built into higher-level software that employs CDF. The programmer who utilizes the CDF data abstraction views the CDF software package as consisting of 13 operations. These abstract routines are designed to make it easy for a programmer to utilize data in terms of CDF, independent of the complexity of the data. FORTRAN language bindings for CDF became operational on DEC VAX/VMS computer systems in 1986. C language bindings have also been developed and are being tested for VAX/VMS, IBM MVS and VM, and UNIX (e.g., Sun, AT&T) environments, coupled with conversion utilities to transparently move the physical files composing a CDF from one computer system to another. These developments will be enhanced for distributed access over local area networks.

Since the implementation of the CDF data abstraction really implies an extension to a conventional programming language for the support of multidimensional data objects, a recasting of CDF into an object-oriented programming language such as C++ will also be pursued. Such efforts 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.

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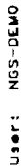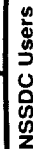
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Figure 8: Common Data Format (CDF) Structure and Examples

MASS STORAGE ACTIVITIES

WORM OPTICAL DISK SYSTEMS
AND
CD-ROM SUPPORT

In order to better preserve current data for future accessibility, to deal with physical storage space constraints, and to prepare for the future onslaughts of greatly increased data volumes, the NSSDC has been actively pursuing a mix of research and operational activities with optical disk technologies. Most such activities have dealt with Write Once Read Many (WORM) technology, although activities are building in 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 forms, 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 from VAX/ VMS, Files-11, Unibus, and Q-bus systems. 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. This work began in collaboration with the space plasma group of W. Hansen at the University of Texas at Dallas.

The NSSDC is currently developing a software package (Virtual Optical Disk, or VOD) to enable a disk written with certain file structures (e.g., DEC's 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. It is expected that 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 will enable the archiving of data on space-conserving optical disks, yet will allow the easy dissemination of user-requested data files on tapes to users having no optical disk reading capability.

WORM technology is the technology of choice when only a small number of copies of the data will be created, and when local write capability is required. For cases where a central organization must create many copies of a given data set for wide dissemination, CD-ROM becomes the technology of choice. Each CD-ROM disk may hold about 600 MB of digital data.

The NSSDC collaborated with the National Oceanographic and Atmospheric Administration's (NOAA) National Geophysical Data Center in the creation of its first multi-data set CD-ROM by providing a copy of the OMNI data set of hourly solar wind field and plasma parameter values. Likewise, the NSSDC has participated in the JPL-organized Interactive Data Interchange (IDI), and has the same OMNI data set on the CD-ROM resulting from the IDI effort.

The NSSDC is now preparing for more active roles in the preparation of CD-ROM disks, including one with selected catalogs of the Astronomical Data Center, which the NSSDC partially operates, and another with International Halley Watch data. Each disk to be generated must be accompanied by indices and retrieval software. It is in the organization of data and the creation of indices and software that CD-ROM creation is most resource intensive.

In the earliest years of CD-ROM creation, organizations needing CD-ROMs sent multiple tapes in their native formats to one of a few commercial firms to organize their data onto a tape formatted for mastering the disk. This step, called premastering, can now be performed at the data owner's site with a premastering hardware/software system. The capital cost may be amortized after the creation of a dozen or so

disks. The NSSDC is currently procuring such a system for its use and for use by other NASA organizations on an as-available basis.

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COMPUTER SCIENCE RESEARCH

DISTRIBUTED ACCESS VIEW INTEGRATED DATABASE

Due to the plethora of devices, operating systems, data base management systems, communication alternatives and data center protocols, NASA space scientists have to learn many different access methods in order to obtain data for their research. Standardization is not a solution because there tends to be no universally agreed upon standard, and systems developed prior to introduction of standards cannot be easily rebuilt.

The goal of the Distributed Access View Integrated Database (DAVID) Project is the development of computer software that will enable NASA scientists to uniformly access data sets and programs independent of the computer on which they are located, the operating system of the computer, or the network on which the computer resides. The approach being used is called "uniformization." A layer will be placed on top of existing and future systems so the user has to learn only two systems, his own and the uniform system.

The DAVID solution entails a three-layered approach. From the bottom up, the layers are as follows:

> **DAVID Engine:** This is the lowest level. It enables all of the devices, operating systems, data base management systems, communications alternatives, and data sets to appear to the user as if they were one centralized, homogeneous computing system. For example, if data sets were regarded as books in different foreign languages, this level would be analogous to putting an English translator on each foreign language book.

> **Library Concept:** This is the middle level. It regards each local area network as if it were a "library." The "library" is divided into two areas: (1) The "main rooms" handle the administrative functions such as library cards, mail, phone, circulation, reproduction, remote library access, etc.; and (2) the "reading rooms," which comprise the majority of the rooms, contain the data to be read. A particular reading room contains the "library catalog" which tells what the "library" has available and in which rooms that information can be found.

Library System or Application Organization: This is the top level. It deals with the way in which the collection of all "libraries" is organized. Since these issues are highly dependent on the particular utilization, it is also referred to as the Application Organization.

The DAVID Project is in the latter stages of development. Building and testing of the basic C language software has been completed for many of the DAVID modules. The DAVID Generalized SQL Primitives, Host Language Interface, Generic Cluster Access, and File Access are now running on each of the computers participating in the DAVID system. The Terminal Interface, Generalized SQL Translation Package, Constraint Realization, View Integration Package, Scheduler, Installation, and Backup are running primarily on an AT&T 3B/2 (designated as the "DAVID Machine") and coordinating DAVID processing on each local area network.

Building and testing interfaces between the DAVID system and underlying data bases and data base management systems have been completed, and design and detailed software specifications for the "library layer" have been completed.

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 an intelligent system that is based on a distributed architecture with value-added services for managing non-spatial, spatial, and object-oriented data in the context of a scientist's domain. These scientists have a need for online access to space and Earth related data, but may not have the needed experience in data base

operations and procedures. Following are the long-term research goals:

- Development of intelligent value-added services that enable scientists to interact with the most complex data base systems with minimal understanding of the systems' architecture, stored data, or query language.

- Development of automatic data cataloging and characterization with minimal user guidance and interaction.

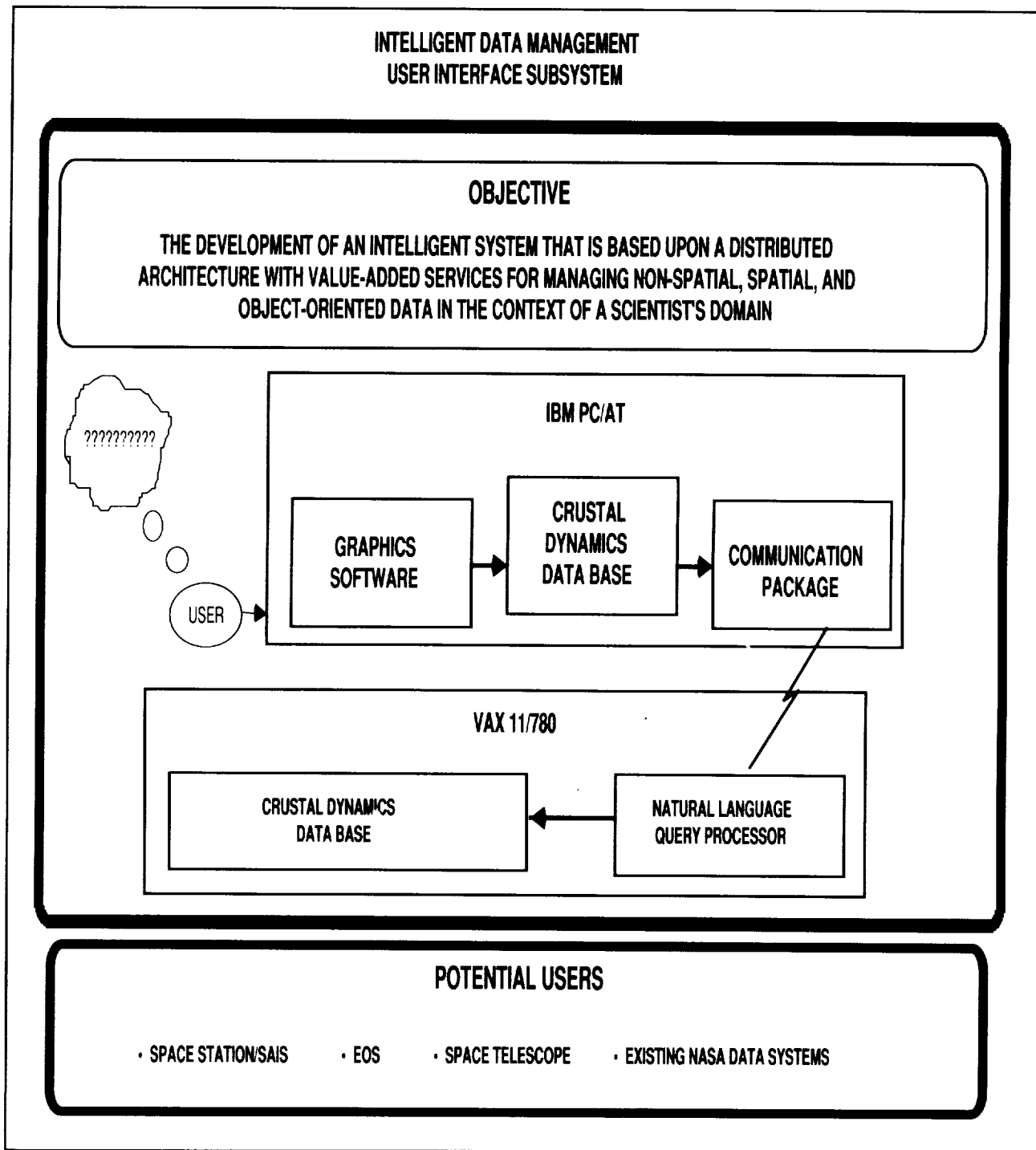- Management of non-spatial, spatial, and object-oriented data in the same operating environment.

Figure 9: The First Generation Prototype Intelligent User Interface

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A first generation prototype Intelligent User Interface (IUI), shown in Figure 9, has been developed that provides the capability for a scientist with no previous training or experience to casually browse a remote operational scientific data base either in plain English or graphically. This system was implemented on an IBM PC/AT using an expert system development tool. The natural language query processor parses the English query into the data base management system language that is remotely located, and processes and returns the desired information to the scientist over a communication network. All software is commercially available.

Coding has begun for the next generation data management system on a LISP machine and a powerful 32-bit microcomputer using advanced expert system shells and 3-D graphics. The integrated environment of these tools provides the mechanism for imbedding knowledge and domain expertise in the data structures themselves (frame-based, quad-trees, etc.), thereby providing, for the first time, a truly generic and robust data management system to rapidly search, access, manipulate, and display specific data relevant to a scientist.

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INTERACTIVE, DISCIPLINE-INDEPENDENT DATA VISUALIZATION TECHNIQUES

Realizing that provision of pictorial or visual representations is critical to the understanding of data, particularly in support of correlative data investigations, the NSSDC has an ongoing program to develop new, generic (i.e., data-independent) techniques for the display of multidimensional data, as well as metadata, or associated information about these data. These techniques utilize the latest methods in computer graphics and imaging, and state-of-the-art hardware. As part of these efforts, the NSSDC Graphics System (NGS) was developed. It is an interactive, discipline-independent toolbox to support the visualization of data on the NSSDC Computer Facility's DEC VAX 8650 and 11/780. To utilize the NGS, data of interest must be stored in terms of the CDF, a data-independent abstraction for multidimensional data structures that has been used to develop a number of generic data management, display, and analysis tools for a wide variety of disciplines at the NSSDC.[29]

The NSSDC has employed several off-the-shelf capabilities to develop the required graphical capabilities in a timely and cost-effective manner. NASA's Transportable Applications Executive (TAE) is employed as an easy-to-use, consistent, uniform user interface. The Template package developed by Template Graphics Software is employed to support two- and three-dimensional interactive graphics on any type of graphics hardware. Template also provides sophisticated graphics-device independence for direct processing and post-processing of graphical objects. As these packages evolve and expand in capability, the NGS will take advantage of the enhancements.

The NGS supports the ability to display or visualize any arbitrary multidimensional subset or slice of any data set by providing a large variety of different representation schemes, all of which are supported by implicit animation. It places a strong emphasis on complete annotation of its graphical products and extensive use of color, supporting the following methods of displaying data: two-dimensional histograms, X-Y plots (including optional multiple axes, pseudo-color and polar coordinates), multiple panel displays, location maps, contour plots with and without maps, surface diagrams with and without maps (including optional pseudo-color), pseudo-color images with and without maps, and solid modeling without maps. Solid modeling with maps, X-Y-Z plots with and without maps, scatter diagram matrices, two- and three-dimensional vector field plots with and without maps, and three-dimensional histograms with and without maps will be supported in the future.

A number of options for each representation scheme are provided such as curve fitting, gridding, scaling, filtering, font selection, statistics, graphics metafile generation, etc. Specific options are associated with all representation schemes (e.g., controlling the range and increment of isolines on contour maps).

To support the visualization of large, geographic data sets and eliminate any distortion in mapped displays, the NGS employs very flexible world mapping capabilities that are quick and very precise. Currently, 22 general projections are supported, and more can be added easily. The user has complete control over the specification of the pole point and

viewing window for any of the display techniques available with world maps, to support arbitrary reprojection of any data set. Both low and medium resolution world coastline data bases are supported, the latter with political boundaries. A very high resolution world coastline data base and a world topographic data base will be added in the future.

The design of the NGS provides an open-ended framework for discipline-independent data visualization, so that new capabilities can be added. For example, the following new techniques have been incorporated into the NGS as a result of this activity's applied computer science research:

- Advanced data structures supporting graphics as well as data analysis and management applications, to assure rapid display and manipulation of large, complex data sets:

  - three-dimensional data storage and sampling via generic oct-trees

  - polygon expansion via quadtree-based rectangular subdivision for pseudo-color imagery

- Rendering and manipulation algorithms with serial (e.g., VAX) and parallel (e.g., MPP) implementations that can operate on any data object or geometry:

  - n-dimensional gridding

  - ray-tracing via recursive spherical triangle subdivision

The NGS is designed to be portable. It is currently available to the users on SPAN of the NSSDC's Network Assisted Coordinated Science (NACS) system in support of CDAW. In the future, it will be available to users of the NSSDC's NCDS, and it is being tested for potential use in future flight projects, as well as to support specific scientific investigations. Expansion to low-cost graphics workstations (e.g., Apple Macintosh II), and high performance graphics workstations (e.g., Silicon Graphics IRIS), and the support of production of presentation-quality animated visualizations is expected in the future.

The illustration in Figure 10, generated by the NGS, depicts the mean sea surface over the Bering Sea

showing the Aleutian Trench. This picture, reflecting changes in the local bathymetry, was derived from altimeter data from the GOES-3 and NASA's SEASAT satellites. The three-dimensional image has been tilted horizontally by 73 degrees, and is viewed from the southwest at an inclination of 36 degrees. It is artificially illuminated at the same location as the eyepoint of the viewer. The mean sea surface reflects the shape of the ocean bottom rather than subsurface changes in the composition of the Earth. The sea height changes by 20 meters over the trench, whereas the depth of the sea floor changes by more than 3,000 meters. A generic ray-tracing algorithm available in the NGS permits a solid, light-shaded object like that illustrated to be generated from any data to bring out details that are not possible with conventional visualization methods.

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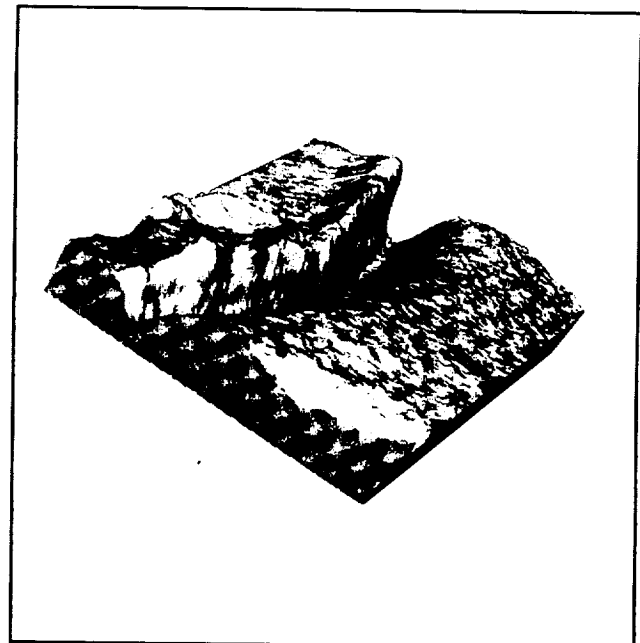   (internet) treinish@nssdca.gsfc.nasa.gov

Figure 10: Mean Sea Surface of the Bering Sea
            Showing the Aleutian Trench

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NSSDC ACRONYM AND ABBREVIATION LIST

ADC — Astronomical Data Center
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 Network (no joke!)

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
CFC — Chlorofluorocarbons
CIRA — COSPAR International Reference Atmosphere
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

DAB — *Data Announcement Bulletin*
DADS — *Document Availability and Distribution Services*
DAN — Data Analysis Network (Canada)
DAVID — Distributed Access View Integrated Database
DBMS — Data Base Management System
DECnet — DEC Networking Products (generic family name)
DSUWG — Data Systems Users Working Group

ECMWF — European Center for Midrange Weather Forecasting
ELSET — Element Set
EOS — Earth Observing System
EROS — Earth Resources Observation System
ESA — European Space Agency; Electrostatic Analyzer
ESO — European Southern Observatory
ESOC — European Space Operations Centre
EUROHEPnet — European High Energy Physics Network
EXOSAT — European X-Ray Observation Satellite (ESA)

FBIS — Foreign Broadcast Information Service
FIFE — First ISLSCP Field Experiment
FIRE — First ISCCP Regional Experiment
FRG — Federal Republic of Germany

GGS — Global Geospace Science
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
IDM	Intelligent Data Management
IGRF	International Geomagnetic Reference Field
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
ISTP	International Solar-Terrestrial Program
IUE	International Ultraviolet Explorer (satellite, NASA-U.K.-ESA)
IUI	Intelligent User Interface
IUWDS	International URSIGRAM and World Days Service
JPL	Jet Propulsion Laboratory (NASA)
JSC	Johnson Space Center (NASA)
KSC	Kennedy Space Center (NASA)
LAS	Land Analysis Software
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
NSDSSO	NASA Science Data Systems Standards Office
NGS	NSSDC Graphics System
NIC	Network Information Center
NOAA	National Oceanographic and Atmospheric Administration (formerly ESSA)
NODS	NASA Ocean Data System
NORAD	North American Air Defense Command
NPSS	NASA Packet Switched System
NRAO	National Radio Astronomy Observatory
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
SEASAT	Sea Satellite (NASA)
SERC	Science and Engineering Research Council
SIMBAD	Set of Identifications, Measurements, and Bibliography for Astronomical Data
SLR	Satellite Laser Ranging
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)
UK	United Kingdom
URSI	International Union of Radio Science
USGS	United States Geological Service
USRSDC	U.S. ROSAT Science Data Center
VAX	Virtual Address Extension (DEC minicomputer)
VICAR	Video Image Communication and Retrieval
VLBI	Very Long Baseline Interferometry
VOD	Virtual Optical Disk
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