The Early Earth Observing System Reference Handbook
Earth Science and Applications Division Missions
1990 - 1997

NASA

Goddard Space Flight Center

The Early Earth Observing System Reference Handbook
Earth Science and Applications Division Missions
1990 - 1997

Goddard Space Flight Center

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

Introduction

Prior to the launch of the Earth Observing System (EOS) series, the National Aeronautics and Space Administration (NASA) will launch and operate a wide variety of new Earth science satellites and instruments, as well as undertake several efforts collecting and using the data from existing and planned satellites from other agencies and nations. These initiatives will augment the knowledge base gained from ongoing Earth Science and Applications Division (ESAD) programs. The primary goal of all ESAD activities is to develop an increased understanding of the Earth system, both by continuing the traditional studies of its various components and by investigating the processes and cycles through which the different components of the Earth system interrelate.

Earth science is evolving into Earth system science, changing from a discipline-specific to an interdisciplinary endeavor. Increased awareness of human dependence and impact upon the environment has made global change research one of the most pressing policy issues facing decisionmakers today. The objectives of the U.S. Global Change Research Program (GCRP) involve focused process studies, long-term observation, and conceptual and predictive models, all of which must be facilitated by an integrated data and information system. These objectives have helped define ESAD plans for the 1990s, and the resulting missions will contribute to their fulfillment.

This volume describes three sets of ESAD activities--ongoing exploitation of operational satellite data, research missions with upcoming launches between now and the first launch of EOS, and candidate Earth Probes. When looking at these sets of missions, three distinct types can be identified, differing in scope and focus.

Satellite Missions. Programs such as the Upper Atmosphere Research Satellite (UARS) are large in scope, and involve the development, flight, and use of new satellites with extensive payload instrument sets.

Instrument Missions. Programs such as the Total Ozone Mapping Spectrometer (TOMS) and the Solar Backscatter Ultraviolet/Version-2 (SBUV/2) experiment focus on the continuing use, or development and use, of research instruments. Some of these instruments are flown on the Space Transportation System (STS) and some on satellites from other nations or U.S. agencies, while others will fly on small dedicated Explorer-class spacecraft under the NASA Earth Probes program.

Data Collection/Use Missions. ESAD is engaged in scientific programs that collect and/or use data from instruments on satellites currently flown or to be launched by other nations and by other agencies of the U.S. Government. For example, the International Satellite Cloud Climatology Project (ISCCP) uses data from the international suite of geostationary meteorological satellites and the National Oceanic and Atmospheric Administration (NOAA) polar orbiters.

The gradual shift from discipline-oriented to interdisciplinary programs for study of the Earth system is an important part of preparing for the full-scale operations of the EOS program, which will begin in FY 98. EOS, a program to continuously measure a large set of key Earth science parameters for a 15-year period, will be the most comprehensive Earth science undertaking ever attempted. Though borrowing heavily from programs and platforms sponsored by our foreign partners, the missions/instruments as described herein are viewed from the U.S. programmatic perspective, with only cursory treatment given to international efforts. All the missions described in this book will provide valuable experience and preliminary measurements of phenomena that will be studied in greater detail in the EOS program. Many of the instruments are the evolutionary precursors of more advanced and capable instruments that will fly on the EOS platforms. Figure 1 shows the relationship of EOS to the missions that precede it.

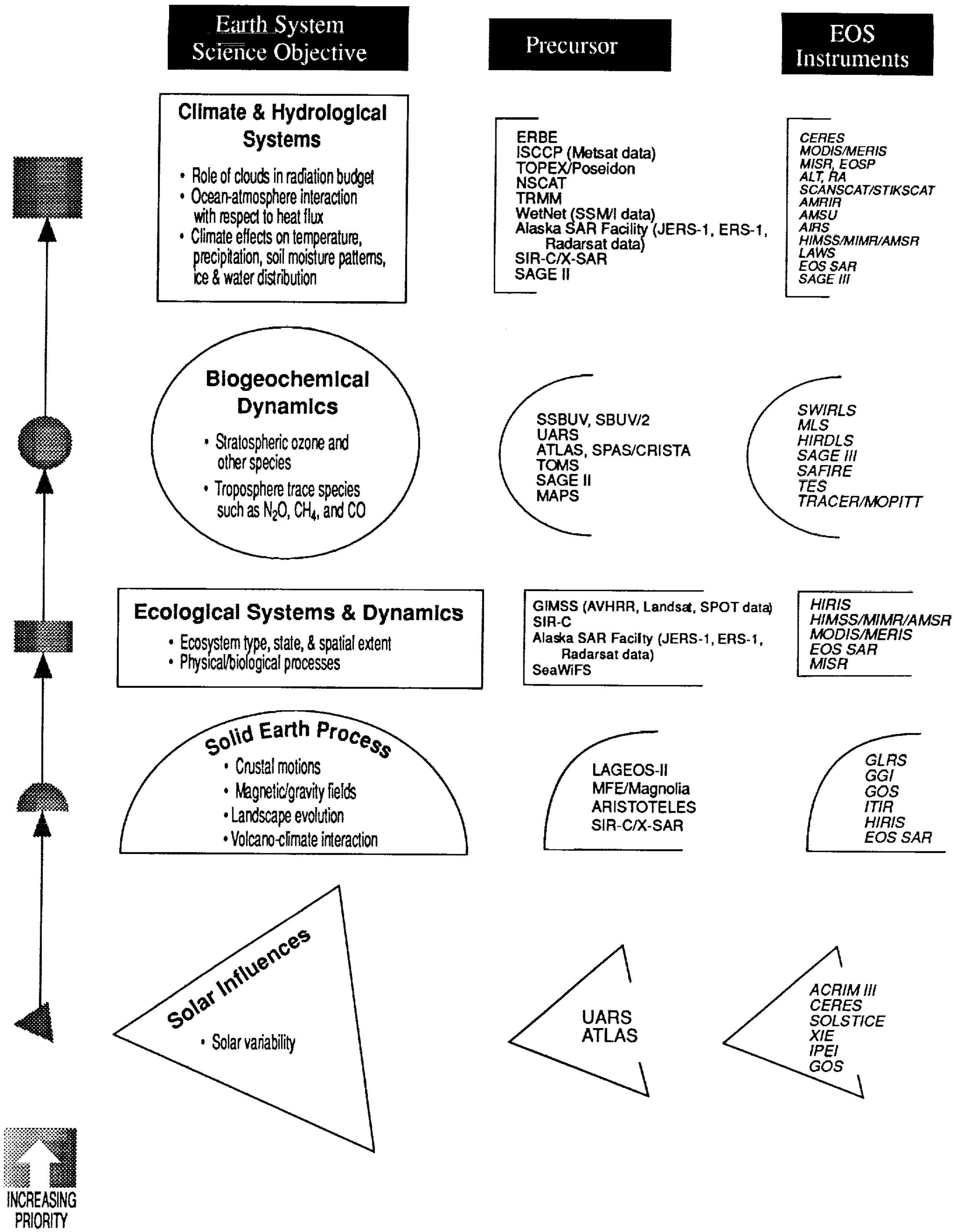

Figure 1. Earth Observing System Evolution

USE OF ONGOING OPERATIONAL MISSIONS

Global Inventory and Monitoring and Modeling Study (GIMMS)

Mission Goal and Objectives

In 1984, NASA established the GIMMS to monitor regional, continental, and global changes in terrestrial vegetation, and to relate those changes to the natural functioning of ecosystems, to the influences of climatic variations, and to anthropogenic forcings. The study relies on data streams from existing operational satellites, emphasizing low spatial resolution (1 to 4 km) and high temporal resolution (daily data) in order to observe phenological changes throughout a growing season and the response to external forcings.

Role in Global Change

Terrestrial vegetation serves as an integrator of the complex inputs of the climatic system as modified by mankind's actions. A multiyear baseline of observations is required to adequately assess the natural variability of the system, but some trends can be established even as the baseline data are acquired.

Measurements to be Made and Resulting Data Products

The primary data product from GIMMS is a time series of continental and global maps of the vegetation index. The vegetation index, which is determined from the reflectance of the land surface in the visible- and near-infrared, has been shown to be a robust measure of the capability of vegetation to intercept photosynthetically active radiation (PAR). These maps can be produced for intervals as short as 10 days, but problems such as cloudiness make 30-day intervals more practical for many applications.

Payload Elements/ Instrument Characteristics

Table 1 briefly summarizes the principal sources of satellite data and the characteristics of pertinent sensors. See the acronym list for a definition of terms.

Data System Design, Archiving, and Data Distribution Plans

Data have been acquired since the 1979 launch of NOAA-6, and continue through the present. NOAA has produced a global vegetation index product with an effective resolution of about 25 km and a weekly compositing period. Regional coverage is available for selected areas at full 1-km resolution. The continental vegetation index data for 10- to 30-day intervals will be available on optical disks to qualified investigators beginning in 1991.

Science Team Selection/Composition

The project activity is led by Dr. C.J. Tucker of NASA/Goddard Space Flight Center.

Table 1. Principal Sources of Digital Data for Vegetation Dynamics

Satellite/ Sensor	Spectral Range	# of Bands	Pixel Size	Repeat Cycle	Coverage
Landsat 1-5/MSS	VIR-NIR	4	80 m	18 days	1972-
Landsat 4-5/TM	VIR-NIR-TIR	7	30 m	16 days	1984-
SPOT/HRV	VIR-NIR	3	20 m	~3 days	1986-
NOAA/AVHRR	VIR-NIR-TIR	5	1,000 m	1 day	1979-

Measurement of Air Pollution from Satellites (MAPS)

Mission Goal and Objectives

In 1976, NASA initiated the MAPS experiment in order to expand understanding of the role of carbon monoxide (CO) in global tropospheric chemistry. Because CO has a short life span (i.e., 1-3 months) and is subject to significant variations in concentration across different areas of the troposphere, conventional ground-based techniques cannot adequately measure its global distribution or quantify its sources. Space-based measurements with MAPS onboard the Shuttle have yielded invaluable information about the global distribution of CO. Data collected from the 1981 and 1984 Shuttle flights demonstrated the strong variability of CO distribution longitudinally, delineated large sources in the Southern Hemisphere, and highlighted a significant positive correlation between low-latitude CO measurements obtained by MAPS with the distribution of tropospheric ozone detected by the Total Ozone Mapping Spectrometer (TOMS).

Technologically, the experiment has demonstrated:

- The feasibility of measuring trace gases in the troposphere from a space platform
- New techniques that greatly lower the cost of reducing data
- Measurements of the vertical structure of CO distribution
- Automated methods of removing cloud-contaminated information from the data set, based on N_2O measurements.

The MAPS instrument (see Figure 2) is a precursor to three experiments--Measurements of Pollution in the Troposphere (MOPITT), Tropospheric Emission Spectrometer (TES), and Tropospheric Radiometer for Atmospheric Chemistry and Environmental Research (TRACER)--selected for definition phase studies for the Earth Observing System (EOS).

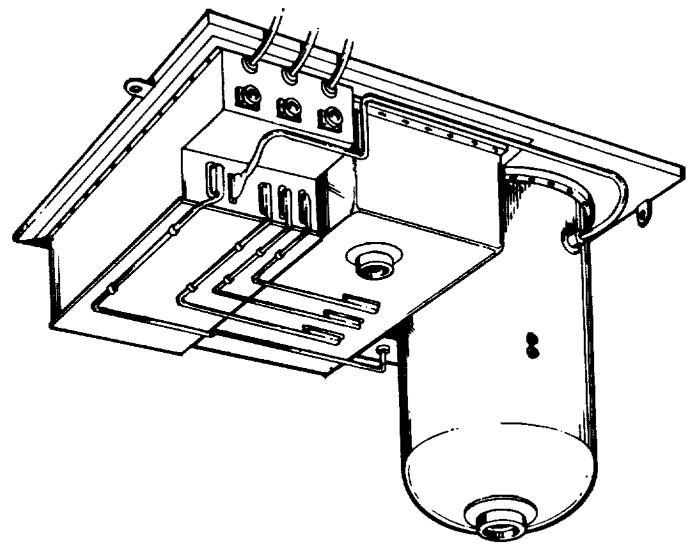

Figure 2. The MAPS Instrument

Role in Global Change

Today, technological and agricultural activities are generating CO in large and growing quantities. This colorless, odorless gas is produced to some degree whenever most fuels are burned, but is produced abundantly by automobile engines and as a result of the burning of forests and grasslands.
Once in the atmosphere, the gas is transported over long distances and is ultimately oxidized to carbon dioxide (CO_2) by the hydroxyl (OH) radical, found "loose" in the atmosphere. The OH radical is the key element in the breakdown and removal of greenhouse gases such as methane, which is also important in the chemistry of stratospheric ozone. However, carbon monoxide is by far the largest consumer of the OH radical. As such, it appears that as CO emissions increase

and CO is oxidized by OH, the amount of OH available to oxidize other gases in the atmosphere will decrease. If concentrations of OH are reduced, the breakdown and removal of greenhouse gases will also be reduced. Reduction of tropospheric OH would thus have a long-term influence on stratospheric ozone, the destruction of greenhouse gases, and potentially on climate.

Measurements to be Made and Resulting Data Products

The archived data consist of instrument calibration constants, raw electrical signals, radiometric signals, and inferred CO mixing ratios as a function of latitude, longitude, and time.

Payload Elements/ Instrument Characteristics

The MAPS experiment takes advantage of the fact that each trace gas species, including CO, has unique infrared (IR) absorption characteristics. The properties of the gas give rise to an absorption spectrum that serves as a "fingerprint," allowing researchers to detect and to quantify a particular gas. Using gas filter radiometry, MAPS measures a telltale IR band in the heat emitted to space by the Earth and its atmosphere. Since measurements are derived from the heat emitted by the planet, MAPS can acquire data both during the day and at night. If CO is present, certain wavelengths characteristic of CO are absorbed in the atmosphere. The MAPS instrument is able to detect the CO- and N_2O-induced reduction of radiation at these specific wavelengths by viewing the Earth simultaneously through three cells, one cell filled with CO, one filled with N_2O, and one filled with helium which does not absorb at these wavelengths. The difference in the energy received as seen through the cell pairs enables a researcher to derive the amount of CO and N_2O in the atmosphere (see Figure 3); since the amount of N_2O in the atmosphere is well known, the N_2O readings allow the cloud-contaminated CO data to be rejected. Table 2 provides some basic facts about the MAPS mission.

Table 2. MAPS Basic Facts

Launch Dates	November 1981 and October 1984, with three additional flights onboard the Shuttle in the 1993 to 1996 time frame
Orbit	28 to 57° inclination, 225- to 350-km altitude
Duration	Nominal 8 days, yet limited by Shuttle capability
Mass	84 kg
Data Rate	50 bps (internal recorder plus Shuttle telemetry)
Gases Measured	CO and N_2O
Data Product	CO mixing ratio vs. latitude, longitude, and time

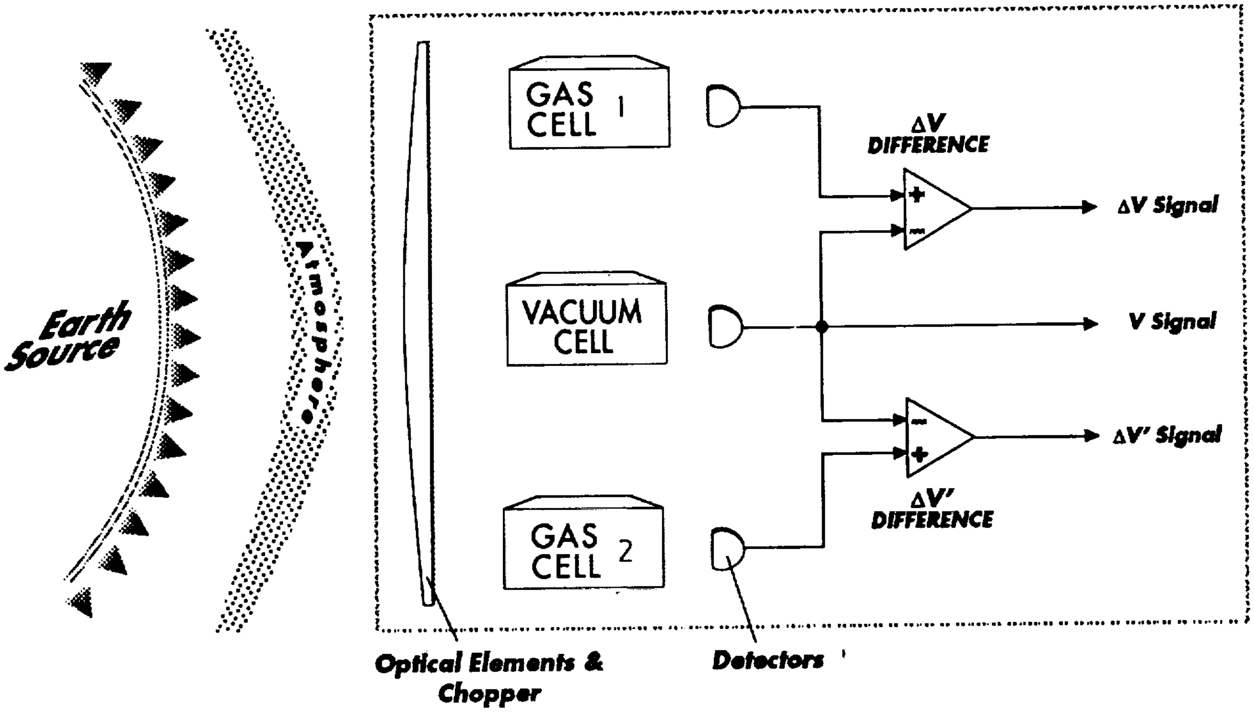

Figure 3. MAPS Cell Schematic

Data System Design, Archiving, and Data Distribution Plans

All of the data listed above are archived in the National Space Science Data Center (NSSDC) at Goddard Space Flight Center (GSFC).

Mission Status

MAPS has flown on two Shuttle flights, STS-2 in November 1981 and STS-41G in October 1984. In 1981, MAPS measured CO in two layers, one in the middle of the troposphere and one in the upper troposphere. For the second flight, the experiment was adapted to measure CO only in a single layer at the middle of the troposphere. Current plans involve additional flights on the Shuttle to corroborate initial findings, with three planned over the 1993-96 time frame. Future Shuttle flights will allow the seasonal variations in distribution to be measured and the variation in source strength to be explored. These flights will also be used to test a refined form of the instrument and to further develop data reduction techniques.

International Cooperation/Participation

Dr. Wolfgang Seiler of the Fraunhofer Institute of Atmospheric Environmental Research (FRG) assists in the dissemination of MAPS-derived data.

Science Team Selection and Composition

Table 3 provides a listing of the MAPS science team, which has remained virtually intact since project inception.

Table 3. MAPS Science Team

Investigator	Institution
H. Reichle, Jr. (Chair)	NASA/LaRC
S. Beck	NASA/LaRC
W. Chameides	Georgia Institute of Technology
W. Hesketh	SpaceTec Ventures, Inc.
R. Lamontagne	Naval Research Laboratory
C. Ludwig	Photon Research, Inc.
R. Newell	Massachusetts Institute of Technology
L. Peters	University of Kentucky
W. Seiler	Fraunhofer Institute of Atmospheric Environmental Research, FRG
H.A. Wallio	NASA/LeRC

International Satellite Cloud Climatology Project (ISCCP)

Mission Goal and Objectives

The ISCCP was established as part of the World Climate Research Program (WCRP) to:

- Produce a global, reduced-resolution, calibrated radiance data set (together with other basic information on the radiative properties of the atmosphere and surface) from which cloud properties can be derived

- Coordinate basic research on cloud analysis techniques

- Derive and validate a global cloud climatology

- Promote research using ISCCP data sets to improve climate model cloud parameterizations

- Improve understanding of Earth's radiation budget and hydrologic cycle.

Role in Global Change

Clouds play a dynamic role in determining climate and seasonal variation. They are directly involved in water exchange in the atmosphere and have first-order effects on the radiation budget of the Earth; reciprocally, since these energy exchanges control the nature and distribution of clouds, cloud composition creates a crucial set of feedback processes that determine the sensitivity of the climate to change. The effects of climatic change on the biosphere are mediated by several cloud-controlled processes, such as surface insolation and precipitation. At present, the uncertainty surrounding such cloud effects proves a hindrance in modeling the future state of the environment.

Data Products and Data Sources

The basic data are "visible" (0.6 micron) and "window" (11 micron) infrared radiances from geostationary platforms, together with atmospheric temperature and humidity profiles, ozone abundances, snow and sea ice cover, and surface temperatures from weather stations and ships. The data products are listed in Table 4. Radiance data are collected from the complete international suite of operational weather satellite imaging radiometers, including the Advanced Very High-Resolution Radiometer (AVHRR) on the NOAA polar orbiters and varieties of the Visible Infrared Spin-Scan Radiometer (VISSR) flown on the geostationary satellites of the Geostationary Operational Environmental Satellite (GOES), Meteorology Satellite (METEOSAT), and Geostationary Meteorological Satellite (GMS) series. In addition, products from the operational temperature/humidity sounders are used in the analysis. When microwave radiometer data are available, their measurements of sea ice cover are included.

Data System Design, Archiving, and Data Distribution Plans

Up to nine institutions comprise the data system: 1) one Sector Processing Center (SPC) for each satellite responsible for collecting, quality-checking, and reducing the resolution of radiance data; 2) a Satellite Calibration Center (SCC) responsible for normalizing the calibrations of all radiometers on the geostationary satellites to that on the polar orbiter; 3) a Global Processing Center (GPC) responsible for calibrating the polar orbiter radiometer, collecting and analyzing all radiance data, and producing the basic data products; and 4) an International Central Archive (ICA) responsible for holding and distributing all ISCCP data products. An additional institution supplies the ancillary atmospheric and surface data sets. Representatives from these institutions form the ISCCP Working Group on Data Management, which establishes all data formats and data exchange procedures. Data access is unrestricted.

Table 4. ISCCP Data Products

Data Set	Product
Infrared Radiances	Reduced-resolution (3-hour and 30-km) calibrated, normalized, and navigated coverage
Cloud Parameters	3-hour global (gridded) coverage of atmospheric/surface properties, as well as original radiances, including average cloud amount, cloud optical thickness, cloud-top temperature and pressure, surface reflectance and temperature, atmospheric temperature, atmospheric humidity, and ozone abundance
Cloud Properties	Amount, uncertainty, and quality information; distribution; and average clear and cloudy radiances, together with viewing and illumination geometry
Cloud Monthly Mean	Average and diurnal variations of cloud properties, amounts and mean properties of 10 cloud types, and surface and atmospheric properties

Mission Status

ISCCP operational data collection and processing has been underway since July 1983, following a Data System Test conducted from April to May 1983. All processing centers are operational, except an SPC for data. Currently, 4 years of radiance data and 2 years of cloud climatology are completed; an additional 2 years of radiance data and 2.5 years of cloud climatology will be completed by the end of 1990.

International Cooperation/Participation

The satellites contributing data to ISCCP are operated by NOAA, the European Meteorological Satellite Agency, and the Japan Meteorological Agency. Data processing is performed by these agencies, together with the French Weather Service (at Lannion, France), the Atmospheric Environment Service (Canada), Colorado State University, and the NASA/Goddard Institute for Space Studies. The University of Wisconsin and the University of Cologne (FRG) have also participated.

Science Team Selection and Composition

Since the ISCCP does not have a formal science investigator team, science participation has been organized through two formal and several ad hoc committees. Science advice to the project is provided by the International Radiation Commission of the International Council of Scientific Unions (ICSU) and by the Working Group on Radiative Fluxes under the Joint Scientific Committee (WMO and ICSU). Ad hoc committees have been formed to:

- Design the data management system
- Compare cloud algorithms and select a design for use in ISCCP
- Examine in detail the performance of cloud algorithms in polar regions
- Design and evaluate radiance and cloud product data formats
- Assess the usefulness of preliminary cloud product parameters in climate and other atmospheric research.

Solar Backscatter Ultraviolet/Version-2 (SBUV/2)

Mission Goal and Objectives

SBUV/2 provides global-scale maps of total ozone and ozone vertical distribution in the stratosphere. The SBUV/2 instrument is a follow-on to the SBUV flown on Nimbus-7. A series of SBUV/2 instruments will be flown on NOAA polar orbiting satellites through the late 1990s. The specific goal of these flights is to determine long-term changes in mean ozone through detailed global analysis of seasonal and interannual changes. NASA's specific role in this program is to develop and provide the instrument, and to perform the pre- and post-launch instrument characterization and data validation.

Role in Global Change

The depletion of ozone has become a major environmental concern, because changes in ozone column amount will modify the amount of ultraviolet radiation reaching the Earth's surface. The SBUV/2 program has been implemented in response to Public Law 95-95, the Clean Air Act of 1977, which calls for stratospheric monitoring by NOAA and continuing research and data validation by NASA. These responsibilities are further defined in the National Plan for Stratospheric Monitoring and Early Detection of Change, 1987-1997.

Measurements to be Made and Resulting Data Products

The series of SBUV/2 instruments will measure the solar spectral irradiance in the wavelength region 160 to 400 nm and the ultraviolet Earth albedo in the region 250 to 340 nm. This latter measurement is used to derive the column amount and vertical distribution of ozone between 25 and 55 km. The observations will be carefully examined to ensure that all instrument drifts are accounted for and removed. After ozone values are produced, they will be compared to other ground-based and spaceborne measurements to further ensure their reliability. These steps are essential to produce an accurate ozone trend record. Data products will consist of the observations and ozone values on a daily basis, and averages such as monthly zonal means and map analyses.

Payload Elements/ Instrument Characteristics

The SBUV/2 is an ultraviolet spectrometer whose single detector has a dynamic range of 10^6. The field of view is 11.3 degrees, resulting in a scene on the Earth of about 200 km. The instrument scans from 160 to 400 nm for the solar irradiance measurement and from 250 to 340 nm for the albedo measurement. The wavelength resolution is 1.1 nm. The instrument contains an onboard calibration device to check the wavelength registration and the reflectance of the diffuser used for the solar irradiance measurement.

Data System Design, Archiving, and Data Distribution Plans

Data from SBUV/2s flying on the NOAA spacecraft will be processed by the NOAA operational data system. NASA/Goddard Space Flight Center (GSFC) will provide the refined calibration values and post-flight analysis to determine long-term instrument characteristics such that trends can be accurately derived. NASA and NOAA personnel will perform data validation using ground-based and other satellite observations. Ozone data and validation products will be released by NASA and NOAA, with data available through the National Space Science Data Center (NSSDC).

Mission Status

The present SBUV/2 flight schedule is as follows: NOAA-I, 1991; NOAA-K, 1993; and NOAA-M, 1996. Each spacecraft has a lifetime of at least 2 years. Two instruments have already been placed in orbit, one in 1984 on NOAA-9 and one in 1988 on NOAA-11.

International Cooperation/Participation

Operational satellite ozone data are available to the entire scientific community. SBUV/2 data will be correlated with other ozone observations being taken by the U.S. and by foreign governments.

Science Team Selection and Composition

Table 5 lists the SBUV/2 science team that is currently in place. These investigators are conducting research on satellite ozone data and the ultraviolet solar spectral irradiance.

Table 5. SBUV/2 Science Team

Investigator	Institution
E. Hilsenrath (Chair)	NASA/GSFC
W. Planet	NOAA/NESDIS
D. Heath	ST Corporation
A.J. Miller	NOAA/NWS
J. Lenisch	NOAA/NESDIS
R. Hudson	NASA/GSFC
R. Donnelly	NOAA/ERL
R. McPeters	NASA/GSFC
J. Deluisi	NOAA/ERL
R. Cebula	ST Corporation

WetNet

Mission Goal and Objectives

WetNet, a 5-year pilot program examining the role of a remote interactive computer network in an Earth science research environment, will serve as a prototype research and data system for Earth system science studies for the Earth Observing System (EOS) era. The research and data network is designed to enhance scientific analysis and to encourage an interdisciplinary approach to the study of the global hydrologic cycle. The primary data source is the Special Sensor Microwave/Imager (SSM/I). The passive microwave data from the SSM/I is of interest to the atmospheric, oceanographic, cryospheric, and land process communities. This program is intended to promote the involvement of a wide variety of users from different disciplines, with the program team composed of science investigators from NASA, NOAA, the university community, and the private sector. It is hoped that this program fosters a cross-fertilization of ideas, leading to a more interdisciplinary approach to tackle the problems of Earth system science.

Role in Global Change

The SSM/I external calibration strategy, along with multiple copies awaiting launch on the Defense Meteorological Satellite Program (DMSP) series of satellites, will result in a valuable record of global hydrologic data. Started in 1987, the SSM/I will provide 10 years of pre-EOS data to the EOS time series, which will start with the launch of the first NASA polar platform in FY 98. WetNet will yield an excellent framework from which to build a spaceborne hydrologic measurement element for the EOS Data and Information System (EOSDIS).

Measurements to be Made and Resulting Data Products

The SSM/I measurements are being used to retrieve global fields of precipitation, snow cover, oceanic wind speed, water vapor, and cloud water. WetNet will ensure the timely production of these fields, and foster an environment where these algorithms can be tested and new algorithms (e.g., vegetation mapping) developed.

Payload Elements/ Instrument Characteristics

The SSM/I images thermal microwave radiation emitted at frequencies of 19.35, 22.235, 37, and 85.5 GHz. The Department of Defense (DoD) developed the instrument primarily to provide typhoon-monitoring capabilities. Conical scanning allows dual polarization measurements to be made at a constant Earth surface incidence angle of 53 degrees. The total power radiometers employ an offset fed parabolic reflector of 60-cm diameter to measure at spatial resolutions varying from 16 km at 85.5 GHz to 70 km at 19.35 GHz (see Table 6).

Table 6. WetNet Satellite and Instrument Characteristics

Launch Schedule	SSM/I #1 - June 1987 #2 - March 1990 later - on demand
Orbit Characteristics	sun-synchronous, near-polar orbit 830- to 850-km altitude 98.84-degree inclination local crossing time (#): 0611
Satellite	DMSP Block 50 series F8 and follow-on
SSM/I Instrument	Mass: 57 kg total Power: 45 W avg Spin Rate: 31.15 rpm Data Rate: 3.3 kbps
Spatial Resolutions	16 km @ 85.5 GHz 38 km @ 37.0 GHz 60 km @ 22.235 GHz 70 km @ 19.35 GHz

Data System Design, Archiving, and Data Distribution Plans

The WetNet data analysis and archive system is based primarily on the Man-Computer Interactive Data Access System (McIDAS) developed at the Space Science and Engineering Center at the University of Wisconsin-Madison. McIDAS is an image analysis and data base software package with an emphasis on simultaneous visualization of multi-source data. The McIDAS software package has been written for host IBM mainframe computers as well as IBM personal computers (PC-McIDAS). WetNet will use both the host and PC versions of McIDAS. The hub of the WetNet system will be at NASA/Marshall Space Flight Center (MSFC) Earth Science and Applications Division. The MSFC mainframe McIDAS will receive SSM/I and auxiliary Geostationary Operational Environmental Satellite (GOES), METEOSAT, and Advanced Very-High Resolution Radiometer (AVHRR) satellite imagery; selected U.S. surface radar products; and conventional surface and upper air observations.

Browse and derived data products will be generated from the SSM/I data base and stored online for 2 weeks. After 2 weeks, the entire data base will be written to a 650 Mbyte magneto-optical disk for archival and subsequent distribution by mail to the WetNet scientists. The magneto-optical disk will contain a catalogue of data stored on the disk, as well as information about the data stored on all previous magneto-optical disks. In addition to the full-resolution data on magneto-optical disk, WetNet browse products will be generated and broadcast on a daily basis to the scientists' PC-McIDAS workstations via high-speed modems. The workstations are composed of IBM PS/2 Model 70 computers with a monitor, modem, and a 650 Mbyte Sony magneto-optical disk. In this manner, the WetNet scientist will receive both a daily overview of the WetNet data base through the high-speed modems and the complete data set via magneto-optical disk distribution. Figure 4 offers a schematic of the WetNet interactive data acquisition process.

Mission Status

WetNet is scheduled to enter the operational phase in the spring of 1990. WetNet users will be introduced into the program in three separate groups over a 9-month period. The first group of scientists will receive WetNet workstations in January 1990, with the first month spent gaining familiarity with the basic system setup. In February, a training seminar will teach the users the "ins and outs" of the workstation capabilities. This includes instructions on the use of the magneto-optical disk drive as well as the WetNet software. Approximately 1 month later, WetNet will begin its operational phase. The remote users will be brought online and will begin receiving a nightly broadcast of the WetNet browse data set. In April, the next set of scientists will be equipped with the workstation hardware. The above-described training seminar and operational phase-in will be repeated. Finally, in July 1990, the last group of scientists will begin the identical 3-month phase-in. A total of 28 scientists are scheduled to be online by September 1990. The graduated three-step addition of scientists to the network will permit many of the "bugs" of a new system to be worked out with minimum impact to the end user.

International Cooperation/Participation

Dr. Eric Barrett of Bristol, UK, will evaluate algorithms used to assess rainfall over the British Isles region of the North Atlantic Ocean. Later foreign involvement will await a 1-year testing of the WetNet system.

Science Team Selection and Composition

The WetNet science team is composed of scientists from Federal agencies, universities, and the private sector (see Table 7). The scientists have grouped themselves into land, ocean, and atmosphere teams based upon

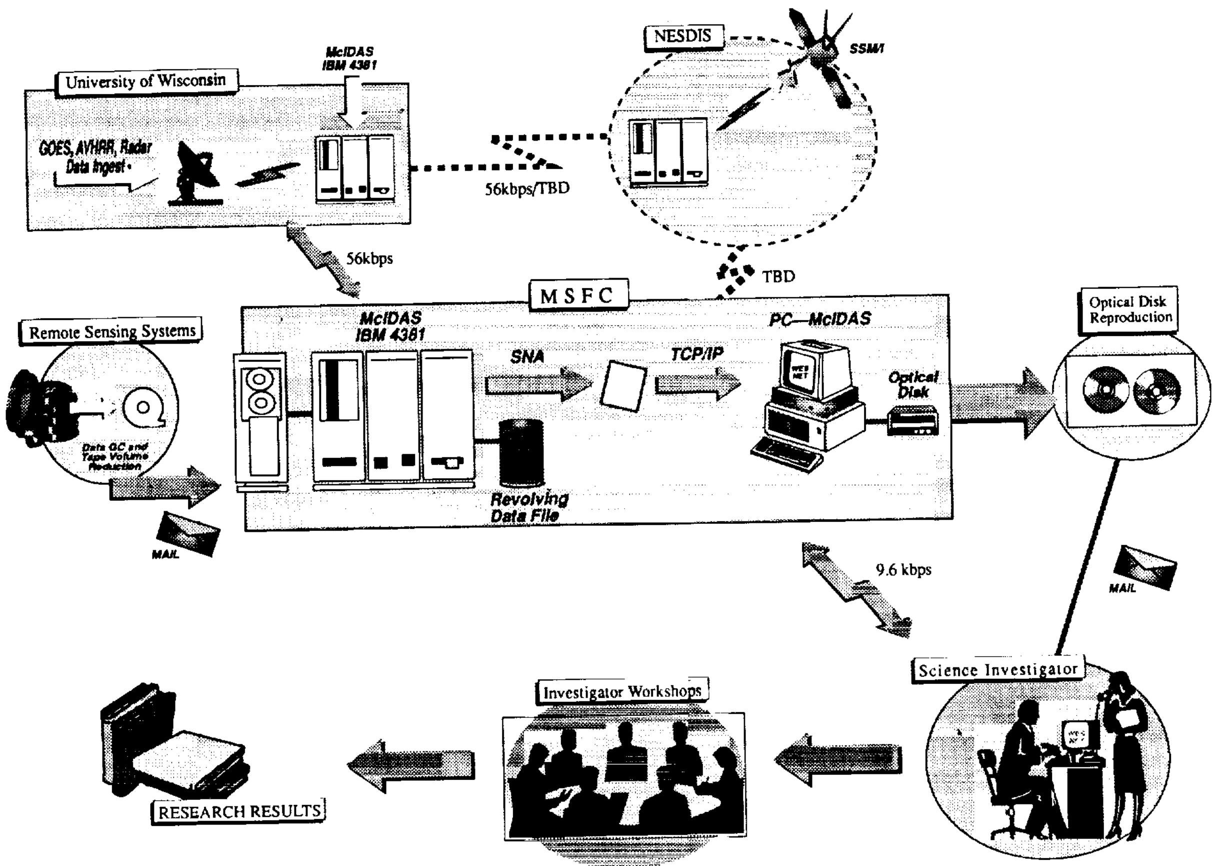

Figure 4. WetNet Interactive Data Acquisition

their principal research interests, which include the following:

- Global precipitation algorithms using VIS, IR, and SSM/I
- Passive microwave precipitation algorithms
- Interannual variation of atmospheric moisture and related dynamics
- Ocean water vapor and evaporation retrievals
- Over-ocean wind speed, water vapor, and liquid water algorithms
- Vegetation, snow cover, and soil moisture characteristics
- Sea ice type and concentration
- Effects of SSM/I precipitation estimates on a simple model of the global hydrologic cycle.

Membership in one team does not preclude working with members of the other teams; in fact, it is encouraged. The role of the science team members is two-fold: 1) to develop new and improved algorithms related to Earth system science, and 2) to act as WetNet system evaluators. This not only means critiquing the functionality of the workstation equipment and data distribution methods, but also requires them to cross the traditional boundaries of a single discipline and interact with the other discipline scientists.

Table 7. WetNet Science Team

Investigator	Institution
	Atmosphere Group
R. Adler	NASA/GSFC
P. Arkin	NOAA/Climate Analysis Center
E. Barrett	University of Bristol, UK
G. Felde	Air Force Geophysical Laboratory
S. Goodman	NASA/MSFC
W. Olson	University of Wisconsin-Madison
P. Robertson	NASA/MSFC
R. Scofield	NOAA/NESDIS
E. Smith	Florida State University
R. Spencer	NASA/MSFC
S. Tilford	NASA/Headquarters
E. Zipser	Texas A&M University
	Oceans and Sea Ice Group
R. Armstrong	National Snow Ice Data Center
F. Bretherton	University of Wisconsin-Madison
R. Brown	University of Washington
D. Cavalieri	NASA/GSFC
R. Chase	University of Colorado, Boulder
R. Crane	Pennsylvania State University
W. Emery	University of Colorado, Boulder
C. Gautier	Scripps Institute of Oceanography
T. Liu	Jet Propulsion Laboratory
F. Wentz	Remote Sensing Systems
	Land Processes Group
A. Chang	NASA/GSFC
B. Choudhury	NASA/GSFC
B. Rock	University of New Hampshire
R. Savage	Hughes Aircraft Company
J. Star	University of California, Santa Barbara

Early EOS Data and Information System (EOSDIS)

Mission Goal and Objectives

The Early EOSDIS program will make an evolutionary transition from the Earth science-related data and information system capabilities of today to those planned for the EOS era, substantially improving scientific productivity during this transition period (i.e., 1990 to launch of EOS-A). The program's near-term goal involves a combination of data set (EOS Pathfinder) and data system (EOSDIS Version 0) activities. As a subset of the envisioned EOSDIS components, the early EOSDIS will consist of an initial Information Management Service (IMS) prototype, Distributed Active Archive Centers (DAACs), initial Scientific Computing Facilities (SCFs), and networks. This evolving system will provide a progressively improving array of data sets and services to Earth science researchers around the world.

Specific objectives of the Early EOSDIS program are to:

- Enhance near-term scientific productivity through improved access to current data and the production/use of new data sets derived from currently available data
- Integrate and evolve current capabilities [e.g., Pilot Land Data System (PLDS), NASA Climate Data System (NCDS), NASA Ocean Data System (NODS)] to establish a working, integrated Earth science data system (EOSDIS Version 0) as a first step towards full implementation of EOSDIS
- Take near-term actions to improve the infrastructure for collaborative, distributed research, including implementation of a Global Change Master Directory and interoperable catalog system; adopting initial standards, protocols, and guidelines; and expanding the exchange of data and the connectedness of the Earth science community
- Build an enhanced experience base that will directly influence the progressive implementation of EOSDIS by the Phase C/D Contractor.

Role in Global Change

The Early EOSDIS program directly supports the Global Change Research Program (GCRP) by generating new and enhanced Earth science data sets and derived products, improving descriptive information about global change data, and improving access for investigators to the descriptive information, data sets, and derived products. The Global Change Master Directory, operated by NASA on behalf of the Interagency Working Group on Data Management for Global Change (IWGDMGC), will describe the Earth science/global change data holdings of NASA, NOAA, U.S. Geological Survey (USGS), and other U.S. and international agencies, and provide users with information on how to access these data.

Pathfinder global change-related data sets play a major role in defining the parameters of the early EOSDIS. Pathfinder efforts include transferring level 1 data to readily accessible working storage and/or safe archive media. In collaboration with NOAA, global level 1 Advanced Very High-Resolution Radiometer (AVHRR) data will be imported to optical disk, and data sets of at least sea surface temperature and vegetation index products will be derived. Science working groups composed of both Government and private sector scientists will guide the level 1 data handling, selecting "community-consensus" algorithms with which to generate new products. Other data sets identified as candidates for pathfinder efforts include the Geostationary Operational Environmental Satellite (GOES), TIROS Operational Vertical Sounder (TOVS), and Special Sensor Microwave/Imager (SSM/I). Pathfinder data sets and products will be made available to the science community through the EOSDIS Version 0 system described below.

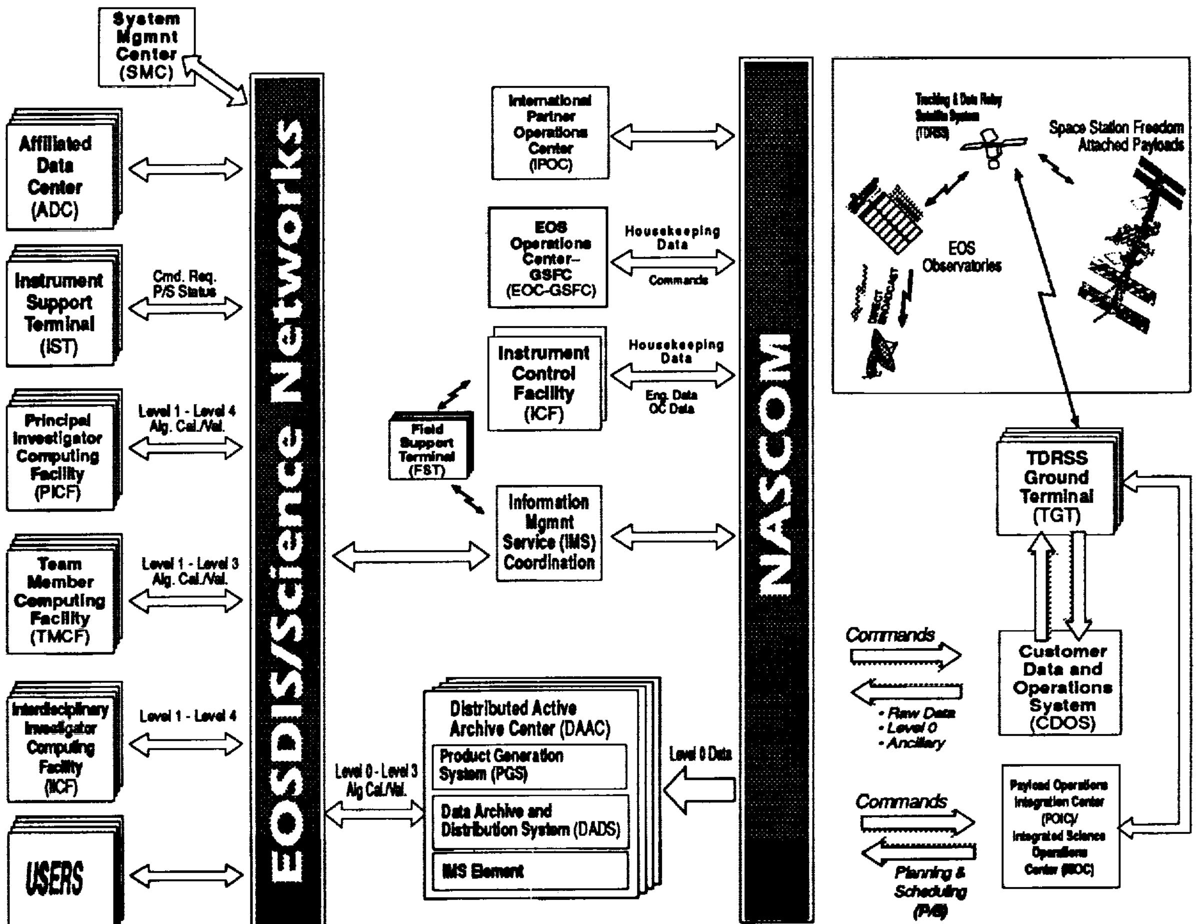

Figure 5. EOSDIS Architecture

Data Products and Data Sources

The integration and evolution of current capabilities now taking place in the Early EOSDIS program will yield a fully functional EOSDIS by the launch of EOS-A in 1998. Refer to Figure 5 for a schematic of the final EOSDIS configuration. Prototypes will garner the necessary experience to guarantee successful implementation of EOSDIS, without which EOS mission objectives could not be met. In addition to the pathfinder data sets mentioned above, currently available and near-term data sets resident at NCDS, NODS, and PLDS will be included in EOSDIS.

- NCDS, resident at the National Space Science Data Center (NSSDC) Computer Facility (NCF), is an interactive system containing climate research data. Data sets currently available include parameters relevant to clouds and radiation, global climatology and oceanography, and atmospheric composition.

- NODS is a distributed system with nodes at institutions where high-level satellite ocean data sets are prepared, archived, and made available to researchers. Each node represents a selective data-sharing facility. For example, the NODS node at the Jet Propulsion Laboratory (JPL) is devoted to satellite ocean measurements related to altimetry, scatterometry, and microwave radiometry (excluding frozen ocean applications). The JPL/NODS data archive contains time series of key oceanographic variables with global coverage, such as sea surface height, surface wind parameters, atmospheric water parameters, sea surface temperature, and surface layer phytoplankton abundances.

- PLDS is currently being developed to satisfy the information management requirements of the NASA land science research community. The Phase I system will contain data sets derived from such instruments as AVHRR, Thematic Mapper (TM), Systeme pour l'Observation de la Terre (SPOT), and Visible Infrared Spin-Scan Radiometer (VISSR), as well as parameters such as digital elevation models, global vegetation index, and snow.

Near-term data sets to be available in the period before EOS-A launch include those from recent and upcoming programs, including virtually all of the missions described in this handbook.

Data System Design, Archiving, and Data Distribution Plans

The EOSDIS will facilitate global change research by offering "one-stop shopping" access to NASA's entire Earth science data base. The EOSDIS IMS and a family of seven primary DAACs will serve as the focal points for this function. These DAACs will generate standard products using algorithms developed by EOS-funded investigators. In addition, they will provide a full suite of data and product archiving and distribution services. The primary centers are located at Goddard Space Flight Center (GSFC), JPL, Langley Research Center (LaRC), Marshall Space Flight Center (MSFC), National Snow and Ice Data Center (NSIDC), EROS Data Center (EDC), and Alaska SAR Facility (ASF). A set of Affiliated Data Centers (ADCs) will complement the primary centers by providing access to non-EOS data or by performing functions outside the scope of the EOS program.

For the Version 0 EOSDIS, each primary DAAC will generate select data products from existing or near-term data, and will perform data archive and distribution functions. DAACs located at NASA facilities and JPL will build upon existing data archive and distribution capabilities; at non-NASA primary DAACs, the Version 0 EOSDIS capability will augment or interoperate with existing data systems.

EOSDIS Version 0 will also include a distributed Information Management Service (IMS), with a central directory node at GSFC and elements at each DAAC. The IMS will provide metadata services to EOSDIS Version 0 users, providing access to directory, catalog, and inventory information that describes existing data and products, and a means of requesting such from the DAACs. Between the IMS and the DAACs, experimental data browse capabilities will be made available to users for evaluation. The IMS and DAACs will be interconnected by a communications network. In turn, they will be readily accessible to the SCFs and other global change research elements via a suite of existing and new networks (e.g., SPAN).

Data processing, archiving, and distribution will be improved over present capabilities, culminating in 1994 when full EOSDIS functionality will be available for existing data and products.

Mission Status

Program- and project-level plans for the early EOSDIS effort will be completed and distributed by September 1990, with implementation commencing in October. These plans will be living documents, and will be regularly updated to reflect progress, lessons learned, and feedback from users of Earth science data services.

An initial pathfinder agreement between NASA and NOAA will be completed, with the possibility of additional agreements involving other U.S. agencies such as USGS.

International Cooperation/Participation

The International Committee on Earth Observations Satellites (CEOS) through its Working Group on Data (WGD) provides the primary forum for international cooperation and participation in the early EOSDIS effort. CEOS members have been invited to observe, comment on, and participate in early EOSDIS start-up as appropriate. Foreign entities involved in the overall EOS program through CEOS include Japan, Canada, the European Space Agency (ESA), Germany, France, Italy, India, and the United Kingdom.

International collaboration is also sought through other global change planning activities, such as the International Geosphere-Biosphere Program (IGBP), International Space Year (ISY), and the International Council of Scientific Unions (ICSU), among others.

Science Team Selection and Composition

The primary source for overall science guidance is the EOSDIS Science Advisory Panel (also known as the "Data Panel"), drawn from the EOS Investigator Working Group (IWG) with a few additional representatives. Each DAAC will have a science advisory group that will work with the DAAC host institution, the Data Panel, the EOSDIS Project, and with its counterparts at the other DAACs. Table 8 lists the members of the Data Panel.

Table 8. EOSDIS Science Advisory Panel Members

Investigator	Institution
J. Dozier (Chair)	University of California, Santa Barbara
J. Barker	NASA/GSFC
B.R. Barkstrom	NASA/LaRC
R.G. Barry	University of Colorado
F.P. Bretherton	University of Wisconsin
J. Curlander	Jet Propulsion Laboratory
W. Emery	University of Colorado
G.D. Emmitt	Simpson Weather Associates, Inc.
R.H. Evans	University of Miami
T. Fisher	Canada Centre for Remote Sensing
D. Glover	Woods Hole Oceanographic Institution
D. Halpern	Jet Propulsion Laboratory
J.F. Kibler	NASA/LaRC
P.A. Newman	NASA/GSFC
B. Schutz	University of Texas
R. Welch	Naval Environmental Prediction Research Facility

UPCOMING MISSIONS

Alaska Synthetic Aperture Radar (SAR) Facility

Mission Goal and Objectives

NASA's Alaska SAR Facility (ASF) program, based at the University of Alaska, Fairbanks, is intended to demonstrate the unique application of spaceborne SAR data to multidisciplinary, large-scale investigations in the Arctic. The program objectives are to create:

- A receiving station for the acquisition of spaceborne SAR data
- Processing systems for the generation of digital SAR images and the extraction of geophysically significant data
- An archiving and distribution system to provide digital and photographic data products to U.S. and foreign science investigators.

Through international agreements, data will be acquired from the European Space Agency's (ESA's) first European Remote Sensing Satellite (ERS-1), the first Earth Resources Satellite (JERS-1), and the Canadian Radarsat satellite.

Role in Global Change

Scientific justification for the ASF was initially outlined by a Science Working Group (SWG) established by NASA in 1982. The SWG published its findings in a report that discusses the utility of SAR data for disciplines such as polar oceanography, geology, glaciology, hydrology, and ecology. The Science Plan for the ASF has been published as JPL Report No. 89-14, 1989. Since the location of the ASF is complementary to other facilities planned by ESA for locations in Canada, Norway, and Sweden, SAR coverage for the entire Arctic is possible.

The ASF has the potential to become a key element in research programs on climate and global change. The high-latitude regions profoundly affect climate variability, and are sensitive indicators of climate change; they play a vital part in the complex interactions and feedbacks of the Earth system. SAR data will be used to monitor and interpret high-latitude, climate-related parameters, including sea ice, snow cover, glaciers, permafrost, and vegetation. Numerical models have shown the sensitivity of sea ice to climate change, and a strong sea ice feedback that further amplifies climate change. Glaciers also play an important part in global change since variations in their mass balance affect sea level. The fourth largest glaciated area in the world is within the ASF station mask.

Instrument Characteristics

The operational parameters of the three SAR satellites are listed in Table 9.

Table 9. SAR Operational Parameters

	ERS-1	JERS-1	Radarsat
Projected Launch Date	1991	1992	1994
Mission Duration (yr)	2	2	5
Orbit Altitude (km)	785	568	798
Orbit Inclination (deg)	97.5	97.7	98.5
Radar Frequency (GHz)	5.3 (C-band)	1.3 (L-band)	5.3 (C-band)
Data Rate (Mbps)	105	60	100
Onboard Storage	None	~12 min	~10 min

The ERS-1 orbit sequence includes two 3-month periods each spring with a 3-day repeat cycle, which will be particularly useful for sea ice studies, followed by 35-day repeat and 176-day repeat mapping cycles. The JERS-1 and Radarsat ground track repeat cycles are 44 days and 24 days, respectively.

Data System Design, Archiving, and Data Distribution Plans

The ASF will acquire, process, archive, and distribute SAR data to science investigators.

Access to the ASF will be accomplished largely through the use of existing computer network connections (i.e., the NASA SPAN and Science Networks). Data products available through the ASF are listed in Table 10, and will include derived products from a geophysical processor system.

Table 10. ASF Data Products

Product Type	Distribution Media	Data Characteristics
Standard Products		
Computer Compatible Signal Data	CCT, DOD	12-second segment
Complex Image Data	CCT, DOD	8m pixel spacing 30 x 50 km area 10m resolution
Full-Resolution Images	CCT, DOD, Film	12.5m pixel spacing 30m resolution 100 x 100 km area
Low-Resolution Images	CCT, DOD, Film	100m pixel spacing 240m resolution 100 x 100 km area
Geocoded Products		
Geocoded Full Resolution	CCT, DOD, Film	12.5m pixel spacing 30m resolution 100 x 100 km area
Geocoded Low Resolution	CCT, DOD, Film	100m pixel spacing 240m resolution 100 x 100 km area
Derived Products		
Ice Motion/Ice Classification Data	CCT, DOD	Ten 100 x 100 km image pairs/day; SSM/I grid information on a 5-km grid
Ocean Wave Products	CCT, DOD	25 ea. 512 x 512 pixel sub-scenes/day from one 100 x 100 km image

Mission Status

The status of ASF's four major components is listed below:

- The Receiving Ground Station (RGS) consists of a 10-meter parabolic antenna, control computer, receivers, and data recorders. This system has been installed and is operational.
- The SAR Processor System (SPS) consists of a custom processor with a throughput rate at 10 percent of the real-time data rate. The SPS will be installed by the Jet Propulsion Laboratory (JPL) in the fall of 1990.
- The Archive and Operations System (AOS) will handle cataloging, mission planning, and data distribution tasks. JPL will install the AOS in the fall of 1990.
- The Geophysical Processor System (GPS) will routinely generate ice motion, ice classification, and ocean wave products. Delivery by JPL will be in the end of 1990.

International Cooperation/Participation

International agreements and arrangements link the ASF to foreign flight agencies and science programs. A Memorandum of Understanding (MOU) between NASA and ESA gives the ASF access to ERS-1 data, an MOU with Japan gives similar access to JERS-1 data, and an MOU with Canada is being negotiated for Radarsat data. The ASF is also involved in international science programs, such as the Programme of International Polar Oceans Research (PIPOR) and the Polar Ice Sheet Program (PISP). With these connections and cooperative programs, and the experience gained over the next few years, the ASF provides an effective springboard to participate in the programs of the Earth Observing System (EOS).

Atmospheric Laboratory for Applications and Science (ATLAS) and Shuttle Pallet Satellite/Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (SPAS/CRISTA)

Mission Goal and Objectives

The ATLAS program is composed of a series of Earth observing Shuttle missions, which are scheduled to fly approximately annually during the 1990s. The instruments selected for the ATLAS payload will provide measurements of solar output and properties of the Earth atmosphere. These include the Atmospheric Trace Molecules Observed by Spectroscopy (ATMOS), Millimeter-Wave Atmospheric Sounder (MAS), and a suite of solar instruments; SPAS/CRISTA, a retrievable satellite from the FRG, will be co-manifested on the ATLAS-3 mission.

Role in Global Change

Unlike most of the other missions described in this document (i.e., continuous measurements over 2- to 5-year periods), ATLAS missions will execute intense, week-long observations on an annual basis for about a decade. While this method lacks the obvious advantage of time continuity, there is a distinct benefit in the ATLAS approach that allows it to play a key role in NASA's Global Change Research Program (GCRP). The ATLAS instruments will be calibrated before and checked immediately after each flight; thus, any questions plaguing longer term satellite studies (i.e., instrument degradation or how changes in calibration should be accounted for in the data analysis) are minimized. ATLAS will provide a set of benchmark measurements against which other measurements can be compared.

Measurements to be Made and Resulting Data Products

The ATMOS instrument measures the absorption of solar radiation by the Earth's atmosphere during solar occultation events (two per orbit). By comparing the spectrum of solar radiation transmitted through the atmosphere at a given height with that transmitted above, including that received well above the atmosphere, concentrations of trace atmospheric species can be inferred.

The MAS instrument also measures the concentration of certain trace species in the atmosphere, but it does so using a very different technique. MAS senses the emission by the Earth's atmosphere of radiation in the microwave region of the spectrum by scanning the atmosphere vertically while viewing to the side of the Shuttle. While the number of species measured is considerably less than ATMOS, MAS operates continuously during the Earth observing segments of the missions, thereby obtaining better spatial coverage. The major data acquired are temperature, pressure, water vapor, ozone, and chlorine monoxide measurements.

The solar instruments make up an ensemble that measures the total energy output of the sun (i.e., the solar constant), as well as spectral information of particular interest to atmospheric scientists.

The West German CRISTA instrument senses properties of the Earth's atmosphere by scanning the limb and recording infrared emission information. Two other non-U.S. instruments on SPAS will measure concentrations of vibrationally excited hydroxyl (OH) in the atmosphere. Table 11 indicates the gases to be measured by selected instruments of the ATLAS series.

Payload Elements/ Instrument Characteristics

The two core ATLAS instruments that employ remote sensing techniques to measure properties of the Earth's atmosphere are ATMOS and MAS. ATMOS uses a fast Fourier transform (FFT) interferometer, which operates in the near- and middle-infrared region of the spectrum. The vertical resolution is about 2 km--the distance that the sun rises through the atmosphere during a single scan of the

Table 11. Atmospheric Constituents Measured by ATLAS

Instrument	Measurement (altitude range in km)
ATMOS Atmospheric Trace Molecules Observed by Spectroscopy	Concentrations of CO (10-130), $ClNO_3$ (10-35), NO (10-140), NO_2 (15-50), H_2O (10-90), HNO_3 (15-40), CH_4 (10-70), N_2O (10-60), O_3 (10-100), F_{12} (10-30), F_{11} (10-25) N_2O_5 (20-40), HCl (10-65), HF (10-60); temperature from 10-120 km
MAS Millimeter-Wave Atmospheric Sounder	Concentrations of ClO (30-45), H_2O (20-90), O_3 (20-90); temperature from 20-100 km
CRISTA Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere	Concentrations of CO (20-40), NO (80-180), NO_2 (20-40), H_2O (20-70), CH_4 (20-70), N_2O (20-45), O_3 (20-80), F_{12} (20-30), F_{11} (20-25), HF (20-70); temperature from 20-120 km

instrument, which takes 1 second. The spectral region of 2.1 to 18 μm is covered at a resolution of 0.01 cm^{-1} through the use of four filters. Because of the high spectral resolution of the instrument, a large data volume is created at a rate of 16 Mbits per second.

The MAS instrument, which is the most massive of the ATLAS instruments, is a joint venture managed by the German Aerospace Research Establishment (DLR) in the Federal Republic of Germany (FRG). The University of Bern (Switzerland) will build the receivers; the Max Planck Institute (FRG) will build the antenna; and the Naval Research Laboratory (U.S.) will build the spectrometer. The 60 GHz channels will measure temperature and pressure by oxygen resonance emission; the 184 GHz channels will measure water vapor and ozone; and the 204 GHz channels will measure chlorine monoxide. The vertical resolution will be about 10 km for temperature and pressure, and 4 km for the higher frequency measurements.

The two solar constant instruments, Solar Constant (SOLCON) and Active Cavity Radiometer (ACR), use different techniques to measure very small changes in solar energy output, therefore providing powerful validation and comparative information. The Jet Propulsion Laboratory (JPL) version uses three ACRs, and SOLCON (Belgium) uses a high-resolution absolute pyrheliometer. The Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) and Solar Spectrum (SOLSPEC) measure the solar spectrum. SUSIM concentrates upon the ultraviolet region (important in Earth atmosphere photochemistry), and SOLSPEC measures from the infrared to ultraviolet. SUSIM is an experiment of the Naval Research Laboratory (NRL), and SOLSPEC is a French experiment.

The SPAS is a West German platform that will be carried into orbit by the Shuttle, deployed to fly separately, and retrieved at the end of the mission. CRISTA is the primary instrument that will operate from the SPAS. Spectral information will be acquired through the use of Ebert-Fastie spectrometers covering the spectral range of 4 to 80 μm. Three telescopes will view at 162, 180, and 198 degrees from the craft's velocity vector. This results in cross-track data points about 700 km apart and along-track horizontal resolution of about 400 km; the vertical resolution will be about 1 km. Two other non-NASA U.S. instruments will also operate from the SPAS carrier. One will measure the concentrations of vibrationally excited OH in the 80- to 95-km altitude region, while the other will measure concentrations of ground state OH at 40- to 90-km altitude.

Data System Design, Archiving, and Data Distribution Plans

The ATLAS data system plan is for the individual instrument teams to manage the data from their respective instruments. Archiving of geophysical data will be provided by the National Space Science Data Center (NSSDC) at Goddard Space Flight Center (GSFC), which will receive the data approximately 1 year after each mission. Interested parties may request earlier access to the data directly from the instrument team.

Mission Status

The instruments that make up the core of the ATLAS ensemble all fit onto a single Spacelab pallet in the Shuttle's cargo bay (see Figure 6 for sample configuration). The first mission (ATLAS-1) is an exception, since several additional instruments from disciplines other than Earth science are being reflown to meet previous Spacelab commitments. ATLAS-1 is currently scheduled for flight in mid-1991 and is undergoing Integrated Requirements Reviews (IRRs) at this time. ATLAS-2 and -3 are scheduled for flight in 1992 and 1993, respectively. Both of the latter two missions

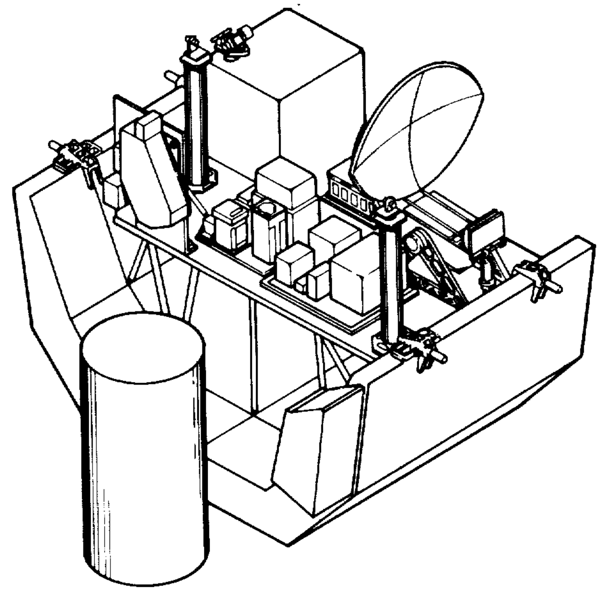

Figure 6. Sample ATLAS Payload Pallet

will underfly the Upper Atmosphere Research Satellite (UARS), making measurements that will complement and be compared with the UARS measurements. Table 12 lists the current launch schedule. All flights will entail a 9-day mission, at 160 nm with a 57-degree inclination.

Table 12. ATLAS Launch Dates

ATLAS-1	March 1991	Columbia
ATLAS-2	July 1992	Columbia
ATLAS-3	July 1993	Endeavour
ATLAS-4	April 1994	Endeavour
ATLAS-5	September 1995	Endeavour

International Cooperation/Participation

ATLAS involves a truly international set of missions. In addition to cooperation with West Germany through partnership in SPAS/CRISTA, several of the instruments are either non-U.S. or have foreign partners. MAS is a partnership of U.S., West German, and Swiss investigators. SOLSPEC is French, and SOLCON is Belgian.

Science Team Selection and Composition

Table 13 lists the ATLAS science team. Each Principal Investigator (PI) is a member of the team by virtue of his instrument being selected for ATLAS. The Investigator Working Group (IWG) is chaired by the Mission Scientist, who is located at Marshall Space Flight Center (MSFC) and appointed by the Marshall Payload Projects Office. The SPAS/CRISTA PI is a member of the IWG for ATLAS-3 only, and the PI for the Shuttle Solar Backscatter Ultraviolet (SSBUV) experiment is included in the ATLAS IWG because current plans include flight of that instrument on all ATLAS flights.

Table 13. ATLAS Science Team

Investigator	Institution
G.S. Wilson (Chair)	NASA/MSFC
C.B. Farmer (ATMOS)	Jet Propulsion Laboratory
C. Hartmann (MAS)	Max Planck Institute, FRG
G. Thuillier (SOLSPEC)	Centre National de la Reserche Scientifique, France
D. Crommelynck (SOLCON)	Royal Meteorological Institute of Belgium, Belgium
R. Willson (ACR)	Jet Propulsion Laboratory
G. Brueckner (SUSIM)	Naval Research Laboratory
Co-Manifested with ATLAS	
E. Hilsenrath (SSBUV)	NASA/GSFC
D. Offermann (SPAS/CRISTA)	University of Wuppertal, FRG

Shuttle Solar Backscatter Ultraviolet (SSBUV) Experiment

Mission Goal and Objectives

A series of NASA and NOAA satellites will conduct observations into the next century to determine ozone concentration fluctuations in the stratosphere. To date, research satellite data have only been marginally adequate for detecting ozone trends, with the biggest hindrance involving unaccounted instrument degradation resulting from extended operation in space. To deal with this problem directly, a Solar Backscatter Ultraviolet Radiometer/Version-2 (SBUV/2) ozone sounder is being flown about once per year on the Shuttle to provide an in-orbit calibration check of satellite instruments. The data from the SSBUV will be compared with nearly coincident ozone measurements taken by the NOAA and NASA satellite instruments to ensure data integrity.

Role in Global Change

The depletion of stratospheric ozone has become a major environmental concern, because changes in ozone column amount will modify the amount of ultraviolet radiation reaching the Earth's surface. Compelling observational evidence now exists that atmospheric ozone is being altered on a global scale. Recent assessment of existing ozone data from research satellites and ground-based data indicate total column ozone changes of 2 to 3 percent in northern hemisphere mid-latitudes, with a significant depletion at 40 km. These changes are consistent with predictions that release of certain man-made gases, such as chlorofluorocarbons (CFCs), would deplete stratospheric ozone. A national plan is now in effect that calls for monitoring the state of the stratosphere for at least the next 10 years.

Measurements to be Made and Resulting Data Products

Observations from the SSBUV involve measurement of the Earth albedo in the near ultraviolet from 250 to 350 nm and the solar spectral irradiance from 160 to 405 nm. The albedo observation is the ratio of the incoming solar irradiance and the subsequent backscattered radiance from the Earth's surface and atmosphere in 12 discrete channels. These data are employed in an algorithm that results in total column ozone and ozone profiles between 25 and 55 km. In addition, the solar spectral irradiance measurements provide data on solar activity that influences the chemistry of the upper atmosphere. The data from the Shuttle instrument will be used as a reference standard for similar global observations made from NASA, NOAA, and foreign satellites. The SSBUV will provide coincident data with these satellites through at least 1998. This coincident data set will be of sufficient precision to remove the uncertainty in the long-term data set to derive an accurate ozone trend.

Payload Elements/ Instrument Characteristics

The SSBUV instrument consists of a 1/4 Ebert spectrometer with a single detector that operates over a dynamic range of 10^6. The wavelength range is 160 to 400 nm with a resolution of 1.1 nm. The field of view is 11.3 degrees, which results in an Earth scene of about 50 km from Shuttle orbit. The instrument weighs 544 kg, uses 70 W average power (200 peak), and has a data rate of 500 bps. The SSBUV payload (developed, calibrated, and maintained at GSFC) carries its own power and data systems. High-level commands are sent by the Shuttle crew. This stand-alone capability allows the frequent flights necessary to achieve SSBUV objectives. The payload includes an onboard calibration system to monitor instrument response during flight. Figure 7 provides a line drawing of the instrument, and Figure 8 illustrates the in-orbit calibration scenario.

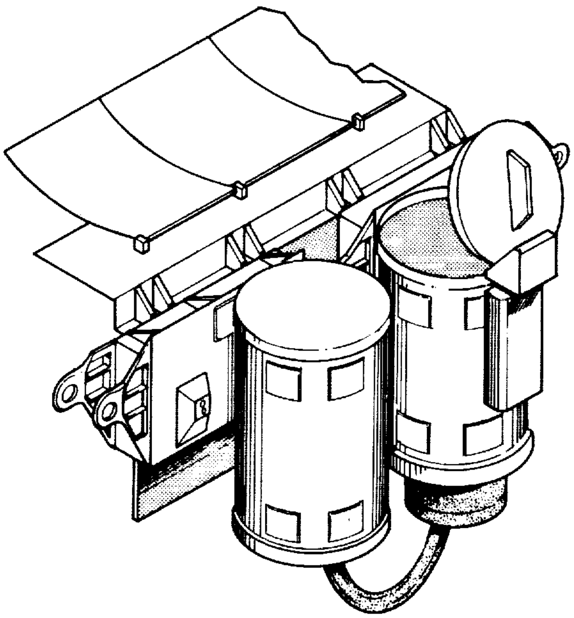

Figure 7. SSBUV Instrument

Data System Design, Archiving, and Data Distribution Plans

The SSBUV data are recorded in orbit. Played back after flight, these data are merged with orbit/attitude information to locate the Earth observations. Using pre-, in-, and post-flight calibrations, the calibrated and Earth-located albedo and solar irradiance data are the first level of achievable data products. These data are then reformatted to simulate the satellite ozone data. A data set coincident with the various satellite ozone observations is produced, then employed to perform the comparisons and ultimately the calibration of the long-term satellite data sets. The comparison data sets will be distributed to the NOAA SBUV/2 and the Total Ozone Mapping Spectrometer (TOMS) investigator teams.

Mission Status

The first SSBUV mission was flown successfully in October 1989. The payload will be refurbished for a second Shuttle flight in 1990. Ten additional flights are scheduled

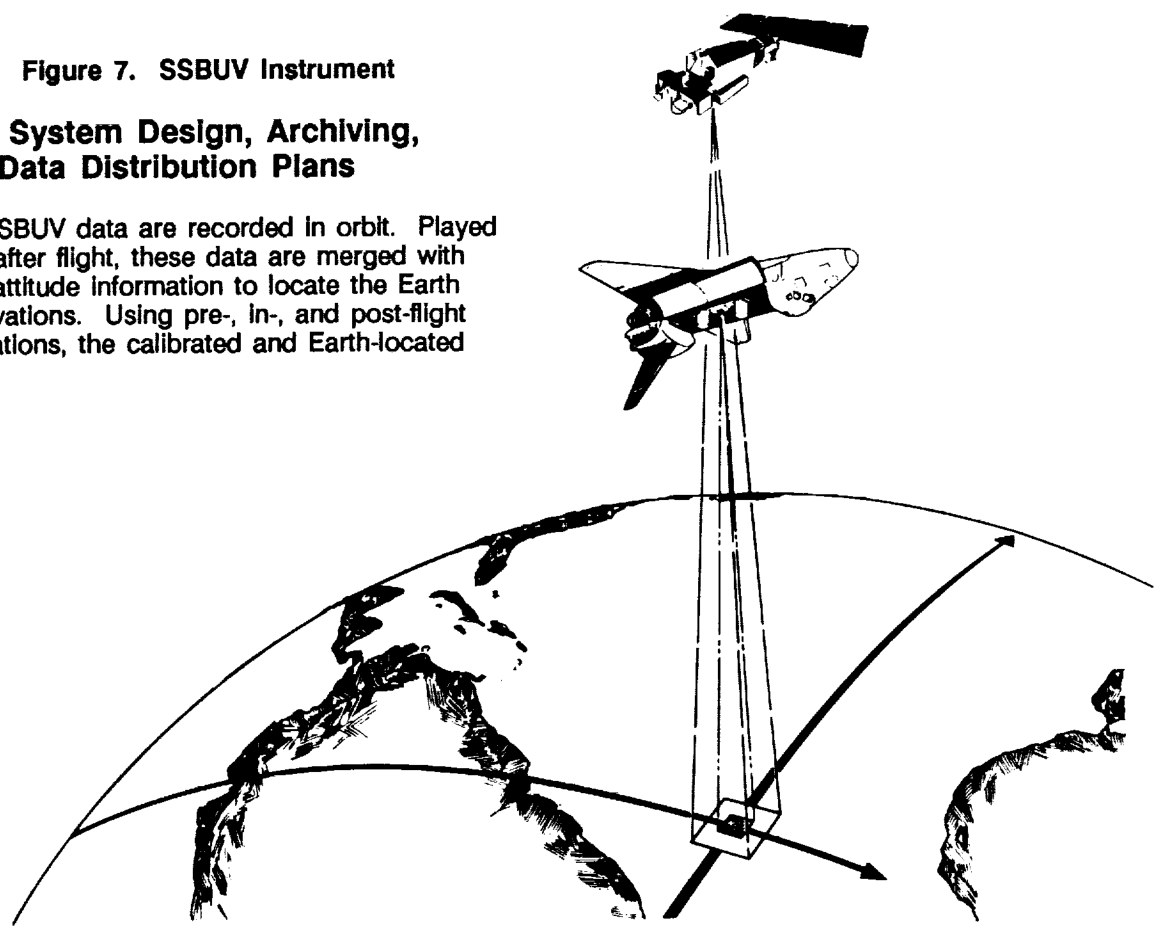

Figure 8. SSBUV In-Orbit Calibration

through 1997, on a schedule of about one per year. SSBUV is co-manifested with ATLAS-2, -3, and -5, and has no launch constraints.

International Cooperation/Participation

SSBUV will fly on the ATLAS Shuttle payload, which includes investigations from Belgium, France, and Germany. Measurements of the solar spectral irradiance from the French and Belgian instruments are similar to SSBUV measurements, and mission plans call for the data to be compared. Comparisons will also be made with data from the TOMS instruments flying on Soviet and Japanese satellites.

Science Team Selection and Composition

The SSBUV science team is in place and includes investigators who are conducting research on satellite ozone data and the ultraviolet solar spectral irradiance. The Principal Investigator is Ernest Hilsenrath of the Laboratory for Atmospheres, Goddard Space Flight Center.

Upper Atmosphere Research Satellite (UARS)

Mission Goal and Objectives

The UARS program consists of a single spacecraft (see Figure 9) and associated ground system designed to obtain a simultaneous, coordinated, global data set of a variety of upper atmosphere parameters. By analyzing upper atmospheric constituents, scientists hope to develop a better understanding of its composition and of the effects induced by man and by natural events, particularly upon stratospheric ozone. The spacecraft will carry 10 instruments using proven technologies to measure the atmosphere's internal structure and the external influences acting upon the upper atmosphere. More specifically, the objectives of the UARS mission are to study: energy input and loss in the upper atmosphere, global photochemistry of the upper atmosphere, dynamics of the upper atmosphere, the coupling among these processes, and the coupling between the upper and lower atmosphere.

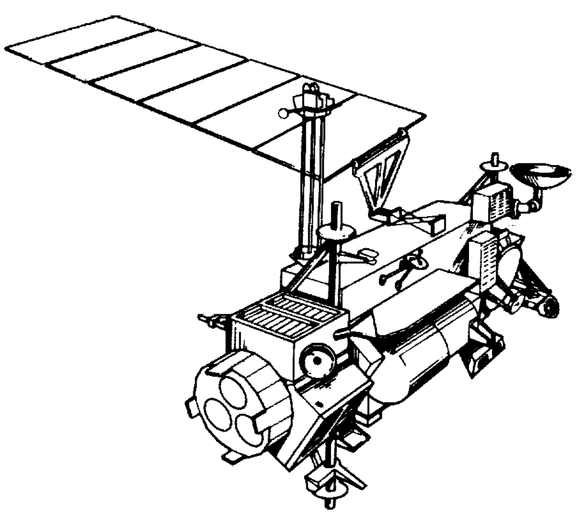

Figure 9. The Upper Atmosphere Research Satellite

Role in Global Change

In 1976, Congress amended the NASA Space Act, directing NASA to undertake research to understand the upper atmosphere and its susceptibility to change. Fulfilling this directive requires a continuous, global, and comprehensive look at the upper atmosphere over an extended time, which can be best accomplished with all instruments carried on a single spacecraft so that the measurements are easily correlated over time. The UARS observatory will provide simultaneous, coordinated measurements of atmospheric internal structure, and measurements of the external influences acting on the atmosphere. The combination of orbit and instrument design will provide nearly global coverage during the mission lifetime of two northern hemisphere winters.

Measurements to be Made and Resulting Data Products

UARS will be able to monitor the global structure, chemistry, and dynamics of the upper atmosphere. UARS instrumentation will provide direct remote sensing measurements of upper atmosphere winds, stratospheric temperatures, solar energy input, and radiative loss. The satellite will also monitor concentrations of a large number of stratospheric and mesospheric chemical species, derivatives from the effects of human activity that are thought to be responsible for the depletion of stratospheric ozone.

Payload Elements/ Instrument Characteristics

The spatial resolution requirements for UARS call for vertical resolution of 2.5 to 3.0 km, and 500 km in latitude. Longitudinal resolution requirements range from 1,000 km to zonal means (i.e., the mean measurement for a band of atmosphere extending around the Earth parallel to the equator). The need for high resolution in altitude measurements requires that all instruments making direct measurements on the atmosphere be limb viewers, meaning that they take their measurements by looking toward the horizon rather than down at the surface. The limb-viewing instruments, combined with the 57-degree inclination orbit, will allow UARS to make measurements up to 80° latitude, covering more than 98 percent of the Earth's surface. Table 14 lists the parameters that will be addressed by the specific UARS instruments.

Data System Design, Archiving, and Data Distribution Plans

Telemetry data from spacecraft tape recorders will be transmitted through the Tracking and Data Relay Satellite System (TDRSS) to the UARS Data Capture Facility (DCF) at Goddard Space Flight Center (GSFC). Data processed at the DCF will be forwarded to an Institutional Data Products Generation Facility (IDPGF), also at GSFC, where software developed by the instrument investigators will convert UARS observations into processed, cataloged data products.

All UARS data will be pooled and made available to Principal Investigators from the beginning of the observing program. These data will be accessed through a network of remote analysis computers operated by scientists at their home institutions. Once the UARS science team approves release, data products will be transferred to the National Space Science Data Center (NSSDC) at GSFC for archiving and distribution to general users.

Mission Status

As currently scheduled, UARS is manifested for Space Transportation System (STS) launch in August 1991 (total launch weight of 7,700 kg). Mission plans call for 36 months of design lifetime, an altitude of 600 km, and a circular orbit with a 57-degree inclination.

International Cooperation/Participation

An important aspect of the UARS program involves its coordination with additional national and international programs of study and data acquisition. Canada and the UK are contributing the Wind Imaging Interferometer (WINDII) and Improved Stratospheric and Mesospheric Sounder (ISAMS), respectively. Furthermore, scientists from many nations will ultimately participate in the analysis and utilization of UARS data.

Science Team Selection and Composition

Table 15 provides a listing of the UARS instrument and science investigation team members.

Table 14. Parameters Measured by UARS Instruments

Instrument	Parameters
CLAES Cryogenic Limb Array Etalon Spectrometer	Concentrations of members of the N and Cl families, O_3, H_2O, CH_4, and CO_2 at altitudes of 10-60 km; atmospheric temperature profiles for indirect wind measurements
ISAMS Improved Stratospheric and Mesospheric Sounder	Atmospheric temperature structure and variability; minor constituent distributions including the N family, water, methane, carbon monoxide, and ozone
MLS Microwave Limb Sounder	Concentrations of ClO, H_2O, O_3, and atmospheric pressure at various altitudes from 5 to 85 km
HALOE Halogen Occultation Experiment	Vertical distributions of HCl, HF, CH_4, CO_2, O_3, H_2O, and members of the N family
HRDI High-Resolution Doppler Imager	Velocity of upper-atmosphere wind field through measurement of Doppler shifts of molecular and atomic emission lines above 80 km (day/night)
WINDII Wind Imaging Interferometer	Velocity of upper-atmosphere wind field through measurement of Doppler shifts of molecular and atomic emission lines above 80 km
SUSIM Solar Ultraviolet Spectral Irradiance Monitor	Spectrum of solar ultraviolet radiation from 120 to 400 nm, with resolution of 0.1 nm
SOLSTICE Solar/Stellar Irradiance Comparison Experiment	Spectrum of solar ultraviolet radiation from 115 to 430 nm, with resolution of 0.12 nm
PEM Particle Environment Monitor	Energy spectrum of electrons (1 eV - 5 MeV), protons (1 eV - 150 MeV), and x-rays (2-50 keV)
ACRIM II Active Cavity Radiometer Irradiance Monitor II	Total solar irradiance measurements extending NASA/ACRIM data base to cover solar cycle 22; investigate the climate and solar physics implications and helioseismological content of collected data

Table 15. UARS Investigator Teams

Investigator	Institution
	UARS Instrument Principal Investigators
G.E. Brueckner (SUSIM)	Naval Research Laboratory
P.B. Hays (HRDI)	University of Michigan
A.E. Roche (CLAES)	Lockheed Palo Alto Research Laboratory
G.J. Rottman (SOLSTICE)	University of Colorado
J.M. Russell (HALOE)	NASA/LaRC
G.G. Shepherd (WINDII)	York University, Canada
F.W. Taylor (ISAMS)	Oxford University, UK
J.W. Waters (MLS)	Jet Propulsion Laboratory
J.D. Winningham (PEM)	Southwest Research Institute
	UARS Modeling and Data Analysis Principal Investigators
D.M. Cunnold	Georgia Institute of Technology
M. Geller	State University of New York, Stoney Brooke
J. Gille	NASA/GSFC
W.L. Grose	NASA/LeRC
J.R. Holton	University of Washington
J. London	University of Colorado
A.J. Miller	NOAA
C.A. Reber	NASA/GSFC
P. White	United Kingdom Meteorological Office, UK
D. Wuebbles	Lawrence Livermore National Laboratory
R.W. Zurek	Jet Propulsion Laboratory

Laser Geodynamics Satellite-II (LAGEOS-II)

Mission Goal and Objectives

LAGEOS-II will promote research in the Earth sciences by providing very precise satellite geodesy. Scientific objectives include research in:

- Regional crustal deformation and plate tectonics
- Geodetic reference datum and Earth orientation
- Earth and ocean tides
- Temporal variations in the geopotential
- Satellite orbital perturbations.

LAGEOS-I and -II are precursors to the Earth Observing System (EOS) Geoscience Laser Ranging System (GLRS), which reverses the standard approach of laser ranging by putting the laser source in orbit and the retroreflectors on the ground. In addition, many satellite laser ranging stations have been established around the world to fill an important supporting role, providing high-precision tracking for future satellite missions such as TOPEX/Poseidon. Figure 10 identifies the sites of these global laser tracking stations.

Role in Global Change

The importance of plate tectonics in the context of global change is multifaceted. In the long term, the shape and configuration of the continents and ocean floors affects atmospheric and deep ocean current circulation. Crustal uplift or subsidence results in regional sea-level change and potential flood hazards. Truly global sea-level changes cannot be confirmed without a complete understanding of the signature of regional crustal deformation. In the short term, earthquakes may be predicted and the consequences minimized to the extent possible. Through the network of satellite laser ranging sites, scientists can provide the ground precursor strain can be measured.

Atmospheric movement, circulation processes deep in the core and mantle, and mass transport cause subtle changes in the orientation of the Earth, the Earth's rotation, and the length of day in ways that are not well understood. Such changes have broad ranging implications for the distribution of water on Earth's surface and for life on Earth in general. These processes can be best documented using high-resolution space geodetic techniques. Besides these direct applications to global change, the LAGEOS missions are fundamental in developing satellite laser ranging techniques necessary for the precise tracking of other satellite sensors contributing in the study of global change.

Measurements to be Made and Resulting Data Products

Both LAGEOS satellites will be tracked by a global network of fixed and transportable lasers from some 65 sites (Figure 10). The current precision of the laser systems varies from 15 cm to less than 1 cm for single-shot range measurements. Further improvements will increase the precision of the majority of the laser systems to the 1-cm level by the time of the LAGEOS-II launch. Data to be made available to investigators consist of both preprocessed and analyzed data (i.e., station positions, baselines, and Earth rotation parameters as a function of time), and include a large body of worldwide data already collected, as well as data expected to be obtained from continuing measurements over the next several years. Satellite Laser Ranging (SLR) data will be collected by the NASA Communications Network (NASCOM), the Working Group of European Geoscientists for the Establishment of Networks for Earthquake Research (WEGENER) consortium, and other cooperating laser ranging facilities.

Payload Elements/ Instrument Characteristics

Like its predecessor, LAGEOS-II is a passive satellite designed specifically and dedicated

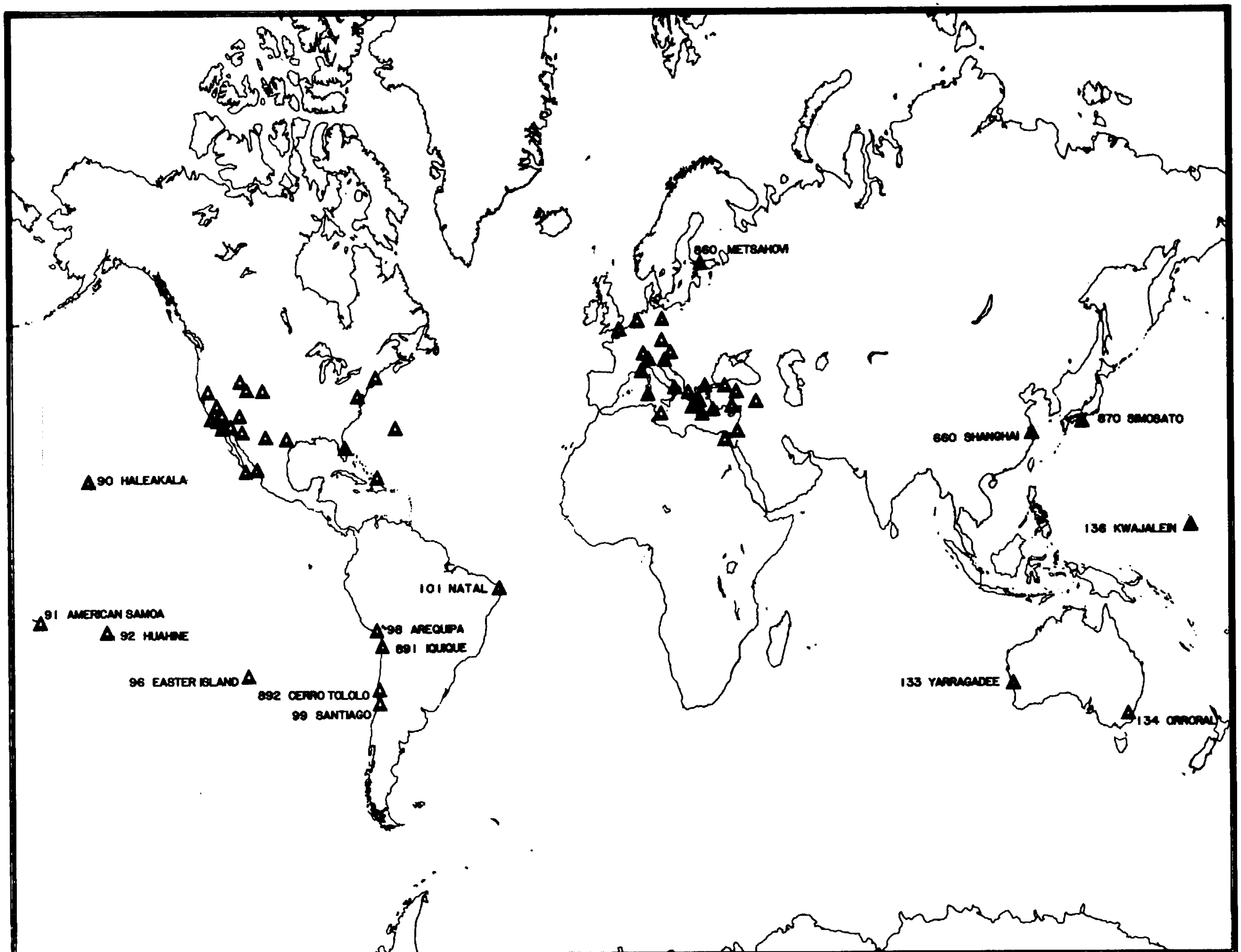

Figure 10. Global Laser Tracking Stations

exclusively for use as a target for laser ranging. Identical to LAGEOS-I, LAGEOS-II is a spherical satellite of aluminum with a brass core (see Figure 11); it is 60 cm in diameter and weighs approximately 406 kg. The exterior surface is covered by 426 equally spaced laser corner-cube retroreflectors that reflect any incident optical signal, such as pulsed laser light, back to its source. After LAGEOS-II is released from the Shuttle, the first stage will boost the spacecraft from 296 km to the satellite injection altitude of 6,000 km. The second stage will place the LAGEOS-II spacecraft in a circular orbit at 6,000 km, with an inclination of 52 degrees that will complement the orbit of LAGEOS-I (orbit of 101 degrees).

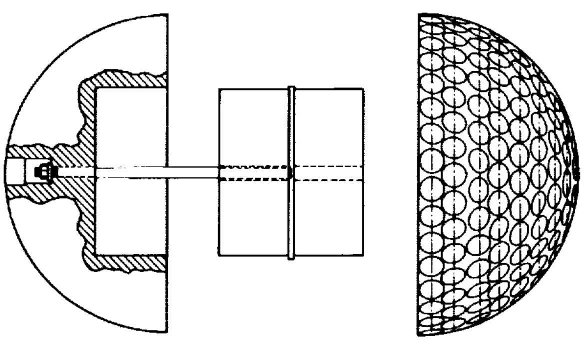

Figure 11. Laser Geodynamics Satellite-II

Data System Design, Archiving, and Data Distribution Plans

All of the data listed above are available to NASA and will be archived in the Crustal Dynamics Data Information System (CDDIS). The CDDIS resides on a dedicated Dec MicroVAX II computer at Goddard Space Flight Center (GSFC). The facility is available 24 hours per day, 7 days per week, and is accessible for interactive log-ins through SPAN, ARPAnet/INTERnet, GTE TELENET, and NASA/GSFC autobaud. The format and details of SLR data preparation are available from the Data Information System (DIS). A qualitative evaluation of LAGEOS-II SLR data and precise orbits of the satellite will be provided. These data will be distributed or made available by NASA to its investigators. A similar data set will be distributed by the Agenzia Spaziale Italiano (ASI) to its investigators. Countries that have executed a Memorandum of Understanding (MOU) or Letter Agreement with NASA will also have access to the DIS data.

Data available on the CDDIS include catalogs of preprocessed SLR and Very Long Baseline Interferometry (VLBI) data from 1976 to present; SLR, Lunar Laser Ranging (LLR), VLBI, and combined analyzed results supplied by the Crustal Dynamics Project (CDP) science support groups and other analysis centers; ancillary data including description of CDP site locations, monument coordinates and calibration data, and *a priori* star coordinates; and project management information including mobile system schedules, site occupation information, and CDDIS operational information such as logs of all laser and VLBI tapes received from the many global sources.

Mission Status

The Italian-constructed LAGEOS-II (based on the same design as the NASA-produced LAGEOS-I) was completed and sent to GSFC in November 1988 for pre-flight testing. Optical characterization tests of the corner-cube retroreflector array were completed, and the satellite is now ready and scheduled for launch in December 1991 on the Shuttle. It has been shipped to the Aeritalia facility at Torino for storage until that time. LAGEOS-II and two solid fuel stages--the Italian Research Interim Stage (IRIS) and the LAGEOS Apogee Stage (LAS)--will be sent to Kennedy Space Center (KSC) for payload integration about 4 months prior to launch.

International Cooperation/Participation

LAGEOS-II is a joint mission between NASA and ASI. The satellite and booster are provided by ASI, and the launch is provided by NASA. This cooperation between NASA and ASI builds on a long history of coordinated effort in the area of geodynamics. The team of 27 investigators represents the following six countries: the U.S., Italy, FRG, France, the Netherlands, and Hungary.

Science Team Selection and Composition

Selection of the international team of investigators was coordinated between NASA and the ASI (then Piano Spaziale Nationale) through simultaneous release of Research Announcements in early 1988, with coordinated evaluation procedures and selection announcements in March 1989. Table 16 provides a listing of the selected investigators.

Table 16. LAGEOS-II Science Team

Investigator	Institution
A. Caporali	University of Bari, Italy
E.R. Ivins	Jet Propulsion Laboratory
E. Mantovani	University of Siena, Italy
A. Milani	Politecnico di Milano, Italy
L.H. Royden	Massachusetts Institute of Technology
G. Soltau	Institut fr Angewandte Geodsie, FRG
M.N. Toksoz	Massachusetts Institute of Technology
G. Weber	Institut fr Angewandte Geodsie, FRG
P. Wilson	Institut fr Angewandte Geodsie, FRG
S. Zerbini	University of Bologna, Italy
A. Cazenave	Centre National d'Etudes Spatiales, France
I. Fejes	FMI Satellite Geodetic Observatory, Hungary
J. Hinderer	Institut de Physique du Globe, France
R.D. Rosen	Atmospheric and Environmental Research, Inc.
D.E. Smith	NASA/GSFC
D.A. Yuen	University of Minnesota
J. Zschau	Institut fr Geophysik, Neue Universitt, FRG
D.D. McCarthy	U.S. Naval Observatory
J.O. Dickey	Jet Propulsion Laboratory
J.G. Marsh	NASA/GSFC
J.M. Wahr	University of Colorado, Boulder
P.L. Bender	National Bureau of Standards
C.F. Martin	EG&G Washington Analytical Services Center, Inc.
G. Rosborough	University of Colorado, Boulder
W. Schluter	Institut fr Angewandte Geodsie, FRG
B.D. Tapley	University of Texas at Austin
K.F. Wakker	Delft University of Technology, Netherlands

TOPEX/Poseidon

Mission Goal and Objectives

TOPEX/Poseidon is a joint U.S. (NASA) and French [Centre National d'Etudes Spatiales (CNES)] mission designed to make substantial contributions to the understanding of global ocean dynamics. Radar altimeters will be used on a well-tracked satellite to make accurate observations of the oceanic sea surface topography for a period of 3 to 5 years. TOPEX/Poseidon is a vital contribution to the following major international ocean/atmosphere research programs: the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmosphere (TOGA) program, both of which are components of the World Climate Research Program (WCRP). Major scientific goals of TOPEX/Poseidon include studies of:

- The permanent and variable circulation of the ocean and its interaction with the atmosphere on global or basin scales, and the role of the ocean in climate
- The oceanic circulation on regional scales or for periods of a few months
- The heat transported by the oceans
- The statistics of oceanic variability
- Oceanic and solid Earth tides
- Ocean surface wave physics
- The marine geoid, lithospheric, and mantle processes.

The TOPEX/Poseidon mission will lay a firm foundation for continuing long-term observations of oceanic circulation and its variability, as a precursor to the precise altimetry instruments included in the 15-year Earth Observing System (EOS) program.

Role in Global Change

TOPEX/Poseidon addresses the fundamental processes through which oceans moderate the Earth's climate. The oceans account for about 50 percent of the heat transport between the tropics and the polar regions, with the atmosphere accounting for the other half. Recent atmospheric modeling studies have predicted significant climate changes as a consequence of greenhouse warming of a few degrees. These models do not adequately account for the oceanic effects on climate, either the exchange of heat between the ocean and atmosphere or the transport of heat by the ocean. Because these quantities have large uncertainties, considerable progress is needed in measuring and modeling these effects.

The ocean has a major role in the global carbon budget; presumably, about half the carbon added to the atmosphere by burning fossil fuel is absorbed by the ocean. The details of this massive ocean-atmosphere exchange involve complex biogeochemical and physical processes that are very poorly understood. TOPEX/Poseidon will measure the mean and variable surface geostrophic circulation to add insight into these processes. In concert with WOCE and TOGA, assimilation of TOPEX/Poseidon and *in situ* data into ocean circulation models will be used to study the surface circulation and massive oceanic thermohaline convection that affects the transport of heat and carbon.

Measurements to be Made and Resulting Data Products

The primary requirement for TOPEX/Poseidon will be to measure the ocean sea surface topography with a precise altimeter. This is done by measuring its altitude above the sea surface from an orbiting platform that is independently tracked relative to a geocentric coordinate system. Refer to Figure 12 for a schematic of TOPEX/Poseidon's 10-day global coverage. The mission requirements for high accuracy require several ancillary instruments for precise orbit tracking and electromagnetic path length corrections. In addition, the altimeter echo is used to extract parameters describing the sea state. The data products obtained from the mission will include:

- Sea surface topography
- Significant wave height
- Surface wind speed
- Ocean tides
- Vertically integrated atmospheric water vapor
- Vertically integrated ionospheric electron content.

Payload Elements/ Instrument Characteristics

Figure 13 offers a line drawing of the spacecraft, and Table 17 provides basic mission highlights. TOPEX/Poseidon instrument descriptions follow:

- **Two Radar Altimeters** (one NASA, one CNES) will share a single antenna and alternating duty cycle (approximately 90% NASA and 10% CNES). The NASA altimeter is the primary instrument, based on Seasat and Geosat heritage. It will have a 2.4 cm rms precision and carry two channels (13.6 and 5.4 Ghz) to correct the ionospheric range delay. The CNES altimeter is a new solid-state design operating at 13.5 GHz with a 10-cm rated precision.

- **TOPEX/Poseidon Microwave Radiometer** (TMR) is a NASA radiometer (Seasat/Nimbus heritage), with nadir viewing at 18, 21, and 37 GHz for correcting the altimeter range delay due to tropospheric water vapor.

- **The Global Positioning System** (GPS) receiver will serve as an experimental test for precise orbit determination. This instrument is a precursor to the EOS GPS Geoscience Instrument (GGI).

- **The French Determination d'Orbite et Radiopositionement Integre par Satellite** (DORIS) instrument is a Doppler receiver (401 and 2036 MHz) for Doppler-based precision orbit tracking.

- **The Laser Retroreflector Array** will be used for altimeter height calibration and laser tracking for precision orbit determination (Seasat, Geosat, and LAGEOS heritage).

Table 17. TOPEX/Poseidon Basic Facts

Launch Date	June 1992
Orbit	1336.2-km altitude, 66.0193° inclination, 10-day repeating ground track
Duration	Nominally 3 years, with expendables for a 5-year total
Launch Vehicle	Ariane-4 (provided by France)
Satellite Mass (kg)	2650
Data Rate	516 kbps (via TDRSS)
Measurement Accuracy	Sea level 13 cm rms

Data System Design, Archiving, and Data Distribution Plans

TOPEX/Poseidon data will be processed into two Geophysical Data Records (GDRs); one will be produced by the NASA TOPEX/Poseidon Project at the Jet Propulsion Laboratory (JPL) when the NASA altimeter is

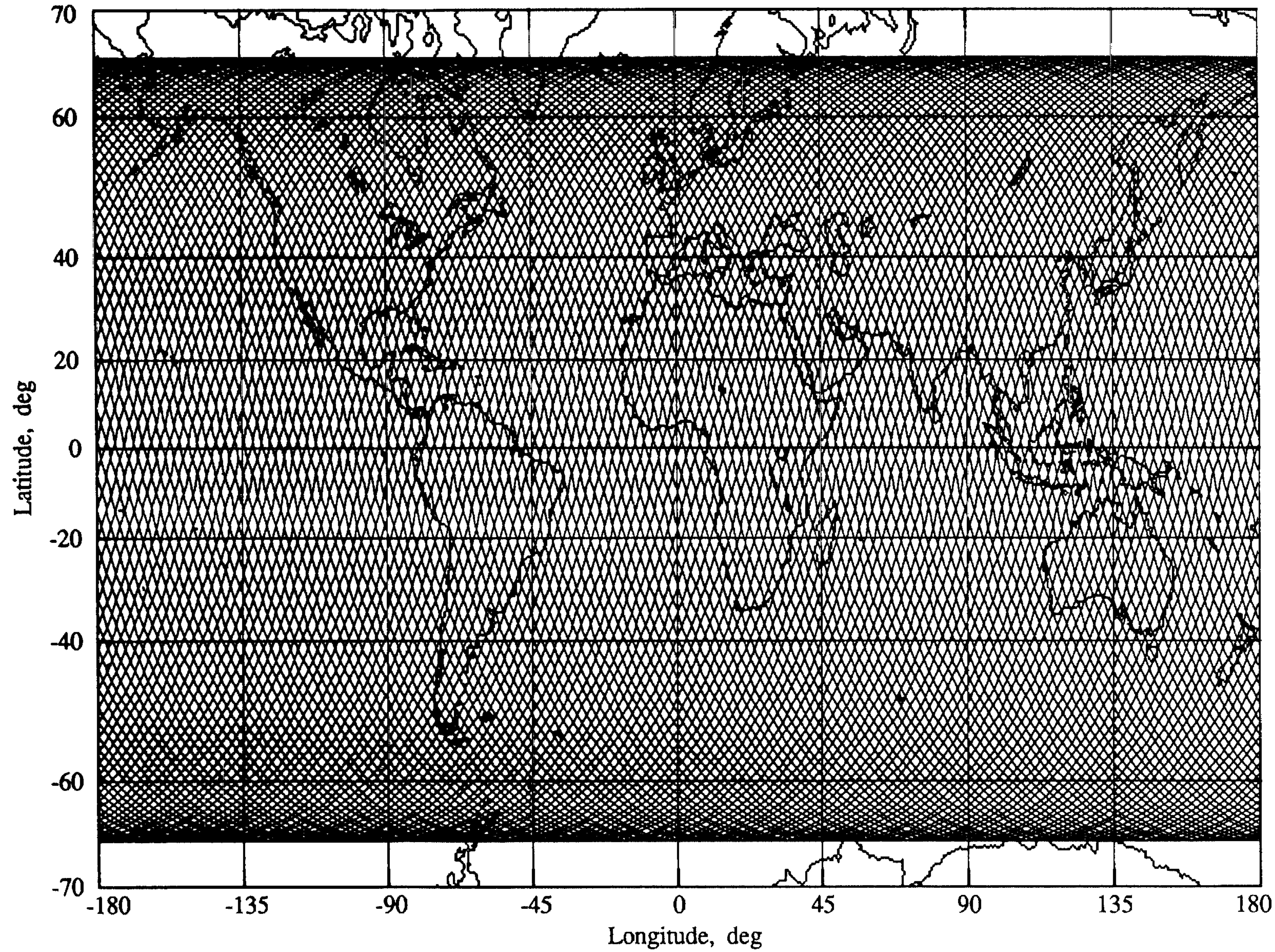

Figure 12. TOPEX/Poseidon 10-Day Global Coverage

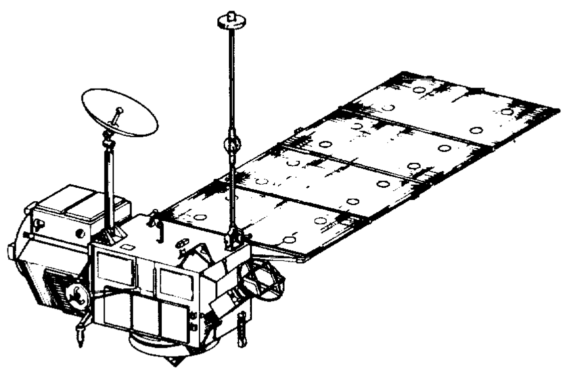

Figure 13. TOPEX/Poseidon

operating, and the other by CNES when the CNES altimeter is operating. The NASA Ocean Data System (NODS) at JPL is NASA's primary data distribution and archive facility for oceanographic satellite altimeter data (as well as satellite scatterometer and radiometer data from the unfrozen ocean). NODS will receive copies of the NASA and CNES GDRs from the respective projects and distribute them to NASA-selected Principal Investigators. NODS will forward copies of the NASA GDR to CNES for redistribution to CNES-selected investigators. NODS will combine the NASA and CNES GDRs into a single GDR for the full mission. All TOPEX/Poseidon GDRs will be made openly available to the oceanographic community as soon as they are distributed to Principal Investigators. GDRs will also be provided to the NOAA National Oceanographic Data Center (NODC) archives.

Mission Status

TOPEX/Poseidon received a program start in FY 87. The prime contract for the spacecraft and integration was awarded to Fairchild in June 1987. Preliminary Design Review (PDR) and Critical Design Review (CDR) were completed in October 1988 and May 1989, respectively. Sensor integration is planned to start in July 1990. Launch is scheduled for June 1992 on a French-provided Ariane-4. The present launch schedule will place TOPEX/Poseidon in orbit to allow a 3-year overlap with WOCE and TOGA.

International Cooperation/Participation

TOPEX/Poseidon is a joint U.S./French mission. NASA is providing the spacecraft, mission operations, primary altimeter, radiometer, GPS receiver, laser retroreflector array, and laser tracking network. CNES will provide an Ariane-4 launch vehicle, an experimental single frequency solid state altimeter, and the DORIS radiometric Doppler tracking system.

Science Team Selection and Composition

In September 1987, NASA and CNES selected an international team of scientists, involved with 38 investigations, who represent the U.S., France, Japan, Australia, Great Britain, the Netherlands, FRG, Norway, and South Africa. Twenty of these investigations were selected by NASA and 18 by CNES, based on proposals submitted in response to a joint Announcement of Opportunity (AO). Science team meetings were held at JPL in November 1987, and in Paris in May 1988. Tables 18 and 19 list the members of the NASA- and CNES-recommended science teams. In November 1988, the Science Working Team (SWT) was confirmed by both agencies after a year-long science definition period. Since confirmation, two more SWT meetings have been held at 6-month intervals. Future meetings will be scheduled annually until launch, with the next to be in Washington, D.C., in October 1990.

Table 18. TOPEX/Poseidon NASA-Recommended Science Team

Investigator	Institution
L.L. Fu (Chair)	Jet Propulsion Laboratory
G. Born	University of Colorado
D.M. Burrage	Australian Institute of Marine Sciences, Australia
D.B. Chelton	Oregon State University
J.A. Church	Commonwealth Scientific and Industrial Research Organization, Australia
B.C. Douglas	National Geodetic Survey
E.J. Katz	Columbia University
W.T. Liu	Jet Propulsion Laboratory
R. Lukas	University of Hawaii
J.G. Marsh	NASA/GSFC
J.L. Mitchell	Naval Ocean Research and Development Activity
R.H. Rapp	Ohio State University
B. Sancho	NASA/GSFC
J. Segawa	University of Tokyo, Japan
P.T. Strub	Oregon State University
C.K. Tai	University of California, San Diego
K. Taira	University of Tokyo, Japan
B.D. Tapley	University of Texas
J. M. Wahr	University of Colorado
C. Wunsch	Massachusetts Institute of Technology

Table 19. TOPEX/Poseidon CNES-Recommended Science Team

Investigator	Institution
T.D. Allan	Institute of Oceanographic Sciences, UK
F. Barlier	Groupe de Reserche de Geodesie Spatiale, France
C. Boucher	Institut Geographique National, France
A. Cazenave	Groupe de Reserche de Geodesie Spatiale, France
P. de Mey	Groupe de Reserche de Geodesie Spatiale, France
Y. DeSaubles	IFREMER, France
M. Grundlingh	National Research Institute for Oceanology, South Africa
C. LeProvost	Institut de Mecanique, France
Y. Menard	Group de Reserche de Geodesie Spatiale, France
J. Merle	Universite Paris VI, France

Shuttle Imaging Radar-C (SIR-C) and X-Band Synthetic Aperture Radar (X-SAR)

Mission Goal and Objectives

The SIR-C/X-SAR flights in 1993, 1994, and 1996 provide the next evolutionary steps in NASA's Spaceborne Imaging Radar (SIR) program. The scientific objectives of SIR are to:

- Conduct geoscience investigations that require the observational capabilities of orbiting radar sensors alone, or in conjunction with other sensors, that will lead to a better understanding of the surface conditions and processes on the Earth
- Explore regions of the Earth's surface that are not well characterized because of vegetation, cloud, or sediment cover in order to better understand land and ocean surface conditions and processes on a global scale
- Incorporate this new knowledge into global models of surface and subsurface processes operating on the Earth and other planets.

To achieve these objectives, process-related biogeophysical models and the ability to monitor key biogeophysical parameters must be developed. The multifrequency, multipolarization, and multitemporal capabilities of SIR-C/X-SAR will specifically provide data required for studies of vegetation extent, biomass, and condition; soil moisture and snow properties; recent climate change and tectonic activity; and ocean wave spectra.

Role in Global Change

Synthetic aperture radar (SAR) has unique benefits; it is sensitive to morphology, feature geometry, land and ocean surface roughness, and dielectric constant. SAR data can provide reliable temporal data through all seasons and at all latitudes, and consistent coverage independent of weather or sun illumination. Depending on wavelength, the SAR can penetrate or interact with vegetation cover and, in some cases, sediment cover. These unique capabilities are vital for several high-priority global change research areas outlined by the Committee on Earth Science (CES), including:

- Elemental storage and cycling processes
- Hydrologic cycle
- Climate-geological processes
- Ocean circulation.

Measurements to be Made and Resulting Data Products

The SIR-C/X-SAR sensors are designed to be versatile enough to meet a variety of observational requirements. SIR-C operates at L-band (24-cm wavelength) and C-band (5.6-cm wavelength). Its polarization modes are HH (horizontally polarized transmission, horizontally polarized reception), HV (horizontally polarized transmission, vertically polarized reception), VH (vertically polarized transmission, horizontally polarized reception), and VV (vertically polarized transmission, vertically polarized reception). SIR-C will provide images of the magnitudes of HH, VV, and cross-polarized returns; images of the relative phase difference between HH, VV, VH, and HV returns; and derivation of linear, circular, or elliptical polarization. SIR-C will provide more detailed information about the geometry and dielectric constant of the Earth's surface and cover than previous spaceborne radars.

Digital correlation to full resolution will result in images with resolution of approximately 25 m (20 MHz bandwidth) and 40 m (10 MHz bandwidth). The SIR-C swath width will depend on the mode, look angle, resolution (bandwidth), signal quantization level, and the surface being imaged. Generally, swath widths for calibrated data will range from 15 to 65 km, and swath widths for mapping mode will range from 40 to 90 km. The antenna can be steered electronically or mechanically to acquire data at a variety of incidence angles.

Investigators can choose between data acquired at 8 bits per sample or 4 bits per sample. In addition, a Block Floating Point Quantizer (BFPQ), which uses an 8-bit uniform quantizer and transmits 4 bits, will be implemented on SIR-C. The 8-bit dynamic range of the SIR-C images is expected to be about 40 dB with 10 dB signal-to-noise ratio (SNR). A 4-bit quantization level would reduce the dynamic range to approximately 17 dB. At 10 dB SNR, BFPQ data will have the same dynamic range as 8-bit data, but a swath width corresponding to 4-bit data.

X-SAR, which is being designed and built in collaboration with the German Aerospace Research Establishment (DLR), will operate at X-band (3.1-cm wavelength) with VV polarization. Swath widths, look angles, and resolutions will all be comparable to those of SIR-C, resulting in a three-frequency capability. The standard digitally processed C- and L-band images will be radiometrically calibrated to compensate for drift or changes in transmitter power, receiver gain, antenna pointing, etc. The goal is to provide data calibrated in such a way as to allow comparisons with other spaceborne SAR data (e.g., ERS-1, JERS-1, Radarsat, and EOS SAR), so that a time-series view of key geophysical parameters may be realized. The expected absolute radiometric calibration is 13 dB and relative calibration is 11 dB.

The Shuttle altitude of approximately 225 km during the missions will result in a slightly drifting orbit to acquire data at multiple incidence angles. The orbital inclination will be 57 degrees, and the node crossing will be fixed based on investigator requirements and Shuttle constraints.

Payload Elements/ Instrument Characteristics

The SIR-C sensor will be composed of several subsystems: the antenna array, the exciter, the receivers, the data handling network, high data rate recorders, and the ground SAR processor. Figure 14 provides a line drawing of the deployed SIR-C/X-SAR elements in the Shuttle's cargo bay. The antenna is composed of two planar arrays, one for L-band dual-polarized operation and the other for C-band dual-polarized operation. Each array is composed of a uniform grid of dual-polarized microstrip antenna radiators, each polarization port of which is fed by a separate corporate feed network. The overall size of the antenna is 12 m x 4 m, with the L-band aperture being 12 m x 2.9 m and the C-band aperture 12 m x 0.7 m.

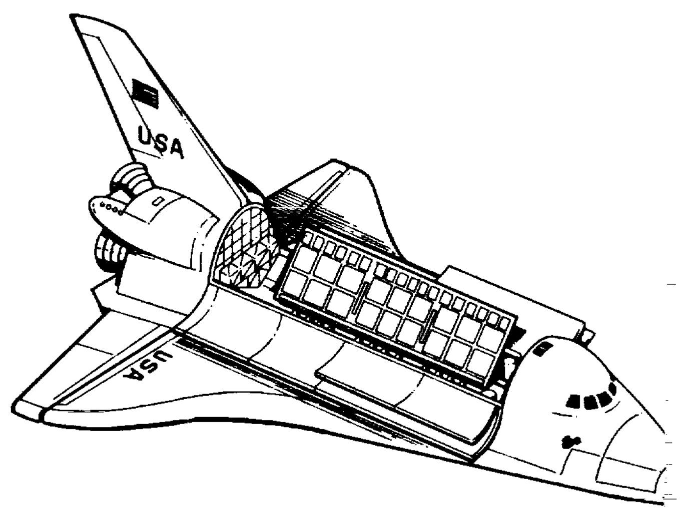

Figure 14. Deployed SIR-C/X-SAR in Shuttle Cargo Bay

Amplification of the radar pulses (both transmitted and received) will be accomplished in distributed fashion, with solid-state high-power amplifiers (HPAs), low-noise amplifiers (LNAs), and 4-bit phase shifters distributed across the array. A transmit/receive (T/R) unit is assigned to 18 microstrip elements distributed along the long dimension of the antenna. The transmitter peak power is 3.8 kW at L-band and 2.1 kW at C-band. Four solid-state receivers are planned, two for L-band and two for C-band. The radar echoes from each receiver are routed through a receiver switching network to four digital data handling system (DDHS) networks.

Data System Design, Archiving, and Data Distribution Plans

Nominally, 50 hours of SIR-C data (on each of four channels) and 50 hours of X-SAR data will be recorded by onboard 180 Mbs tape recorders during each flight. In addition, a limited amount of SIR-C data may be transmitted to the ground (via the TDRSS Ku-band 50 Mbs data link) for near-real-time digital processing during the mission. This combination of real-time (TDRSS) or delayed-time (tape recorder) data steering allows coverage of virtually any location on the Earth over which the Shuttle flies.
Data will be processed at the Jet Propulsion Laboratory (JPL), producing SAR images in both computer-compatible tape (CCT) and film formats. Standard products will be single-look complex, compressed polarimetric, and four-look detected data. Current plans are to distribute a complete data set (one channel only) in survey mode on CD-Roms 3 months after each flight. If funding is available, SIR-C/X-SAR data will be archived and made available as part of the EOS Data and Information System (EOSDIS).

Mission Status

The first SIR-C/X-SAR flight is planned for 1993, with subsequent flights in 1994 and 1996to enable data acquisition during different seasons. A baseline mission scenario, data product requirements, and the need for data from the NASA/JPL Aircraft SAR (a prototype for SIR-C) have been defined.

International Cooperation/Participation

SIR-C/X-SAR is a cooperative mission between NASA, the Bundesministerium fur Forschung und Technologie (BMFT) of the Federal Republic of Germany, and the Agenzia Spaziale Italiano (ASI). Thirteen countries are represented on the science team. Field activities will include extensive international collaboration, with plans for aircraft campaigns in Europe, North Africa, Brazil, and possibly Australia.

Science Team Selection and Composition

The SIR-C/X-SAR science team, made up of 49 team members and three team associates, was selected in July 1988. Twenty universities are represented. A list of the science team Principal Investigators is contained in Table 20.

Table 20. SIR-C/X-SAR Science Team

Investigator	Institution
Geologic Investigations	
E. Dabbagh	King Fahd University, Saudi Arabia
T.G. Farr	Jet Propulsion Laboratory
A.R. Gillespie	University of Washington
R. Greeley	Arizona State University
B. Isacks	Cornell University
F.A. Kruse	University of Colorado
J.F. McCauley	Northern Arizona University
P.J. Mouginis-Mark	University of Hawaii
L.G. Napolitano	Instituto U. Nobile, Italy
G.G. Schaber	U.S. Geological Survey

Table 20. SIR-C/X-SAR Science Team (Continued)

Investigator	Institution
	Geologic Investigations (Continued)
Y. Shiren	National Remote Sensing Center, China
R.J. Stern	University of Texas at Dallas
G.R. Taylor	University of New South Wales, Australia
C.A. Wood	NASA/JSC
	Ecologic Investigations
R.J. Brown	Canada Center for Remote Sensing, Canada
E.S. Kasischke	Environmental Research Institute of Michigan
T. Le Toan	Centre d'Etudes Spatiales des Rayonnements, France
F. Lozano-Garcia	National University of Mexico, Mexico
J.M. Melack	University of California, Santa Barbara
J.F. Paris	California State University at Fresno
K.T. Paw-U	University of California, Davis
K.O. Pope	NASA/ARC
K.J. Ranson	NASA/GSFC
D.S. Simonett	University of California, Santa Barbara
F.T. Ulaby	University of Michigan
N.J. Veck	GEC - Marconi Research Centre, UK
R. Winter	German Aerospace Research Establishment (DLR), FRG
	Hydrologic Investigations
P. Canuti	University of Florence, Italy
J. Dozier	University of California, Santa Barbara
E.T. Engman	USDA ARS Hydrology Laboratory
H. Rott	University of Innsbruck, Austria
J.V. Soares	Instituto de Pesquisas Espaciais, Brazil
D. Vidal-Madjar	CNET/CRPE, France
J.R. Wang	NASA/GSFC
	Oceanographic Investigations
W. Alpers	University of Hamburg, FRG
R.C. Beal	The Johns Hopkins University
P. Flament	University of Hawaii at Manoa
G. Keyte	RAE, Space Department, UK
F.M. Monaldo	The Johns Hopkins University
D. Montgomery	Office of the Navy Oceanographer
K. Raney	Radarsat Office, Canada

Table 20. SIR-C/X-SAR Science Team (Continued)

Investigator	Institution
	Calibration
A. Freeman	Jet Propulsion Laboratory
M. Fujita	Communications Research Laboratory, Japan
R.M. Goldstein	Jet Propulsion Laboratory
F. Heel	German Aerospace Research Establishment (DLR), FRG
A.R. Jameson	Applied Research Corporation
F.K. Li	Jet Propulsion Laboratory
R.K. Moore	University of Kansas
C.G. Rapley	University College London, UK
S. Vetrella	University of Naples, Italy
	Electromagnetic Modeling Theory
J.A. Kong	Massachusetts Institute of Technology
H.A. Zebker	Jet Propulsion Laboratory

CANDIDATE EARTH PROBES

Total Ozone Mapping Spectrometer (TOMS)

Mission Goal and Objectives

The primary goal of the TOMS mission is to continue the high-resolution global mapping of total ozone on a daily basis. The scientific objectives are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. In addition, TOMS data can be used to diagnose the dynamics of the lower stratosphere and to detect sulfur dioxide clouds resulting from major volcanic eruptions.

Role in Global Change

The release of man-made gases (e.g., chlorofluoromethanes) into the troposphere has a direct causal relationship to changes in stratospheric ozone. Although researchers have determined that the immediate effect involves reduction of ozone in the stratosphere, concern over long-term climatic effects must be addressed. Trend detection is a difficult problem since the total ozone record shows modulation by slowly varying factors, such as atmospheric circulation and solar flux. The TOMS mission will continue the precise ozone measurements started on Nimbus-7 in order to clarify the difference between man-induced and natural perturbations.

Measurements to be Made and Resulting Data Products

TOMS derives total ozone measurements by observing backscattered ultraviolet (UV) sunlight and direct irradiance at 6 wavelength bands, in the region 306 to 360 nm, each with a 1.0 nm bandpass. Measured albedo as a function of wavelength can be used to determine the integrated ozone column above the ground. The TOMS instrument has a cross-track scanning capability, making it possible to obtain high spatial resolution (50 km by 50 km) global maps of total ozone on a daily basis.

Instrument Characteristics

The TOMS instrument consists of a fore-optics unit, an $f/5$ 250 mm focal length Ebert-Fastie configuration polychromator, and a photomultiplier (see Figure 15). Figure 16 shows a schematic drawing of the TOMS instrument being built for the Earth Probe and Advanced Earth Observation Satellite (ADEOS) missions. The spectrometer is a standard design with a long history of successful space flight experiments (e.g., TOMS on Nimbus-7). The combined weight of the optics, diffuser, and electronics modules is 21.6 kg; the sensor module and electronics module are 51 cm x 24 cm and 15 cm x 20 cm x 37 cm, respectively. Table 21 lists the performance characteristics, and Table 22 gives the orbital characteristics for the Earth Probes and Nimbus missions. The data rate from TOMS is less than 1 kbps.

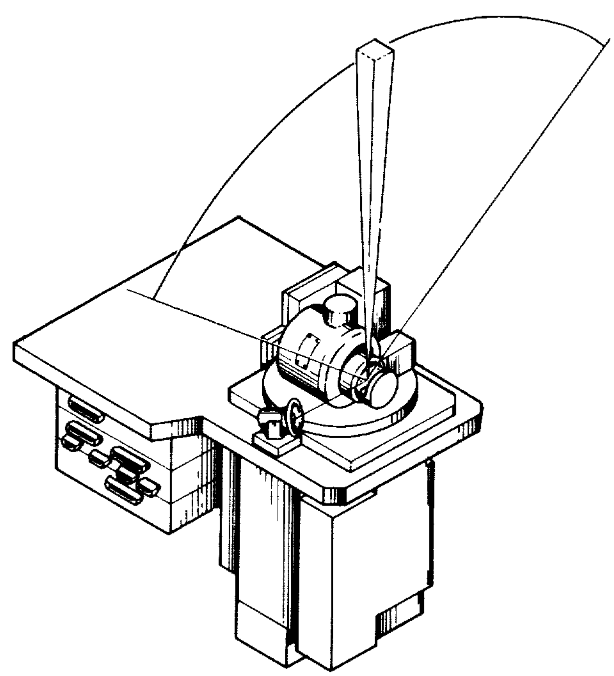

Figure 15. Total Ozone Mapping Spectrometer

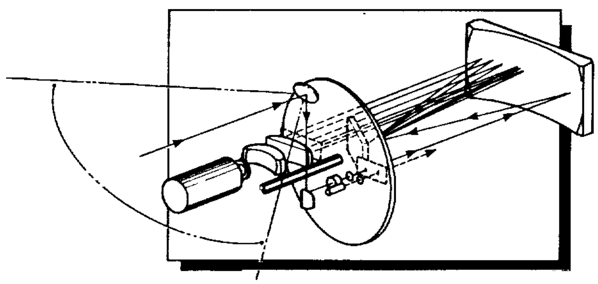

Figure 16. TOMS Instrument as Designed for Earth Probe and ADEOS Missions

Data System Design, Archiving, and Data Distribution Plans

The data from Nimbus-7 has been routinely processed at NASA/Goddard Space Flight Center (GSFC) since 1978. The same processing software, with a few minor modifications, will be used to process future data streams. These modifications deal mainly with different raw data input and calibration constants. NASA's objective is to make the TOMS ozone data available to the general scientific community as quickly as possible.

Mission Status

Current plans call for a series of three TOMS missions. The instrument is scheduled for launch on a Soviet Meteor-3 spacecraft in 1991, a NASA Earth Probe dedicated satellite in 1993, and the Japanese ADEOS satellite in 1995. The first mission uses the TOMS engineering unit from the Nimbus-7 program. New instruments are being purchased for the second and third missions. The selections for both the Earth Probe and the ADEOS satellites were the result of a response to an Announcement of Opportunity (AO).

Table 21. TOMS Performance Characteristics

Parameter	Measurement
Instantaneous Field of View	3 x 3 degrees square
Cross-Track Scan Coverage	105 degrees
Spatial Resolution (at 900 km)	Nadir - 47 km x 47 km Average - 62 km x 62 km
Image Motion Compensation	Interleaved wavelength sampling
Steps per Scan	35
Step and Settle Time	32 msec
Dwell Time per Step	168 msec
Step Rate	200 msec/step (5 steps/sec)
San Time	7 secs
Retrace Time	1 sec
Sounding Wavelengths	306. 0nm, 312.5 nm, 325.0 nm, 317.5 nm, and 332.6 nm
Reflectivity Wavelength	360 nm

Table 22. TOMS Orbit Parameters

	Nimbus	Earth Probe
Orbit Altitude	955 km	900 km
Orbit Period	104.2 min	103.1 min
Ground Speed	6.40 km/sec	6.47 km/sec
Orbit Plane	12:00 LST	12:00 LST
Motion/Scan	51 km	51.8 km
Footprint, Nadir	50 km	47.2 km
Swath Width	2961 km	2752 km
Inter-Orbit Distance at Equator	2892 km	2860 km
Equatorial Overlap	34 km	-54 km

International Cooperation/Participation

A TOMS instrument is scheduled for launch on a Soviet Meteor-3 spacecraft in the second half of 1991. This project is a key activity of the US/USSR Earth Science Joint Working Group (ESJWG). Another TOMS instrument has been accepted for Japan's ADEOS satellite, scheduled for launch in 1995.

Science Team Selection and Composition

No official science team has been chosen for the TOMS/Meteor-3 mission; Charles Cote of NASA/Goddard Space Flight Center is the Principal Investigator for TOMS/Earth Probe. The science team for TOMS/ADEOS is listed in Table 23.

Table 23. TOMS/ADEOS Science Team

Investigator	Institution
A.J. Krueger (PI)	NASA/GSFC
J.R. Herman	NASA/GSFC
M.R. Schoeberl	NASA/GSFC
R.S. Stolarski	NASA/GSFC
L. Ucellini	NASA/GSFC
L. Walter	NASA/GSFC
J.E. Frederick	University of Chicago
W.I. Rose	Michigan Tech University
T. Ogawa	University of Tokyo, Japan
T. Matsuno	University of Tokyo, Japan
Y. Makino	Meteorological Research Institute, Japan
T. Watanabe	University of Tsukuba, Japan
Y. Ida	University of Tokyo, Japan
Y. Sawada	Japan Meteorological Agency, Japan

Sea-Viewing Wide Field Sensor (SeaWiFS)

Mission Goal and Objectives

SeaWiFS is a global ocean color mission designed to deliver worldwide high-precision, moderate-resolution, multispectral visible observations of ocean radiance for research in biogeochemical processes, climate change, and oceanography. The scientific objectives of SeaWiFS are to determine the mean and variable bio-optical reflectance characteristics of the upper ocean and to understand the processes responsible for observed variations. This understanding is crucial to:

- Establish the mean rate of primary productivity and its variability in the global ocean
- Quantify the oceanic portion of the global cycle of carbon and other elements and trace gases important to global biogeochemistry and oceanic biological processes
- Quantify how the oceans affect, and respond to, changes in global biogeochemical and climate processes
- Investigate and monitor coastal ocean processes, in particular human impacts on the coastal zone, and effects on fisheries resource utilization and management
- Predict oceanic optical properties, including that required for visible remote sensing and for national defense needs.

Role in Global Change

Biological and chemical processes in the upper ocean have a presumed large, but unknown, effect on concentrations of atmospheric carbon dioxide and the cycling of carbon in the global biosphere. Since the oceans cover 70 percent of the Earth's surface, these processes have a dynamic role in global change. SeaWiFS will deliver data that, in combination with data from process-oriented research programs, will contribute to the resolution of the ocean's role in the global carbon cycle.

Other trace gases, notably dimethylsulfide which has been implicated in the formation of cloud condensation nuclei, are also strongly affected by biological activity in the upper ocean. SeaWiFS will contribute to an understanding of processes affecting the fluxes of these trace gases across the air-sea interface.

Measurements to be Made and Resulting Data Products

Measurements will be made of upwelling radiance at eight spectral bands in the visible/near infrared (VNIR) portions of the spectrum at a spatial resolution of 1 km. The entire cloud-free globe will be imaged once per day. Data products will include daily global maps of oceanic pigment concentration; optical attenuation length scales; and visible, water-leaving radiances. The instrument, data system, and scientific investigations build on the experience gained from the Coastal Zone Color Scanner (CZCS).

Payload Elements/ Instrument Characteristics

Figure 17 provides a line drawing of SeaWiFS, and Table 24 gives a few basic facts about instrument capabilities.

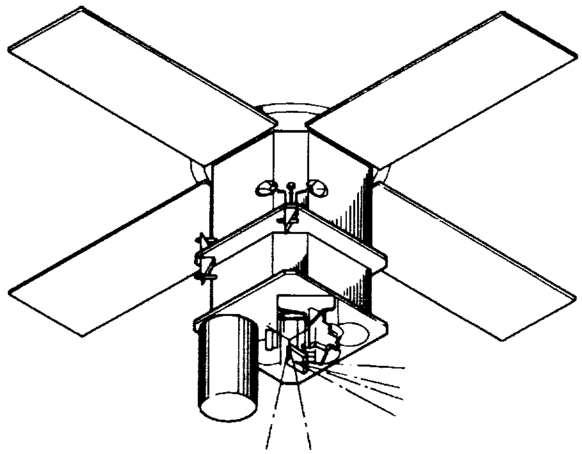

Figure 17. Sea-Viewing Wide Field Sensor

Table 24. SeaWiFS Instrument Characteristics

Instrument	8 VNIR band radiometer
Spatial Coverage	1-km spatial resolution over the global ocean
Temporal Coverage	Daily revisit (2800-km swath)
Data Rates	665 kbps (direct), 2.6 Mbps (tape dump)
Size	51 cm x 64 cm x 46 cm
Weight	25 kg (sensor/electronics)
Power	125 W peak
Launch Vehicle	Pegasus or Scout
Orbit	Polar, sun-synchronous, noon equatorial crossing, 700 km
Scheduled Launch	Late 1993

Data System Design, Archiving, and Data Distribution Plans

The SeaWiFS data system is in an advanced state of development and is based on the CZCS data system. Goddard Space Flight Center (GSFC) will be the primary archive of the data; 10 secondary distribution sites at U.S. universities and research centers will oversee distribution of processed data to the scientific community.

Mission Status

Proposed. Phase A/B studies are complete.

International Cooperation/Participation

International governmental and non-governmental bodies have been, and continue to be, active in the development of the U.S. ocean color program. Receiving stations for CZCS were maintained worldwide, and extensive scientific collaboration exists both in the analysis of CZCS ocean color data and in the planning for future missions. Principal proponents include the European Community, Japan, Canada, and Australia. At present, the largest demand for ocean color data arises from the Joint Global Ocean Flux Study (JGOFS), an international program under the auspices of the Scientific Committee for Oceanographic Research (SCOR), which is a core program of the International Geosphere-Biosphere Program (IGBP). Its goal is to evaluate the global fluxes of carbon and other biologically active elements in the ocean and their exchange with the atmosphere and sea floor.

Other large-scale international programs that will depend on ocean color data include the Tropical Ocean Global Atmosphere (TOGA) study, which will use equatorial heat and carbon fluxes data; the World Ocean Circulation Experiment (WOCE), which will use upper ocean heat fluxes and circulation data; and the International Global Atmospheric Chemistry (IGAC) program, which will use ocean boundary fluxes of carbon and sulfur compounds data. Many of the planned activities under the IGBP umbrella will also depend on SeaWiFS data. For all of these global programs, there is no substitute for spaceborne observations of the ocean biota.

Science Team Selection and Composition

Table 25 lists the members of the SeaWiFS Prelaunch Science Working Group.

Table 25. SeaWiFS Prelaunch Science Working Group

Investigator	Institution
W. Esaias (Chair)	NASA/GSFC
M. Abbott	Oregon State University
J. Aiken	IMER, England
R. Bidagare	Texas A&M University
P. Brewer	Woods Hole Oceanographic Institution
O. Brown	University of Miami
J. Campbell	Bigelow Laboratory
K. Carder	University of South Florida
P. Cornillon	University of Rhode Island
D. Clark	NOAA/NESDIS
C. Davis	Jet Propulsion Laboratory
K. Denman	IOS, Canada
H. Ducklow	University of Maryland
B. Evans	University of Miami
D. Eppley	Scripps Institute
H. Gordon	University of Miami
G. Harris	Commonwealth Scientific and Industrial Research Organization, Australia
P. Holligan	IOS, England
A. Morel	Villefrance, France
M. Perry	University of Washington
T. Platt	BIO, Canada
S. Matsumora	Far East Fishery, Japan
J. Mueller	San Diego State University
J. Simpson	Scripps Institute
R. Smith	University of California, Santa Barbara
C. Trees	San Diego State University
J. Walsh	University of South Florida
J. Yoder	University of Rhode Island

NASA Scatterometer (NSCAT)

Mission Goal and Objectives

NSCAT will fly on the Japanese Advanced Earth Observing Satellite (ADEOS) in 1995 (see Figure 18). NSCAT will provide frequent, accurate, all-weather high-resolution surface vector (speed and direction) wind measurements over the global oceans, which are required for studies in oceanography, meteorology, and air-sea interaction. Satellite scatterometers are the only instruments that can provide such measurements; therefore, the unique NSCAT vector wind data will enhance studies of geophysical phenomena with time scales ranging from hours to years. NSCAT measurements will allow, for the first time, calculation of large-scale fluxes of momentum, heat, and moisture between the atmosphere and ocean, thus contributing essential information to studies on air-sea coupling and interannual variability of the Earth's climate.

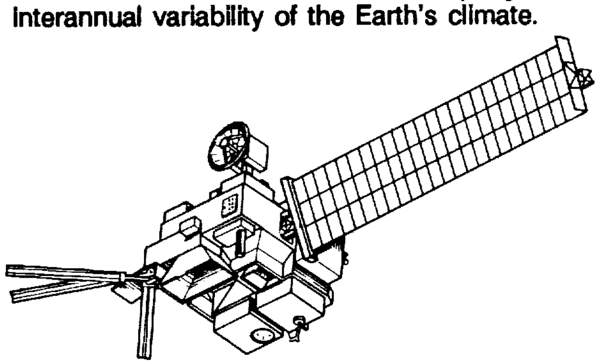

Figure 18. NASA Scatterometer on ADEOS

NSCAT will be a key contribution to the following major international ocean/atmosphere research programs: the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmosphere (TOGA) program, both of which are components of the World Climate Research Program (WCRP). Primary scientific objectives of NSCAT include studies of:

- Local, regional, and basin-wide ocean response to wind forcing
- Exchanges of heat, momentum, and water vapor between the oceans and atmosphere on a variety of scales
- Atmospheric circulation and meteorological phenomena over length and time scales resolved by NSCAT
- Techniques for the assimilation of NSCAT wind data into atmospheric, oceanographic, and coupled models
- Techniques for combining NSCAT wind measurements with other *in situ* or remotely sensed data with the aim of constructing accurate maps of atmospheric forcing functions for use by oceanographic and meteorological models.

The NSCAT mission will provide a foundation for a continuing program of long-term observations of the oceanic surface wind field and its variability, serving as a precursor to the scatterometry elements of the 15-year Earth Observing System (EOS) program.

Role in Global Change

NSCAT addresses fundamental processes in which the oceans and atmosphere play a role in moderating the Earth's climate. Surface marine winds modulate the fluxes of momentum, heat, and moisture between the atmosphere and ocean. These fluxes drive both the atmospheric and oceanic circulations, and are critical to understanding and developing accurate coupled atmosphere/ ocean circulation models needed for short- and long-range climate forecasting. NSCAT will contribute the single most important missing factor for advancing the understanding of wind-driven ocean circulation--the lack of systematic high-resolution wind observations over the ocean. Observations by ships and buoys are too sparse and of inconsistent quality. Present capabilities to model and predict climate phenomena, such as the El Nino in the tropical Pacific, are limited not by the physics represented in the models but by the deficiencies in available wind data used to force the models.

Measurements to be Made and Resulting Data Products

The primary requirement for NSCAT will be to measure the wind speed and direction at the air-sea interface. NSCAT directly measures the radar cross section (backscattered radar energy) of the ocean surface. The cross section is related to sea-surface roughness, which is a function of both wind speed and direction. By combining near-simultaneous and co-located backscatter measurements from different view angles, wind speed and direction are calculated. NSCAT vector wind measurements will be made in two 600-km-wide swaths, separated by a 300-km-wide gap at nadir. The broad NSCAT swaths and near-polar orbit of ADEOS result in virtually complete coverage of the ice-free oceans every 2 days, with a spatial resolution of 50 km (see Figure 19).

Payload Elements/ Instrument Characteristics

NSCAT will be one of two NASA instruments to fly on the Japanese ADEOS satellite, which is sponsored by the National Space Development Agency (NASDA) of Japan. Figure 20 provides a line drawing of the instrument detached from the ADEOS platform. In addition to NSCAT, ADEOS will carry the following instruments: Ocean Color and Temperature Scanner (OCTS) and Advanced Visible and Near-Infrared Radiometer (AVNIR) from Japan; Total Ozone Mapping Spectrometer (TOMS) from the U.S.; and Polarization and Directionality of Reflectances (POLDER) from France. The OCTS will provide high-resolution (1 to 4 km) ocean color and temperature to combine with the dynamics from the NSCAT wind fields. Refer to Table 26 for ADEOS launch information.

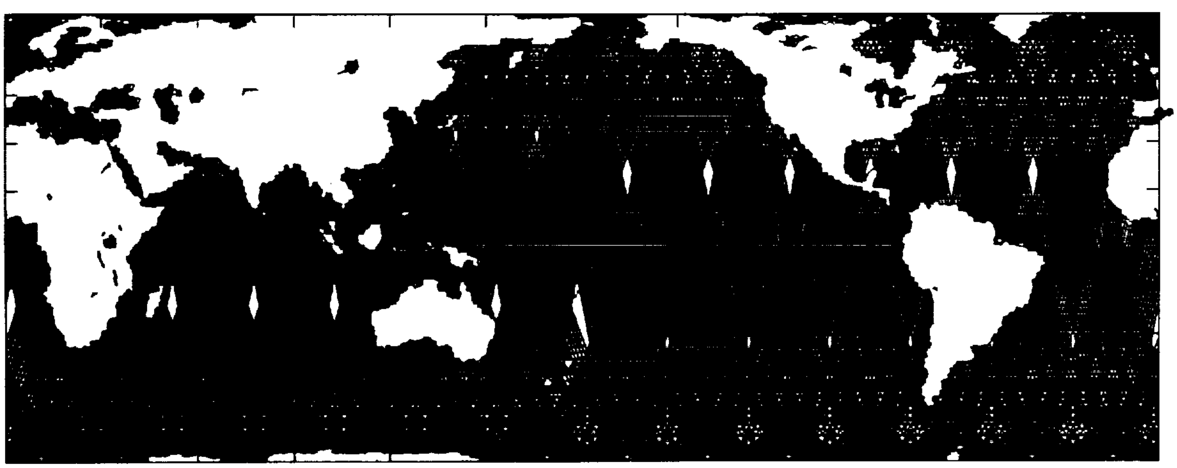

Figure 19. NSCAT/ADEOS 2-Day Coverage

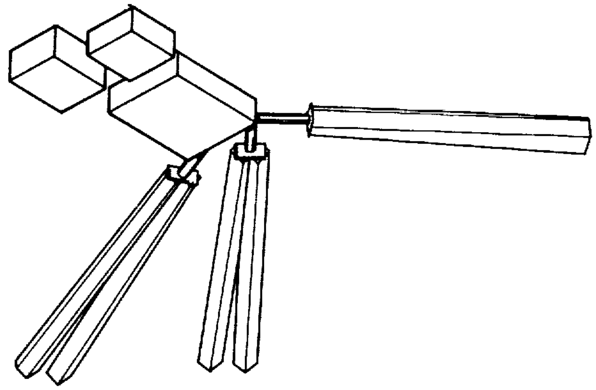

Figure 20. NASA Scatterometer

Table 26. ADEOS Launch Information

Launch Date	February 1995
Orbit	796-km altitude, 98.6° inclination, sun-synchronous
Duration	Nominally 3 years
Launch Vehicle	Japan H-2
Foreign Participation	NASDA
Measurement Accuracy	Greater than 2 m/s of 10% of the true wind speed; 20° rms in direction

Data System Design, Archiving, and Data Distribution Plans

NSCAT time-ordered data will be delivered to the NSCAT Project at the Jet Propulsion Laboratory (JPL) by NASDA. The project will compute geo-located backscatter and vector wind Geophysical Data Records (GDRs), and deliver these to the NASA Ocean Data System (NODS) at JPL for distribution to the NSCAT Science Working Team (SWT) within 2 weeks of acquisition. NODS is NASA's primary data distribution and archive facility for oceanographic satellite scatterometer data (as well as satellite altimeter and radiometer data from the unfrozen ocean). All NSCAT GDRs will be made openly available to the oceanographic and meteorological communities as soon as they are distributed to Principal Investigators. GDRs will also be provided to the NOAA National Oceanographic Data Center (NODC) archives.

Mission Status

NSCAT received a program start in FY 85 and was originally scheduled to fly on the U.S. Navy Remote Ocean Sensing System (NROSS) satellite in 1989. With the Navy cancellation of NROSS in March 1988, NASA submitted a proposal to NASDA to include NSCAT as a payload on ADEOS. NSCAT was selected by NASDA in January 1989, and confirmed in December 1989. Development of the instrument is in progress, with all major contracts in place and the flight antennas complete. Funding for the completion of NSCAT to fly on ADEOS is included in the Earth Probes Initiative for FY 91. The instrument is scheduled for delivery in November 1993. Launch date is February 1995.

International Cooperation/Participation

NSCAT is now developing into an international cooperative effort as a result of the agreement with Japan. NASA will provide the scatterometer, and Japan will provide the spacecraft, mission operations, and launch.

Science Team Selection and Composition

In 1986, based on proposals submitted in response to an Announcement of Opportunity (AO), NASA selected 14 science investigations representing the U.S., Canada, and France. Three science team meetings were held during 1986-1988, but none have been held since because of the uncertainties of the NROSS and ADEOS missions. Confirmation of the science team is planned for 1990. A second AO sponsored by NASDA, or jointly by NASDA and NASA, is being considered. Table 27 lists the current members of the NSCAT science team.

Table 27. NSCAT Science Team

Investigator	Institution
M. Freilich (Chair)	Jet Propulsion Laboratory
W.T. Liu	Jet Propulsion Laboratory
R.N. Hoffman	Atmospheric and Environmental Research, Inc.
M.A. Cane	Columbia University
R.A. Brown	University of Washington
R. Atlas	NASA/GSFC
J.G. Richman	Oregon State University
D.B. Chelton	Oregon State University
J.J. O'Brien	Florida State University
L.L. Fu	Jet Propulsion Laboratory
W.R. Holland	National Center for Atmospheric Research
R.C. Beardsley	Woods Hole Oceanographic Institution
M.A. Donelan	Canada Centre for Inland Waters, Canada
P. Cornillon	University of Rhode Island
M. Crepon	Laboratoire d'Oceanographie Physique du Museum, France

Tropical Rainfall Measuring Mission (TRMM)

Mission Goal and Objectives

At present, tremendous uncertainty exists about the quantity and distribution of precipitation, especially in the tropics; for example, the quantitative distribution of rainfall over tropical oceans is known only to within a factor of two. This uncertainty prohibits definition of the mass and energy exchange between the tropical ocean and atmosphere, thus limiting the accuracy with which scientists can model the general circulation of the atmosphere. Since the tropical atmosphere and oceans are closely coupled, cloud radiation and rainfall are likely to have significant effects on ocean circulation and marine biomass. Given the importance of understanding the hydrologic cycle of the tropics, the goal of TRMM is to obtain a minimum of 3 years of climatologically significant observations of rainfall in the tropics.

Because rainfall is such a variable phenomenon, adequate sampling is a difficult problem. By averaging the instantaneous rainfall rates for 30 days over a 5° by 5° grid, TRMM can obtain observations that meet climatological requirements. TRMM measurements, used together with cloud models, will also provide accurate estimates of the vertical distributions of latent heating in the atmosphere.

Role in Global Change

TRMM will play a significant role in global change studies, especially in developing an interdisciplinary understanding of atmospheric circulation, ocean-atmospheric coupling, and tropical biology. General circulation models require detailed data on the latent heating of equatorial air masses, and the forcing and propagation speed of waves involved in the 30- to 60-day tropical oscillations. TRMM data on tropical clouds, evaporation, and heat transfer will be used to understand the larger scale coupling of the atmosphere to oceans, especially in the development of El Nino events, and in the more general understanding of ocean-atmosphere circulation. Tropical rainfall is also closely coupled to tropical forest processes. Convective mixing of trace gases, including carbon dioxide and methane, provides a direct link between tropical rainfall and the global biogeochemical cycles that regulate life on Earth.

Measurements to be Made and Resulting Data Products

Current plans call for TRMM to include three principal types of instruments. The most innovative of these is the first quantitative Precipitation Radar to be flown in space. The TRMM Precipitation Radar will provide accurate measurements of rain rates over both land and ocean. When properly constrained by passive microwave measurements, the radar will obtain the height profile of precipitation content, from which the profile of latent heat release can be obtained.

The second class of instruments aboard the TRMM satellite is composed of two passive microwave sensors: Special Sensor Microwave/Imager (SSM/I) and the Electrically Scanning Microwave Radiometer (ESMR). SSM/I is a cross-track scanning, multichannel, dual-polarized passive microwave radiometer, and ESMR is a single-channel radiometer scanning in a similar mode. These two radiometers will yield rainfall rate measurements over the oceans; however, these measurements are less reliable over land, due to the inhomogeneity of the background surface emissivity. An Advanced Very High-Resolution Radiometer (AVHRR) is the third element in the TRMM instrument package. This sensor will provide a baseline for comparing TRMM results to visible and infrared measurements from past and future operational satellites, and will also aid in interpreting the active and passive microwave radar results.

Payload Elements/ Instrument Characteristics

The TRMM instrument complement (see Figure 21) will contain a Precipitation Radar, a modified AVHRR, and two passive microwave radiometers (i.e., ESMR and SSM/I). The ESMR is a space-qualified flight prototype from the Nimbus series of research satellites. The SSM/I is a copy of this radiometer developed for the operational Defense Meteorological Satellite Program (DMSP) series of satellites. Table 28 provides instrument-specific information.

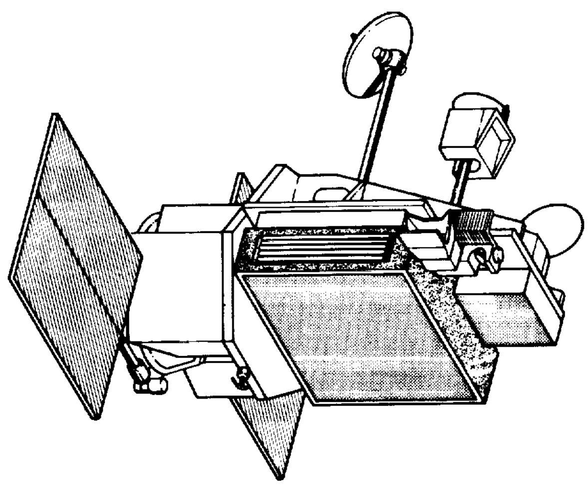

Figure 21. TRMM Instrument Complement

Plans call for the TRMM orbit to be circular at an altitude of 350 km and at an inclination of 35 degrees. This orbit will give intensive coverage in the tropics and will permit extraction of the diurnal cycle in climatological rainfall. The relatively low altitude also allows for much smaller instrumental footprints than those of previous microwave space sensors, leading to substantially more accurate retrieval capabilities of the rain variations, which normally occur over rather small space scales.

Data System Design, Archiving, and Data Distribution Plans

Instrument data will be transmitted via the Tracking and Data Relay Satellite System (TDRSS) once per orbit, and relayed through the White Sands Ground Tracking Facility to Mission Data Operations at NASA/Goddard Space Flight Center (GSFC) via Domsat. After formatting, processed level 0 data will be transmitted to Japan and to the TRMM Science Data Processing Center (SDPC) at GSFC via the NASA Communications Network (NASCOM). The SDPC will then process the data to generate several levels of science data products. Most of the data will be processed to basic physical parameters within 24 hours after receiving the level 0 data. Data processed by the SDPC will be available to TRMM science team members in the U.S. and Japan via telecommunications lines or through physical transfer of electronic storage media. Once the TRMM science team approves the release of data, products will be transferred to the National Space Science Data Center (NSSDC) at GSFC for archiving and distribution to general users.

Mission Status

The TRMM Science Steering Group Report was published in 1989. This report, written by an ad hoc team of distinguished scientists, documented the scientific requirements for the mission and the instrumentation needed to acquire these data. The TRMM Phase A study was completed in May 1988, and a Phase B study was initiated in September 1989. TRMM is a candidate for a New Start in FY 91 under the Earth Probes program in the NASA budget.

International Cooperation/Participation

NASA and the Science and Technology Agency of Japan will implement TRMM as a joint mission. Japan will provide the launch vehicle and the Precipitation Radar; NASA will provide the spacecraft, passive microwave sensors, the AVHRR, and the data system. There will also be broad international participation in the ground-based validation of the TRMM measurements. Much of this validation will be generated under the program, which is directed toward an understanding of the coupled tropical ocean-atmosphere system, with particular emphasis on El Nino/Southern Oscillation events. The Global Energy and Water Cycle Experiment (GEWEX), an initiative of the World Climate Research Program

(WCRP), will also employ and validate TRMM data. GEWEX objectives include a better understanding of the transport of water and energy in the global atmosphere, and the development of methods to predict changes in global water distribution. A number of other international programs, such as the International Geosphere-Biosphere Program (IGBP), will also use TRMM data for investigation of hydrologic processes important to global change.

Science Team Selection and Composition

The TRMM science team membership will be announced in 1990.

Table 28. TRMM Instrument Characteristics

	Bands	Swath Width	Footprint (min)	Footprint (max)	Data Rate
Precipitation Radar	14 GHz	220 km	4.3 x 4.3 km	5.0 x 4.5 km	85 kbps
ESMR	19.356 GHz	700 km	9 x 9 km	12 x 24 km	1 kbps
SSM/I	19.35 22.235, 37, 85.5 GHz,	580 km (@ 85 GHz)	4 x 5 km (@ 19 GHz)	16 x 23 km	3.3 kbps
AVHRR	665 (20), 650 (50), 1610 (60) nm* 6.72 (0.36), 10.7 (1.0), 12.0 (1.0) μm*	700 km	1 X 1 km	2 X 3 km	80 kbps

* bandcenter (bandwidth)

Magnetic Field Experiment (MFE)/Magnolia

Mission Goal and Objectives

Understanding the physical mechanisms that generate the Earth's magnetic field was described by Einstein as one of the most important unsolved problems in modern physics. In pursuing this problem, the MFE/Magnolia mission will address the following scientific objectives:

- Derive an accurate description of the main field and its secular variation throughout the measurement interval
- Investigate the correlation between changes in the geomagnetic field and length-of-day variations
- Study properties of the core fluid and their correlation with Earth rotation
- Study the conductivity of the mantle, and investigate ionospheric currents and field-aligned currents coupling the ionosphere and magnetosphere
- Measure the global morphology of the Earth's electric field at all local times and latitudes
- Investigate the relationship between large-scale structure in the direct current electric field with simultaneous measurements of ionospheric currents
- Investigate the vector electric fields of both electrostatic and electromagnetic plasma waves in space.

Figure 22 highlights the regions that will be studied in meeting the above objectives.

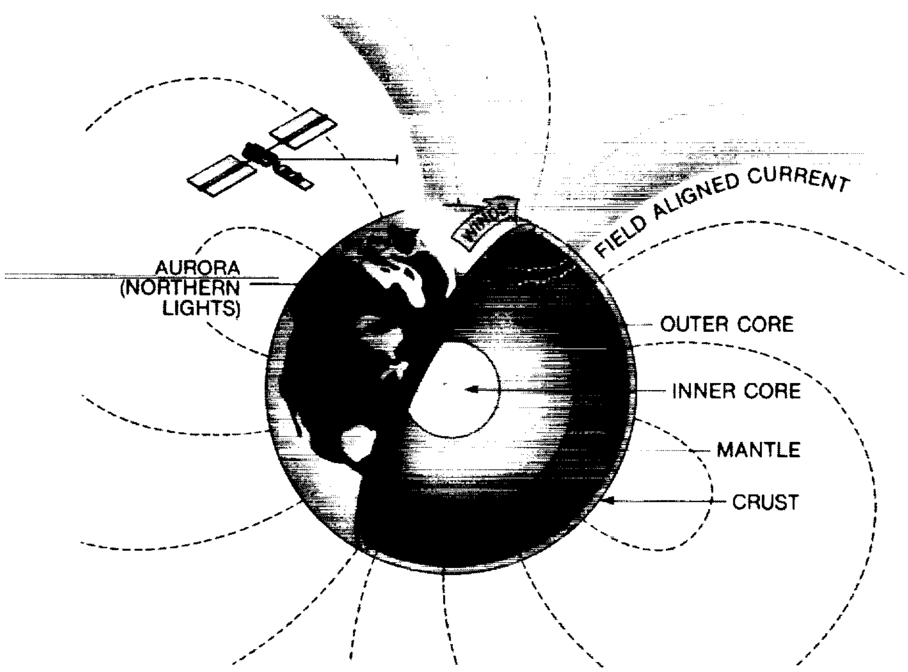

Figure 22. Important Regions to be Addressed by MFE/Magnolia

The measurements involved require decade-long observations from spaceborne platforms. When combined with the data from Magsat (1980), the data from MFE/Magnolia will give an estimate of the temporal change of the Earth's main field between those missions; yet, adequate long-term monitoring of field variation will require judicious phasing of more than just these missions. The ARISTOTELES mission described in the next section and the Geomagnetic Observing System (GOS) experiment of the Earth Observing System (EOS) era are viewed as extensions of MFE/Magnolia. Figure 23 identifies the key issues that said missions need to resolve.

Role in Global Change

The change in strength of the magnetic field has direct application to global change. The rate of change of the dipole field correlates closely with changes in length of day; magnetic disturbances cause current surges in power systems and in oil transfer pipes; and the steady decrease in the strength of the field since 1840 poses a potential threat to life on Earth. The Earth's dipole field reverses itself in a way that is not well understood, but which

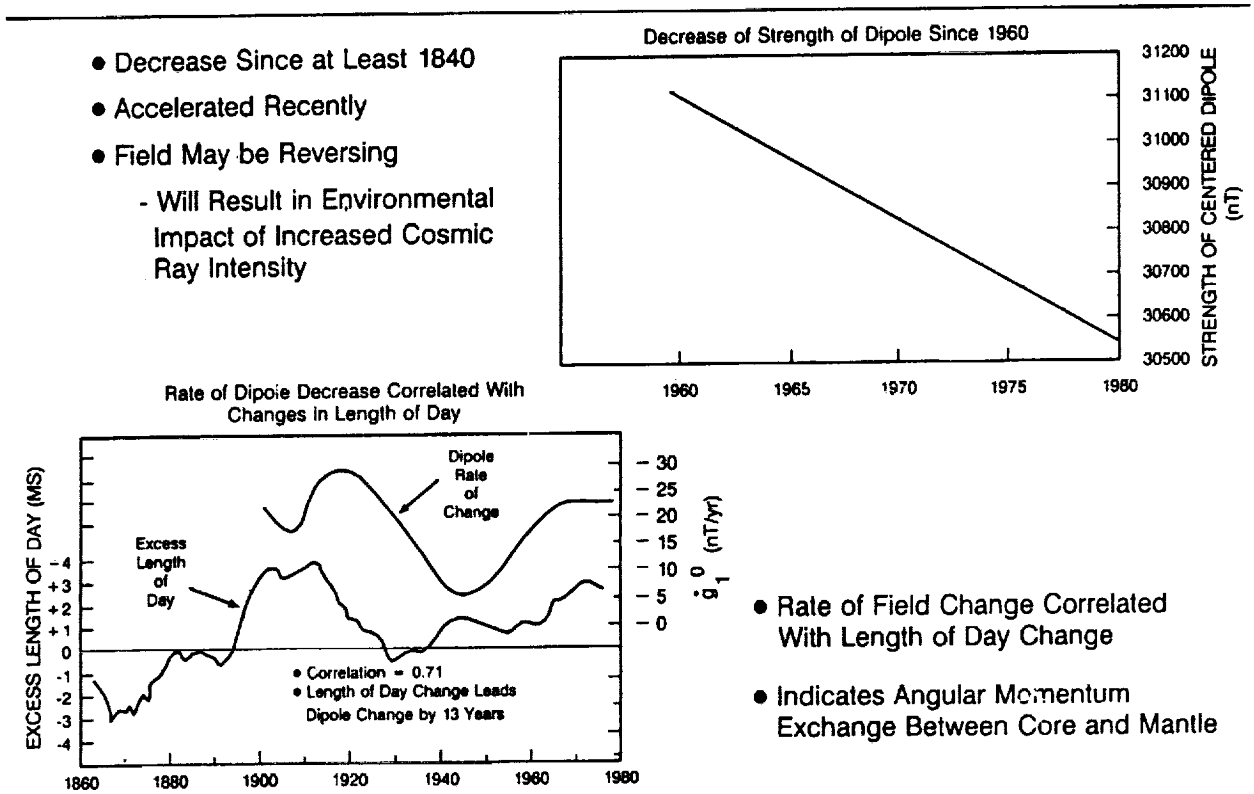

Figure 23. Temporal Change of the Geomagnetic Field

has been well documented. There have been three major magnetic field reversals within the last million years. The resulting rapid decrease in field strength results in destruction of the Earth's ozone layer during solar flares as a result of increased exposure to cosmic rays. Understanding the mechanisms through which Earth's main field is generated and how and why it changes with time drives studies into the nature, composition, thermal budget, and circulation of Earth's core and mantle.

Payload Elements/ Instrument Characteristics

Five instruments are proposed for MFE/Magnolia: two NASA magnetometers, two Centre National d'Etudes Spatiales (CNES) magnetometers, and one NASA-provided electric field instrument. The NASA precision fluxgate vector magnetometer, a copy of that used on the Magsat mission, will measure the projections of the ambient field in three orthogonal directions. The NASA scalar helium magnetometer (similar to those used in several planetary missions) will measure the magnitude of the total field independent of its orientation with respect to the sensor. The scalar measurement is absolute, and is used to calibrate the vector instrument. CNES will provide a scalar proton magnetometer, using electronically pumped nuclear magnetic resonance, and a fluxgate vector magnetometer. A technical objective of the mission is to cross-check the NASA and CNES magnetometers. A three-axis double probe electric field instrument will study the direct current and wave electric field structure of the Earth's ionosphere. Refer to Figure 24 for a cross section of the instrument complement.

Measurements to be Made and Resulting Data Products

The instruments on MFE/Magnolia will measure:

- Projections of the ambient field in three orthogonal directions
- The magnitude of the total field independent of its orientation with respect to the sensor
- The direct current and wave electric field structure of the Earth's ionosphere.

Data products include processed scalar magnetometer data and processed vector magnetometer data in spacecraft coordinates, in topocentric coordinates using the intermediate attitude determinations, and in topocentric coordinates using the time-attitude determinations.

Data System Design, Archiving, and Data Distribution Plans

Data will be collected on two spacecraft tape recorders. Recorded data will be played back via S-band transponder to the Applied Physics Laboratory (APL) ground station and forwarded to Goddard Space Flight Center (GSFC) for processing. Orbit determination will be required throughout the mission. APL will arrange for very high frequency Doppler tracking data to be acquired and processed by the Defense Mapping Agency. The scalar and vector magnetometer data are separated from the processed telemetry data and forwarded to the project scientists on daily tapes. Processing by the project scientist includes establishing validity of the data and the time assigned to it, intercomparing data from the various magnetometers, determining and applying recalibration as necessary, converting the data to topocentric coordinates, deriving initial field models, and formatting the data for distribution to the various investigators.

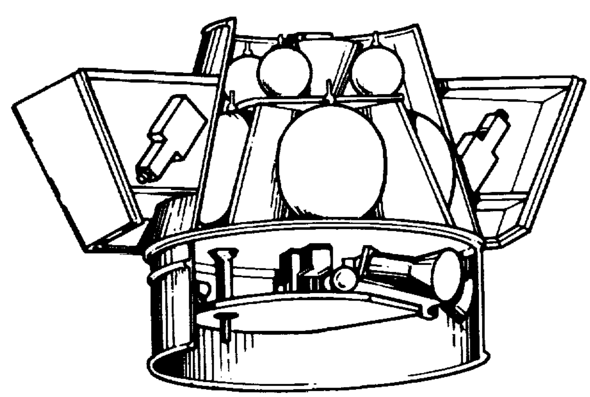

Figure 24. Magnetic Field Experiment (MFE)/Magnolia

Preliminary data will be distributed to the investigator team in a coordinated manner by CNES and NASA as soon as possible. For the first few months, French and U.S. data will not be intercompared. After this initial period, fully corrected and calibrated data (from French and U.S. experiments) will be intercompared and differences suitably accounted for. One year after release to the investigator team, the data will be made available to the general scientific community. Full documentation of the magnetometers, calibrations and corrections, quality information/data quirks, and tape formats will be prepared by the project scientists. NASA will release data via the National Space Science Data Center (NSSDC), and CNES will release data via the data center at CNES Toulouse.

Mission Status

NASA and CNES have completed joint Phase A and Phase B studies, which have been well received both programmatically and by the scientific community. NASA and CNES executives up to the Associate Administrator level have met to express interest and to discuss respective agency roles and schedules for this mission. Further commitment depends upon the details associated with approval of the Earth Probes program in the NASA budget.

International Cooperation/Participation

MFE/Magnolia is a proposed joint project between NASA and CNES.

Science Team Selection and Composition

Approximately 3 years prior to the launch of MFE/Magnolia, NASA and CNES will coordinate a simultaneous issue of Research Announcements. Proposals to use data from MFE/Magnolia to study main field magnetics will be solicited, with review and selection by each agency run in parallel. Presumably, the international team of investigators will include U.S., European, and Asian representation. The group will meet twice a year in the U.S and in France, beginning approximately 2 years before launch.

Applications and Research Involving Space Technologies Observing the Earth's Field from Low Earth Orbiting Satellite (ARISTOTELES)

Mission Goal and Objectives

ARISTOTELES is a proposed European Space Agency (ESA)/NASA multistage mission that will begin scientific observation from an altitude of about 200 km for 6 to 8 months, then move to an elevation of 800 km for 3+ years of operation. A gravity gradiometer, onboard Global Positioning System (GPS) receiver, and suite of magnetometers comprise the scientific payload.

Earth structure and mineralogy is reflected in both the magnetic and gravity crustal fields. ARISTOTELES will, for the first time, measure both these quantities simultaneously and with the same resolution. Interpretation of the two data sets together can reduce ambiguities inherent in either data set taken alone. The ARISTOTELES gravity data will provide a high-resolution and high-precision equipotential surface that will serve as a basic reference for past and future altimetry missions.

With a lifetime of over 3 years, ARISTOTELES magnetometers will contribute to the long-term monitoring of the Earth's main field, as described in the section on MFE/Magnolia:

- Understand the physical mechanisms through which the Earth's magnetic field is generated
- Monitor the current decrease in the strength of the magnetic field
- Monitor the relationship between magnetic field rate of change and changes in the length of day.

Role in Global Change

ARISTOTELES will generate important information about the Earth during both the low- and high-altitude portions of the mission. A high-resolution reference surface (i.e., geoid) for past and future altimetry missions will be particularly valuable in the study of the long-term variability of the ocean surface, providing one of the basic building blocks for systematic and sustained study of the oceanic response to global change.

Study of the current state of the Earth's crust via gravity and magnetic fields contributes substantially in determining the evolution of that crust. ARISTOTELES magnetic field data will map broad magnetization variations resulting from changing mineralogy, topography, structure, and depth to the Curie isotherm. These reflect the past history of the rock (e.g., the chemistry of the rock source and the tectonic processes by which it was formed), the thermal and mechanical history of the rock formation, and chemical alteration. Continental crustal magnetic features mapped at lower resolution (see Figure 25) show a close correspondence to geological features and contribute to understanding their three-dimensional structure.

Monitoring the change in strength of the field has direct application to global change. The rate of change of the dipole field correlates closely with changes in length of day; magnetic disturbances cause current surges in power systems and oil transfer pipes; and the steady decrease in the strength of the field since 1840 poses a potential threat to life on Earth. The Earth's dipole field reverses itself in a way that is not well understood but which has been well documented. There have been three major magnetic field reversals within the last million years. The resulting rapid decrease in field strength results in destruction of the Earth's ozone layer during solar flares due to increased exposure to cosmic rays.

Payload Elements/ Instrument Characteristics

The non-drag free gradiometer will be planar, fixed to the satellite body, and consist of four accelerometers. The accelerometers have two highly sensitive measurement axes perpendicular to flight direction, with a third axis

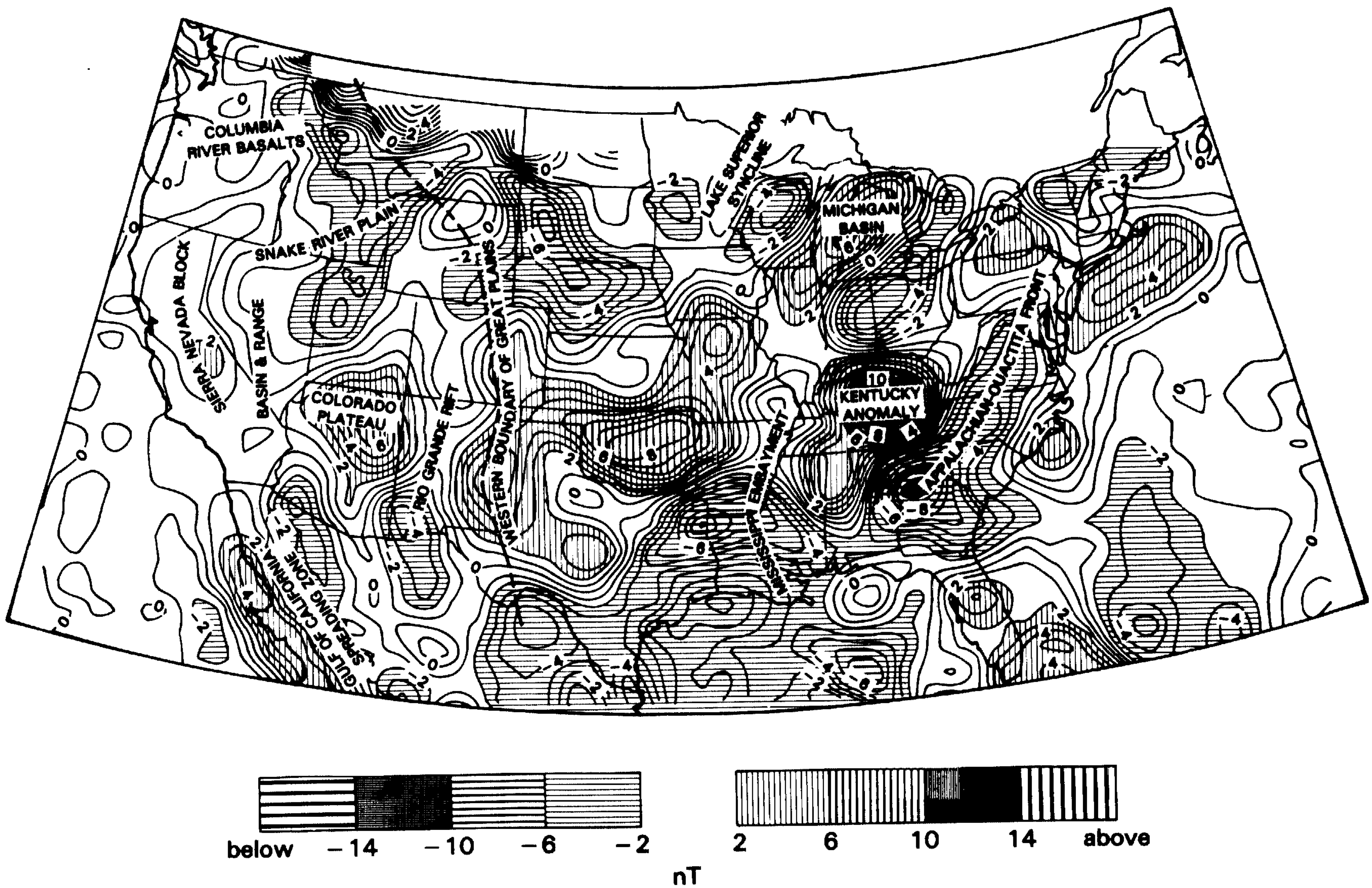

Figure 25. Magnetic Anomaly Map of the U.S.

less sensitive in order to cope with the decelerations resulting from atmospheric drag. A central calibration device allows matching alignment and scale factors of the individual sensors. The accelerometer proof mass consists of Pt-Rh alloy (320 g; 4 x 4 x 1 cm^3). The cage surrounding the proof mass and carrying 12 internal electrodes consists of three gold-plated slats of ultralow expansion titanium silicate glass.

The magnetometer mission will include a precision fluxgate vector magnetometer and a scalar helium magnetometer that will measure the magnitude of the total field. The scalar measurement is absolute, and is used to calibrate the vector instrument. In order to eliminate the perturbing magnetic field of the spacecraft, the magnetometers will be separated from the main craft by a boom of approximately 3 m. See Figure 26 for more detail.

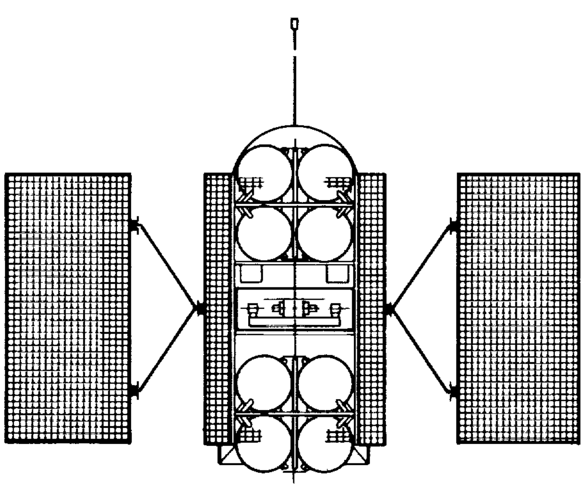

Figure 26. ARISTOTELES

The payload will include an onboard GPS receiver and ground tracking support such as that provided for NASA's TOPEX/Poseidon mission; the experimental microwave tracking system will be made up of about seven operational tracking ground stations.

Measurements to be Made and Resulting Data Products

The low-altitude mission will produce global gravity data accurate to ±5 mgals at 100-km resolution and global crustal magnetic anomaly data accurate to better than 2 nT at 200-km resolution. Such global data sets are unprecedented in terms of resolution level and internal consistency. A high-resolution global geoid will be determined, against which oceanic surface variation could be assessed, filling an important gap in wavelengths of less than about 1,000 to 1,500 km for the study of sea-surface elevations across specific current systems.

The high-altitude mission will produce global magnetic field data accurate to better than 2 nT sufficient to resolve the observable main field. Continuous position determination accuracy in the range of 25 to 35 m will be made by an onboard GPS receiver, with an internal computer to perform real-time processing of the received codes. In addition, an experimental microwave tracking system will provide precise operational orbit determination measurements during the entire mission.

Data to be made available to investigators will consist of both preprocessed and analyzed data (i.e., magnetic anomaly maps, magnetic field maps, geoid constructions).

Data System Design, Archiving, and Data Distribution Plans

The data system design will combine the best features of the Magsat data system and the Crustal Dynamics Data Information System (CDDIS). The CDDIS resides on a dedicated Dec MicroVAX II computer at Goddard Space Flight Center (GSFC). The facility is available 24 hours per day, 7 days per week, and is accessible for interactive log-ins through SPAN, ARPAnet/INTERnet, GTE TELENET, and NASA/GSFC autobaud. These data will be distributed or made available by NASA to its investigators. A similar data set will be distributed by ESA to its investigators. Countries that have executed a Memorandum of Understanding (MOU) or Letter Agreement with NASA will also have access to the Data Information System (DIS) products.

Mission Status

NASA and ESA executives up to the Associate Administrator level have met to express interest and to discuss respective agency roles and schedule for this mission. Further commitment depends upon the details associated with approval of the Earth Probes program in the NASA budget.

International Cooperation/Participation

ARISTOTELES is a proposed joint project of NASA and ESA. NASA provides the magnetometers, attitude transfer system, optical bench, onboard GPS receiver, and launch vehicle (Delta 2 type). ESA provides the gravity gradiometer, star trackers, the magnetometer boom, and the instrument platform. Ground tracking support will be provided by both NASA and ESA.

Science Team Selection and Composition

Approximately 3 years prior to the launch of ARISTOTELES, NASA and ESA will coordinate a simultaneous issue of Research Announcements in the areas of crustal magnetics, main field magnetics, and gravity studies using data from ARISTOTELES. Review of proposals and announcement of selections will be run in parallel. The international team of investigators will include U.S., European, and Asian representation. The group will meet twice a year in the U.S. and in Europe, beginning approximately 2 years before launch.

ACRONYMS

ACR	Active Cavity Radiometer
ACRIM	Active Cavity Radiometer Irradiance Monitor
ADC	Affiliated Data Center
ADEOS	Advanced Earth Observing Satellite
AIRS	Atmospheric Infrared Sounder
ALT	Altimeter
AMRIR	Advanced Medium-Resolution Imaging Radiometer
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
AO	Announcement of Opportunity
AOS	Archive and Operations System
APL	Applied Physics Laboratory
ARC	Ames Research Center
ARISTOTELES	Applications and Research Involving Space Technologies Observing the Earth's Field from Low Earth Orbiting Satellite
ASF	Alaska SAR Facility
ASI	Agenzia Spaziale Italiano
ATLAS	Atmospheric Laboratory for Applications and Science
ATMOS	Atmospheric Trace Molecules Observed by Spectroscopy
AVHRR	Advanced Very High-Resolution Radiometer
AVNIR	Advanced Visible and Near-Infrared Radiometer
BFPQ	Block Floating Point Quantizer
BMFT	Bundesministerium fur Forschung und Technologie
Cal/Val	Calibration/Validation
CCT	Computer-Compatible Tape
CDDIS	Crustal Dynamics Data Information System
CDOS	Customer Data and Operations System
CDP	Crustal Dynamics Project
CDR	Critical Design Review
CEOS	Committee on Earth Observations Satellites
CERES	Clouds and Earth's Radiant Energy Systems
CES	Committee on Earth Science
CFC	Chlorofluorocarbon
CLAES	Cryogenic Limb Array Etalon Spectrometer
CNES	Centre National d'Etudes Spatiales
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CRISTA	Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere
CSIRO	Commonwealth Scientific and Industrial Research Organization
CZCS	Coastal Zone Color Scanner
DAAC	Distributed Active Archive Center
DADS	Data Archive and Distribution System
DCF	Data Capture Facility
DDHS	Digital Data Handling System
DIS	Data Information System
DLR	German Aerospace Research Establishment
DMA	Defense Mapping Agency
DMSP	Defense Meteorological Satellite Program
DOD	Digital Optical Disk
DoD	Department of Defense
DORIS	Determination d'Orbite et Radiopositionement Integre par Satellite
EC	European Community
EDC	EROS Data Center
EOC	EOS Operations Center
EOS	Earth Observing System

EOSDIS	EOS Data and Information System
EOSP	Earth Observing Scanning Polarimeter
ERBE	Earth Radiation Budget Experiment
ERL	Environmental Research Laboratory
EROS	Earth Resources Observation System
ERS-1	European Remote Sensing Satellite-1
ERS	Earth Remote Sensing Satellite
ESA	European Space Agency
ESAD	Earth Science and Applications Division
ESJWG	Earth Science Joint Working Group
ESMR	Electronically Scanning Microwave Radiometer
FAO	Food and Agriculture Organization
FFT	Fast Fourier Transform
FRG	Federal Republic of Germany
FST	Field Support Terminal
GCRP	Global Change Research Program
GDR	Geophysical Data Record
Geosat	Geodesy Satellite
GEWEX	Global Energy and Water Cycle Experiment
GGI	GPS Geoscience Instrument
GIMMS	Global Inventory and Monitoring and Modeling Study
GLRS	Geoscience Laser Ranging System
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GOS	Geomagnetic Observing System
GPC	Global Processing Center
GPS	Geophysical Processor System
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
HALOE	Halogen Occultation Experiment
HIMSS	High-Resolution Microwave Spectrometer Sounder
HIRDLS	High-Resolution Dynamics Limb Sounder
HIRIS	High-Resolution Imaging Spectrometer
HPA	High-Power Amplifier
HRDI	High Resolution Doppler Imager
HRV	High-Resolution Visible
ICA	International Central Archive
ICF	Instrument Control Facility
ICSU	International Council of Scientific Unions
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere-Biosphere Program
IICF	Interdisciplinary Investigator Computing Facility
IMS	Information Management Service
IPEI	Ionospheric Plasma and Electrodynamics Instrument
IPOC	International Partner Operations Center
IR	Infrared
IRIS	Italian Research Interim Stage
IRR	Integrated Requirements Review
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISCCP	International Satellite Cloud Climatology Project
ISLSCP	International Satellite Land Surface Climatology Project
ISOC	Integrated Science Operations Center
IST	Instrument Support Terminal
ISY	International Space Year
ITIR	Intermediate Thermal Infrared Radiometer

IWG	Investigator Working Group
IWGDMGC	Interagency Working Group on Data Management for Global Change
JERS-1	Japanese Earth Resources Satellite-1
JGOFS	Joint Global Ocean Flux Study
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JWG	Joint Working Group
KSC	Kennedy Space Center
LAGEOS	Laser Geodynamics Satellite
LaRC	Langley Research Center
LAS	LAGEOS Apogee Stage
LAWS	Laser Atmospheric Wind Sounder
LeRC	Lewis Research Center
LLR	Lunar Laser Ranging
LNA	Low-Noise Amplifier
MAPS	Measurement of Air Pollution from Satellites
MAS	Millimeter-Wave Atmospheric Sounder
McIDAS	Man-Computer Interactive Data Access System
MERIS	Medium-Resolution Imaging Spectrometer
METEOSAT	Meteorology Satellite
MFE	Magnetic Field Experiment
MIMR	Multiband Imaging Microwave Radiometer
MISR	Multi-Angle Imaging Spectro-Radiometer
MLS	Microwave Limb Sounder
MODIS-N/T	Moderate-Resolution Imaging Spectrometer-Nadir/Tilt
MOPITT	Measurements of Pollution in the Troposphere
MOU	Memorandum of Understanding
MSFC	Marshall Space Flight Center
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASDA	National Space Development Agency
NCDS	NASA Climate Data System
NCF	NSSDC Computer Facility
NESDIS	National Environmental Satellite, Data, and Information Service
NIR	Near Infrared
NOAA	National Oceanographic and Atmospheric Administration
NODC	National Oceanographic Data Center
NODS	NASA Ocean Data System
NRL	Naval Research Laboratory
NROSS	Navy Remote Ocean Sensing System
NSCAT	NASA Scatterometer
NSIDC	National Snow and Ice Data Center
NSSDC	National Space Science Data Center
NWS	National Weather Service
OCTS	Ocean Color and Temperature Scanner
OH	Hydroxyl
PAR	Photosynthetically Active Radiation
PC	Personal Computer
PDR	Preliminary Design Review
PEM	Particle Environment Monitor
PGS	Product Generation System
PI	Principal Investigator
PICF	Principal Investigator Computing Facility

PIPOR	Programme of International Polar Oceans Research
PISP	Polar Ice Sheet Program
PLDS	Pilot Land Data System
POEMS	Positron Electron Magnet Spectrometer
POIC	Payload Operations Integration Center
POLDER	Polarization and Directionality of Reflectances
PRC	People's Republic of China
PRF	Pulse Repetition Frequency
P/S	Planning and Scheduling
RA	Radar Altimeter
Radarsat	Radar Satellite
RGS	Receiving Ground Station
SAFIRE	Spectroscopy of the Atmosphere Using Far Infrared Emission
SAGE	Stratospheric Aerosol and Gas Experiment
SAR	Synthetic Aperture Radar
SBUV/2	Solar Backscatter Ultraviolet/Version-2
SCC	Satellite Calibration Center
SCF	Science Computing Facility
SCOR	Scientific Committee for Oceanographic Research
SDPC	Science Data Processing Center
SeaWiFS	Sea-Viewing Wide Field Sensor
SIR	Spaceborne Imaging Radar
SIR-C	Shuttle Imaging Radar-C
SLR	Satellite Laser Ranging
SMC	System Management Center
SNR	Signal-to-Noise Ratio
SOLCON	Solar Constant
SOLSPEC	Solar Spectrum
SOLSTICE	Solar/Stellar Irradiance Comparison Experiment
SPAN	Space Physics Analysis Network
SPAS	Shuttle Pallet Satellite
SPC	Sector Processing Center
SPOT	Systeme pour l'Observation de la Terre
SPS	SAR Processor System
SSBUV	Shuttle Solar Backscatter Ultraviolet
SSM/I	Special Sensor Microwave/Imager
STS	Space Transportation System
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
SWG	Science Working Group
SWIRLS	Stratospheric Wind Infrared Limb Sounder
SWT	Science Working Team
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
TES	Tropospheric Emission Spectrometer
TGT	TDRSS Ground Terminal
TIR	Thermal Infrared
TIROS	Television Infrared Operational Satellite
TM	Thematic Mapper
TMCF	Team Member Computing Facility
TMR	TOPEX/Poseidon Microwave Radiometer
TOGA	Tropical Ocean Global Atmosphere

TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment
TOVS	TIROS Operational Vertical Sounder
T/R	Transmit/Receive
TRACER	Tropospheric Radiometer for Atmospheric Chemistry
TRMM	Tropical Rainfall Measuring Mission
U.S.	United States
UARS	Upper Atmosphere Research Satellite
UK	United Kingdom
USAF	United States Air Force
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UV	Ultraviolet
VIR	Visible Infrared
VIS	Visible
VISSR	Visible Infrared Spin-Scan Radiometer
VLBI	Very Long Baseline Interferometry
VNIR	Visible and Near Infrared
WCRP	World Climate Research Program
WEGENER	Working Group of European Geoscientists for the Establishment of Networks for Earthquake Research
WGD	Working Group on Data
WINDII	Wind Imaging Interferometer
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
X-SAR	X-Band Synthetic Aperture Radar
XIE	X-Ray Imaging Experiment