N93-27044

Astrophysics Science Operations in the Great Observatories Era

Presentation to the Workshop on Astrophysical Information Systems

May 23, 1990

Guenter R. Riegler
Chief, Science Operations Branch
Astrophysics Division
National Aeronautics and Space Administration
Washington, DC 20546

ABSTRACT

Plans for Astrophysics science operations during the decade of the nineties are described from the point of view of a scientist who wishes to make a space-borne astronomical observation or to use archival astronomical data. "Science Operations" include proposal preparation, observation planning and execution, data collection, data processing and analysis, and dissemination of results. For each of these areas of science operations we derive technology requirements for the next ten to twenty years. The scientist will be able to use a variety of services and infrastructure, including the "Astrophysics Data System." The current status and plans for these science operations services are described.

TABLE OF CONTENTS

INTRODUCTION TO SCIENCE OPERATIONS

Until recently, the Astrophysics community had access to data from just a few Astrophysics missions. With a small number of datasets, the use of mission-unique data and analysis tools was considered to be acceptable. With the launch of a large number of Astrophysics missions in the timespan of a few years (see Figure 1), a better approach had to be found. The NASA Astrophysics Science Operations Program was established as an Astrophysics-wide program in order to encourage multi-mission, panchromatic research in Space Astrophysics. By fostering coordination and cooperation among all mission operations and data analysis efforts in Space Astrophysics, NASA expects to maximize the scientific return from operating Astrophysics missions, as well as from existing Space Astrophysics data.

The objectives of the Science Operations Program are to maximize the scientific return from operating Astrophysics missions, to maximize the scientific return from existing Astrophysics data, and to enable multi-mission, panchromatic research in Space Astrophysics.

The term "Science Operations" includes four areas (see Figure 2):

- the "**Astrophysics Data System (ADS)**", providing the data-related infrastructure for all of the following items,
- **research programs**, consisting of guest observations and archival research by members of the Astrophysics science community,
- **science support services**, including multi-mission archive centers and science databases, and
- management of **mission operations and data analysis**, typically carried out at a NASA field center or a mission center.

The purpose of this paper is to present

- the current status of Astrophysics Science Operations, in order to serve as reference information for Workshop participants,
- the plans for Astrophysics Science Operations for the next few years (the Workshop will, of course, focus on a more distant epoch, i. e. the next ten to twenty years), and
- the relationship between the four Science Operations functions and the "Topics for Panels in the Astrophysical Information Systems Workshop".

SCIENCE OPERATIONS: IN A STATE OF TRANSITION

The principles and day-to-day execution of Astrophysics science operations are in a state of **transition**. Although all Astrophysics missions have their unique history and future plans, they tend to evolve towards the same long-term goals.

The **character of Astrophysics missions** is changing from Principal-Investigator (PI) instruments (or even PI-type missions) to facility-class observatories, where the instruments are still built by PIs, but many Guest Observers are expected to use them. Several of these missions are also planned to be operational for sufficiently long periods of time that a significant turnover in technical and scientific personnel will take place during the active life of the mission. Furthermore, analysis methods and computing hardware will evolve through several generations during the data analysis phase of these missions.

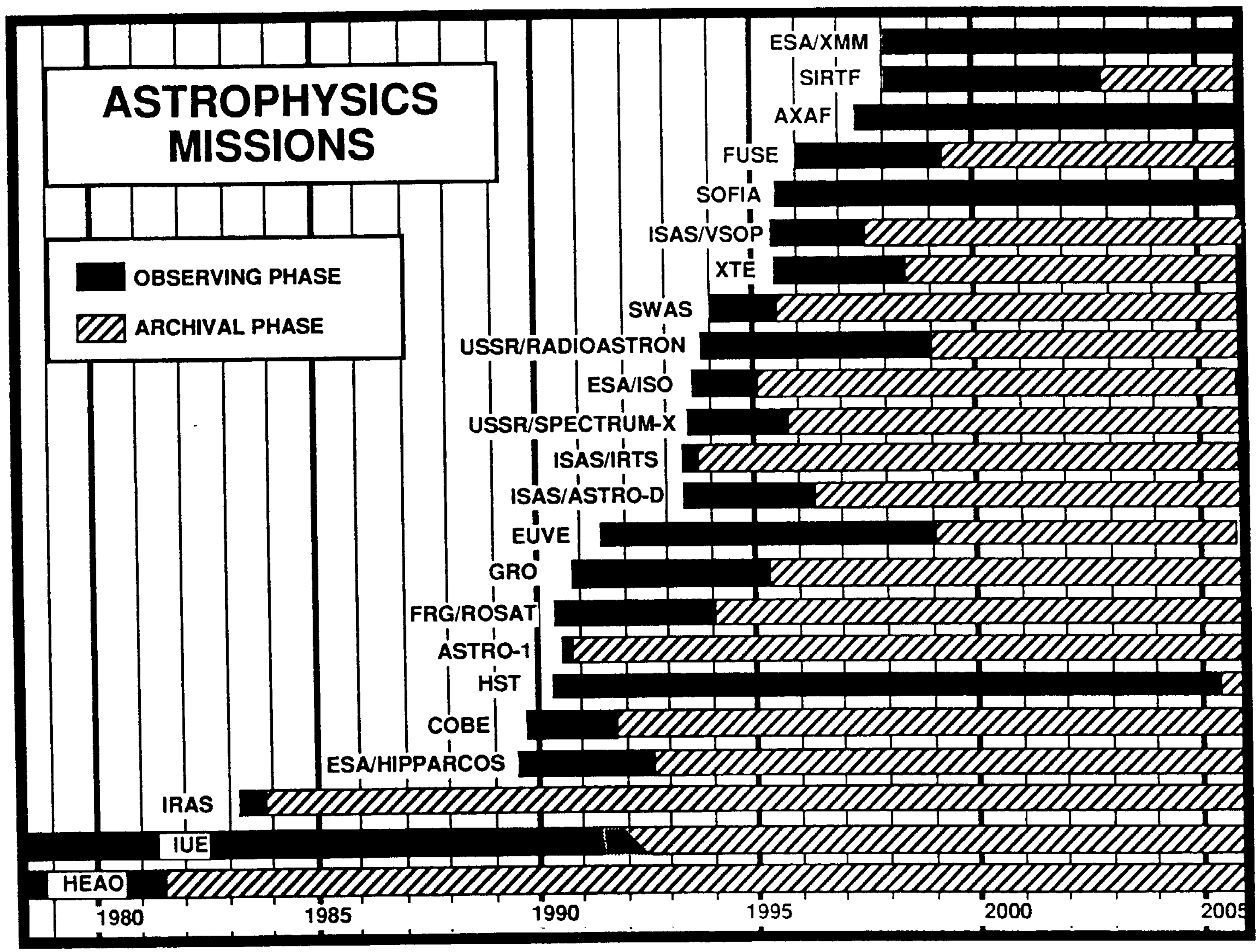

Figure 1. The active operations/observation phases and subsequent archival research phases for the major space astrophysics missions shown as a function of time.

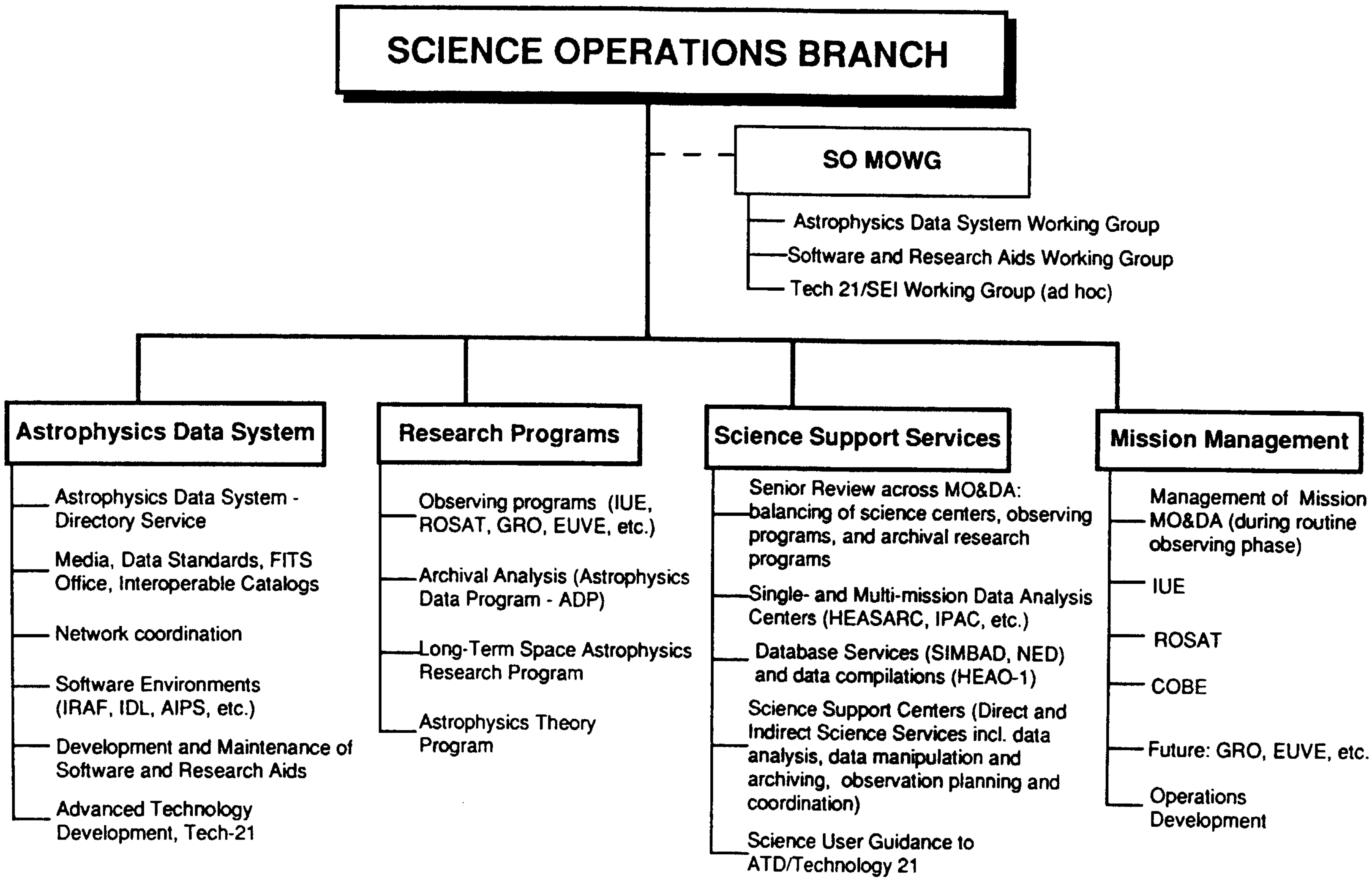

Figure 2. The four major components of Astrophysics Science Operations.

For PI instruments, most of the data analysis was carried out by members of the PI team at the PI institution. In the future we expect to see **distributed analysis**, primarily carried out by Guest Investigators at their home institutions.

The **character of scientific research** is also expected to evolve, from single-mission or single-wavelength research to science topic-oriented, panchromatic research. For example, a recent study showed that of all the scientists who used data from the Infrared Astronomy Satellite (IRAS), only 30% considered themselves "IR Astronomers" proper, while 70% came from radio, UV/Optical, high-energy, or theoretical astrophysics. To enable panchromatic research, we require:

- the ability to execute coordinated (simultaneous or contemporaneous) observations involving space- and ground-based observatories, and

- the ability to carry out multi-mission and multi-wavelength data analysis and interpretation.

This means that Astrophysics missions must supply the necessary expertise, as well as data, data analysis tools, and other services to enable and encourage such topic-oriented research.

SCIENCE OPERATIONS NEEDS FOR A TYPICAL GUEST OBSERVATION

The table below shows steps in a typical Astrophysics investigation, and examples of the types of science operations services required at each step. Several of these services are described in more detail below.

INVESTIGATION TASK	SCIENCE OPERATIONS SERVICES REQUIRED BY INVESTIGATOR
Release of the NASA Research Announcement (NRA)	Supplemental information and proposal preparation available electronically from mission science data center
Proposal writing	Obtain information about existing or approved observations through the ADS, on-line databases, database services
Proposal submission	Electronic submission, electronic peer review, publication of approved investigations (abstracts, source lists) in databases
Observation planning	Database tools for coordinated observations
Data reduction and analysis	Remote data processing and analysis, portable software, standard software packages, software interchange, ADS, data format standards, databases, discipline-specific archives

ASTROPHYSICS DATA SYSTEM (ADS)

The Astrophysics Data System provides the **infrastructure** for locating data, and for the subsequent data analysis. The ADS Project is managed at the Infrared Processing and Analysis Center (IPAC, Dr. John Good, Project Manager) in Pasadena, California. Figure 3 shows the current configuration of the ADS. It is designed to

- allow remote access by scientists at their home institution through the NASA Science Internet,

- permit scientific inquiries (e. g. "where are UV high-resolution spectra of active galactic nuclei?") to be answered simultaneously by all ADS science center nodes ,

- locate data holdings, select data (sensor, correlative, and ancillary data), browse through the data archives, and order data for electronic or mail-order transmission,

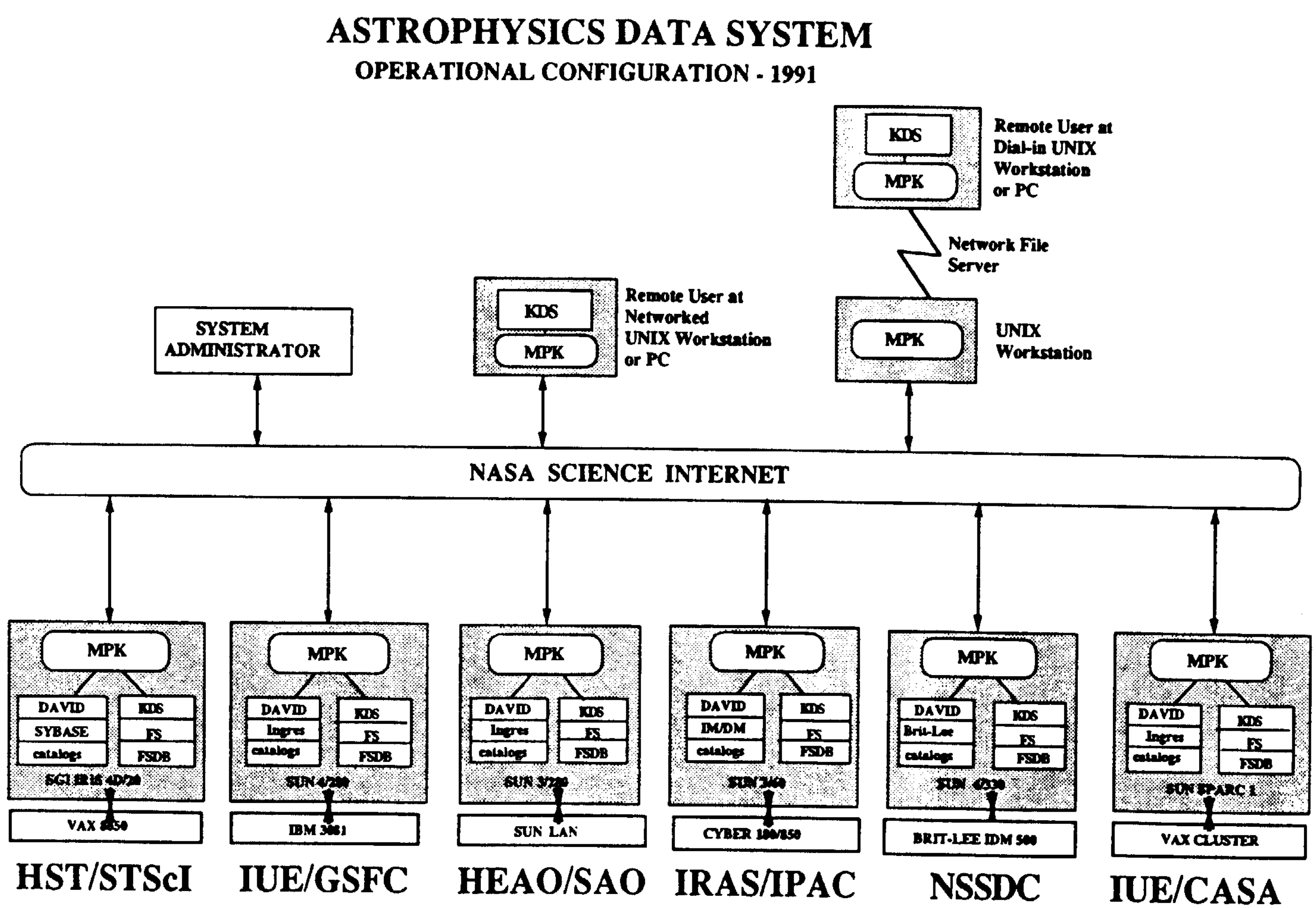

Figure 3. The Directory Service of the Astrophysics Data System (ADS): Operational configuration of the Directory Service of the Astrophysics Data System, showing the message passing kernel (MPK), the data-independent access method to databases ("DAVID"), factor space (FS), and the factor space database (FSDB) portion of the Knowledge Dictionary System (KDS). In the initial configuration (planned to be operational in 1991), the ADS nodes will include the Space Telescope Science Institute (STScI), the International Ultraviolet Explorer (IUE) at the Goddard Space Flight Center (GSFC) and the Center for Astrophysics and Space Astronomy (CASA) at the University of Colorado, the High Energy Astronomy Observatory (HEAO) Data Center at the Smithsonian Astrophysical Observatory (SAO), the Infrared Astronomy Satellite (IRAS) data center at the Infrared Processing and Analysis Center (IPAC), and the National Space Science Data Center (NSSDC) at GSFC.

- make the exact nature of the operating systems or database management systems at the various data centers (see Figure 2) transparent to the remote user.

After two years of development, the ADS is currently in the test phase, and training of new users and node managers has begun. The full ADS is expected to be operational in mid-1991.

The ADS is very similar in philosophy and design to ESA's European Space Information System (ESIS, developed by ESRIN, Frascati, Italy). Access to the ADS from outside the US will be possible through the NASA Master Directory (developed at the Goddard Space Flight Center, Greenbelt, Maryland) and via direct connection through the NASA Science Internet.

Two very important components of the infrastructure for Astrophysics science operations are **communications** and **data format standards**. As a result of the recommendation of the International Astronomical Union for the adoption of the "Flexible Image Transport System (FITS), NASA has adopted a policy for the use of FITS formats for the **exchange of data** (NOT for data files internal to reduction and analysis programs). In addition to special, mission-specific extensions, the FITS system accomodates basic images, random groups, ASCII tables, IEEE floating-point data, 3-D floating-point data, keyword hierarchies, and single-photon data. In order to assist missions and individual scientists in the use of FITS structure, a **FITS Standards Office** has been established at the Goddard Space Flight Center, Greenbelt, Maryland.

On the basis of requests from working scientists, we can identify the following requirements for future technology development:

- Media for: data transfer, medium- and long-term storage,

- Networks: higher throughput, dynamic routing/routing table changes, priority system,

- Software: tools for development, dissemination, and maintenance of analysis tools,

- Software: tools for integration of service software for on-line, networked use,

- Software environments which are highly convertible and transportable.

RESEARCH PROGRAMS

The NASA Astrophysics Division has more than ten research programs which are dedicated to astronomical observations (IUE, HST, ROSAT, GRO, etc.), archival data analysis (the Astrophysics Data Program), and longer-period research efforts (Long-Term Space Astrophysics Research Program, Astrophysics Theory Program).

On the basis of requests from proposers, peer reviewers, users' groups, and science data centers, we can identify the following requirements for future technology development:

- For proposal handling: Electronic proposal submission, tracking, acknowledgements,

- For proposal forwarding to reviewers, ingest of initial and subsequent evaluations, grading, budget assessments: Proofreading of text and numerical data from review; electronic notification of results, grades, comments, budgets; dissemination of results to science community, into databases, to contracts department; and statistical analysis, preparation or reports,

- Electronic conferencing: Voice contact and simultaneous data transmission; controlled transfer of text, numerical, and graphical data to reviewers; and controlled editing of data by chairman and peers,

- Security for all of the above: read-only transmissions; pre-set or commandable erasure of transmitted information and any copies.

SCIENCE DATABASES AND OTHER SCIENCE SUPPORT SERVICES

In response to requests from the science community, and after peer review, a number of services are either under development, or are already accessible to remote users. The "Astrophysics Software and Research Aids" Program explicitely solicits proposals for software packages, databases, operational tools, etc., and supports them after competitive science peer review. The science databases and science operations services include:

- convenient and inexpensive **access to the SIMBAD database** (developed at the Centre de Données Stellaires, Strasbourg, France)

- the **National Extragalactic Database (NED)** (developed at the Infrared Processing and Analysis Center, IPAC, Pasadena, California) containing comprehensive data on extragalactic objects, including cross-references, literature citations, and complete abstracts of referenced articles,

- **"MultiWaveLink"**, an interactive database for the coordination of multiwavelength space and ground-based observing programs (developed at Pennsylvania State University), and

- a **"Comprehensive Atomic Spectroscopy Database for Astrophysics"** (developed at the National Institute of Standards and Technology, Gaithersburg, Maryland).

As a matter of policy, NASA encourages and supports the wide dissemination of data to the astronomical community. Examples of such dissemination are the distribution, on CD-ROMs, of the HST Guide Star Catalog, of the National Space Sciences Data Center's machine-readable versions of frequently used astronomical catalogs, and of the Einstein Observatory's Imaging Proportional Counter and High Resolution Imager results.

Requirements for future technology development exist in the areas of:

- Data management: of digital, textual, and graphics data,

- Data display: visualization, animation, and

- Data analysis: analysis software, software environments.

MISSION OPERATIONS

For mission operations, technology developments are needed for:

- Planning tools: for observation and resource planning,

- Computing: on-board and ground data processors, command processors,

- Command management: software and hardware for command generation, verification, implementation,

- Autonomous scheduling tools,

- Autonomous state-of-health analysis tools: for observatory, instruments, resources,

- Autonomous analysis tools for planned and serendipitous observations, and

- Executives: to assess consequences and implement follow-on actions from all of the above.