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Paper Session II-B - Mission to Planet Earth Program Overview

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GLOBAL CLIMATE CHANGE

To understand global change and the increasing demands of human activity, it is essential that we monitor and comprehend how the Earth works as a system. In the next century, planet Earth faces the potential hazard of rapid environmental change, including climate warming, rising sea level, deforestation, desertification, ozone depletion, acid rain, and reduction in biodiversity. Such changes would have a profound impact on all nations, yet many important scientific questions remain unanswered. For example, while most scientists agree that global warming is likely, its magnitude and timing (especially at the regional level) are quite uncertain. Additional information on the rate, causes, and effects of global change is essential to develop the understanding needed to cope with it. The National Aeronautics and Space Administration (NASA) is working with the national and international scientific communities to establish a sound scientific basis for addressing these issues through research efforts coordinated under the U.S. Global Change Research Program (USGRP), the International Geosphere-Biosphere Program (IGBP), and the World Climate Research Program (WCRP).

The USGRP is an integrated effort of nine U.S. governmental agencies under the auspices of the Committee on Earth and Environmental Sciences (CEES); the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the Department of Commerce/National Oceanic and Atmospheric Administration (NOAA), the Department of the Interior (DOI), U.S. Department of the Agriculture (USDA), the Environmental Protection Agency (EPA), the Department of Energy (DOE), the Smithsonian Institute, and the Department of Defense (DoD).

Space exploration has changed the way we view the Earth. Photographs from space show the limits of a world dominated by water and shielded from space by a thin layer of atmosphere. From this perspective we see the Earth as a whole - the land, oceans, and atmosphere that provide our life-supporting environment.

Observations from space have provided extensive global views that allow us to study the Earth as a unified system. This systematic approach to Earth science will help us understand how local activities might produce effects on a worldwide or global scale. The goal is to understand relationships among atmosphere, land, and ocean processes on scales that range from chemical reactions to global climate change. To do this. Earth science needs an interdisciplinary approach that combines the classical disciplines of physics, chemistry, and biology.

MISSION TO PLANET EARTH

Global studies require new and different tools. NASA will contribute to this effort through its Mission to Planet Earth (MTPE), which began in 1991 as a part of the U.S.

Global Change Research Program. The MTPE focuses NASA's experience in planetary and space research on studies of the Earth.

The goal of the MTPE is to establish the scientific basis for national and international policymaking relating to natural and human-induced changes in the global Earth system. To accomplish this goal; an integrated, comprehensive, and sustained program will be established to document the Earth system on a global scale; a program of focused and exploratory studies will be conducted to improve the understanding of the physical, chemical, biological, and social processes that influence Earth system changes and trends on global and regional scales; and integrated, conceptual, and predictive Earth system models on global and regional scales will be developed.

NASA's CONTRIBUTION TO THE GLOBAL CHANGE RESEARCH PROGRAM

- MTPE Phase 1 Missions:

NASA SATELLITES (Launch Status)	MISSION OBJECTIVES
ERBS (Operating) Earth Radiation Budget Satellite	Radiation budget, aerosols, and ozone
TOMS/Meteor-3 (Operating) Total Ozone Mapping spectrometer	Ozone mapping and monitoring (joint with Russia)
UARS (Operating) Upper Atmosphere Research Satellite	Stratospheric and mesopheric chemistry.
TOPEX/Poseidon (Operating) Ocean Topography Experiment	Ocean circulation (joint with France)
LAGEOS-2 (Operating) Laser Geodynamics Satellite	Crustal motion and Earth rotation (joint with Italy)
Shuttle-based experiments (1992 on) - **ATLAS** - **SIR-C** - **LITE**	Atmospheric and solar dynamics (ATLAS), atmospheric aerosols (LITE), and surface radar backscatter, polarization, and phase function (SIR-C and X-SAR (joint with Germany)
SeaWIFS (March 1994) Sea-Viewing Wide Field Sensor	Ocean primary production (data purchase)
TOMS/Earth Probe (July 1994) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring
NSCAT/ADEOS (February 1996) NASA Scatterometer	Ocean surface wind speed and direction (joint with Japan)
TOMS/ADEOS (February 1996) Total Ozone Mapping Spectrometer	Ozone mapping and monitoring (joint with Japan)
TRMM (August 1997) Tropical Rainfall Measuring Mission	Precipitation, clouds, and radiation in low latitudes (joint with Japan)
Landsat-7 (September 1998) Land-Remote Sensing Satellite	Land surface features at high spatial resolution

NASA's CONTRIBUTIONS, cont.

- o EARTH PROBES:
  Earth Probes are satellite missions that address specific Earth science observational requirements complementing EOS with critical near term observations. Earth Probes will provide a focus on observing specific Earth processes where smaller platforms and/or different orbits from EOS are needed. The goal these small to moderate-sized spacecraft and instruments have will be an economical, rapid-response, scientific gap filler. Missions already approved are:
  TRMM (Tropical Rainfall Measuring Mission) launch in 1997,
  TOMS (Total Ozone Mapping Spectrometer) launch in 1996, and
  NSCAT (NASA Scatterometer) launch in 1996 on ADEOS.
  Missions proposed are:
  TOMS/Russian METEOR 3 (TOMS instrument on Russian Spacecraft)
  SAGE/Russian METEOR 3 (Stratospheric Aerosol and Gas Experiment III)
  GAMES (Gravity and Magnetic Earth Surveyor mission)

- o LANDSAT
  Public Law 102-555 was passed by Congress in October 1992 which repeals the Land Remote Sensing Commercialization Act of 1984. The new law removes full commercialization of Landsat as a near-term goal of U.S. policy. NASA is now establishing a program to procure, launch, and operate a Landsat-7 to maintain continuity with Landsat-4 through -6, and undertake a technology development program for future land remote-sensing systems.

- o EARTH OBSERVING SYSTEM (EOS)

The central element in MTPE is the Earth Observing System (EOS). The EOS has three components: a series of Earth-observing satellites, an advanced computing system, and teams of scientists.

The objectives of the EOS are to:

- * Establish an integrated, sustained, and comprehensive program to observe the Earth on a global scale;
- * Conduct focused and exploratory studies to improve understanding of the physical, chemical, biological, and social processes that influence the Earth's climate;
- * Develop models of the Earth system to integrate and predict climate changes; and
- * Assess impacts of natural events and human activities on the Earth's climate.

The overriding goal of the EOS is to establish the scientific basis for informed policy decisions related to our influence on the global environment.

Scientists have known of and studied for decades many of the scientific issues described in the following sections. What is different is the challenge of unifying these studies to produce an understanding of the Earth as a single system The EOS is the most ambitious single project dedicated to Earth system science and global climate change research. Building on existing and near-term missions, the EOS is supporting scientific studies and improving access to existing data that yield valuable information about the Earth and its climate system. In 1998, EOS leadership in climate change research will grow considerably by beginning a 15-year series of consistent, high-quality, global observations.

The EOS Investigators Working Group (IWG) has defined the following science and policy priorities for EOS observations, based on IPCC, EPA, and CEES recommendations:

- o Water Energy Cycles
  - Cloud formation, dissipation, and radiative properties, which influence response of the atmosphere to greenhouse forcing.
  - Large-scale hydrology and moisture processes, including precipitation and evaporation
- o Oceans
  - Exchange of energy, water, and chemicals between the ocean and atmosphere, and between the upper layers of the ocean and deep ocean (includes sea ice and formation of bottom water)
- o Chemistry of Troposphere and Lower Stratosphere
  - Links to the hydrologic cycle and ecosystems, transformations of greenhouse gases in the atmosphere, and interactions inducing climate change
- o Land Surface Hydrology and Ecosystem Processes
  - Improved estimates of runoff over the land surface and into the oceans
  - Sources and sinks of greenhouse gases
  - Exchange of moisture and energy between the land surface and atmosphere
  - Changes in land cover
- o Glaciers and Polar Ice Sheets
  - Predictions of sea level and global water balance
- o Chemistry of the middle and Upper Stratosphere
  - Chemical reactions, solar-atmosphere relations, and sources and sinks of radiatively important gases

- o Solid Earth
  - Volcanoes and their role in climatic change

EOS INSTRUMENTS AND SPACECRAFT

The most visible part of the EOS will be the series of satellites carrying advanced remote-sensing instruments. These small-to-intermediate-size satellites, each carrying one to six instruments, will be launched beginning in 1998. Replacement satellites, launched every three to five years, will provide a minimum of 15 years of continuous global observations.

EOS MISSION LAUNCHES

SATELLITES (Launch Status)	MISSION OBJECTIVES
EOS-AM Series (1998) Earth Observing System Morning Crossing (Descending)	**Clouds, aerosols and radiation balance, characterization of the terrestrial ecosystem; land use, soils, terrestrial energy/moisture, tropospheric chemical composition; contribution of volcanoes to climate, and ocean primary productivity (includes Canadian and Japanese instruments)**
EOS-COLOR (1998) EOS Ocean Color Mission	**Ocean primary productivity**
EOS-PM Series (2000) Earth Observing System Afternoon Crossing (Ascending)	**Cloud formation, precipitation, and radiative properties; air-sea fluxes of energy and moisture; and sea-ice extent (includes European instruments)**
EOS-AERO Series (2000) EOS Aerosol Mission	**Distribution of aerosols and greenhouse gases in the lower stratosphere (spacecraft to be provided through international cooperation)**
EOS-ALT Series (2002) EOS Altimetry Mission	**Ocean circulation and ice sheet mass balance (may include French instruments)**
EOS-CHEM Series (2002) EOS Chemistry Mission	**Atmospheric chemical composition; chemistry-climate interactions; air-sea exchange of chemicals and energy (to include as a yet to be determined Japanese instrument)**

Most of the satellites will orbit over the polar regions and be synchronous with the sun to get consistent, global coverage. The EOS-AEROSOL satellite series, an exception, will fly in a different orbit relative to the sun. This orbit will provide a second view of atmospheric aerosols compared with identical instruments on EOS-CHEMISTRY. EOS-COLOR will make a single flight needed to continue the series of afternoon ocean color measurements between the Sea-Viewing Wide Field Sensor (SeaWiFS) mission to begin in 1994, and the first EOS-PM mission in 2000.

The EOS will involve 23 different instruments. The United States and Japan will collaborate to place the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on the EOS-AM-1 satellite and to place SeaWinds on

Japan's Advanced Earth Observing System (ADEOS) satellite series. The U.S. and the United Kingdom together will develop and build the High-Resolution Dynamics Limb Sounder (HIRDLS). The EOS will carry instruments from Canada (Measurements of Pollution in the Troposphere, or MOPITT), France (Doppler Orbitography and Radiopositioning Integrated by Satellite, or [DORIS], and Solid State Altimeter, or SSALT), and Europe's Multifrequency Imaging Microwave Radiometer (MIMR). Within the U.S., NASA will work with the National Oceanic and Atmospheric Administration (NOAA) to develop the Advanced Microwave Sounding Unit (AMSU) instrument. In addition, NASA consults with the remote-sensing programs of other U.S. agencies and international partner space agencies to coordinate measurements that complement those of the EOS.

A NATIONAL AND INTERNATIONAL EFFORT

The Earth Observing System is the core program of NASA's Mission to Planet Earth initiative. It represents, however, only part of the efforts underway in the U.S. and other countries to conduct long-term observations and scientific studies of global climate change.

INTERNATIONAL MISSION LAUNCHES

SATELLITES (Launch Status)	MISSION OBJECTIVES
POEM-ENVISAT Series (ESA - 1998) Polar-Orbit Earth Observation Mission Environmental Satellite	**Environmental studies in atmospheric chemistry and marine biology, and continuation of ERS mission objectives.**
ADEOS IIa and IIb (Japan - 1999) Advanced Earth Observing Satellite IIa and IIb	**Visible and near-infrared microwave radiance/reflectance, scatterometry, infrared and laser atmospheric sounding, tropospheric and stratospheric chemistry, and altimetry (may include French and U.S. instruments)**
POEM-METOP Series (ESA - 2000) Polar-Orbit Earth Observation Mission Meteorological Operational Satellite	**Operational meteorology and climate monitoring, with the future objective of operational climatology (joint with EUMETSAT and NOAA)**
TRMM-2 (Japan & NASA - Proposed for 2000) Tropical Rainfall Measuring Mission	**Precipitation and related variables and Earth radiation budget in tropics and higher latitudes.**

EOS DATA & INFORMATION SYSTEM (EOSDIS)

The EOS will support researchers by developing a computing and communication system to receive, process, store, and distribute sizable amounts of data and information about the Earth. One general goal of data and information systems is to remove the need for each user to have detailed knowledge of remote-sensing instruments and methods. Along with scientific research, the user community for EOS

Data & Information System (EOSDIS)-provided information and services could include those interested in commercial applications, education, resource inventories and planning, policy decisions, and disaster assessment.

Teams of scientists will bear responsibility for ensuring the quality of EOS data products, subject to the peer review common in scientific research. The EOSDIS currently archives and distributes data from past and current satellite missions. Projects to improve availability and quality for existing data sets, called Pathfinders, are providing information with recognized value to global climate change research. Pathfinder projects and ongoing satellite missions will serve as the first step for scientists and EOSDIS developers.

The technical goal of the EOSDIS is to develop a system that will evolve and grow to allow increasingly sophisticated uses and analysis of data and information. For a system as large and complex as the EOS, an inadequate computing system could limit or discourage the efficient use of data and information. Given the international nature of the EOS program, data and information must flow easily worldwide.

The EOSDIS components consist of a network of data centers and facilities for instrument control, data storage, computing, and communications. These components of EOSDIS will appear as a single entity to users. Distributed Active Archive Centers (DAACs) will bear responsibility for product generation, information management, and data and information archive and distribution. The data centers selected for the EOSDIS each focus on a particular type of data or scientific field. Users will access the EOSDIS from external computer networks such as the U.S. National Research and Education Network (NREN).

The EOS Data and Operations System (EDOS) provides data capture and processing, communications processing, Level-0 Distribution to the DAACs and Level-0 back-up archive functions.

The Science Computing Facilities (SCF) provide the primary user community of environmental researchers with the capability to interact with the EOSDIS. SCFs will range from personal workstations to supercomputers. They will access EOSDIS via external networks.

The EOS Communications (Ecom) provide the network communications from White Sands to Fairmont, West Virginia for data traffic and White Sands to Goddard Space Flight Center (GSFC) for Command and Control for EOS Observatories, in addition to the inter-DAAC networks.

Fulfilling user needs will require an EOSDIS that can evolve constantly to incorporate new computer technology. At launch of the first EOS satellite in 1998, EOSDIS will continue to evolve throughout the EOS mission in response to requirements for global change research, mission operations, and broad user access.

EOS DATA POLICY

The EOS data policy is designed to be consistent with the U.S. National Data Policy and to further the EOS objectives of acquiring a comprehensive global, long-term data set; maximizing data utility for scientific purposes; and simplifying access to and analysis of EOS data. A common set of data exchange principles will cover the Japanese, European, and U.S. missions comprising International Earth Oberving System (IEOS). Some of the key aspects of data policy are:

- Data from EOS instruments will be acquired according to priorities recommended by IWG and Earth Obervations International Coordination Working Group (EO-ICWG), and confirmed by NASA Headquarters.

- EOS data and data products will be available to all users; there will be no period of exclusive access.

- All data requeste for approved research, non-commercial operational, and applications demonstration purposes will incur a modest charge consistent with the actual marginal costs of filling the request.

- EOSDIS will provide the capability for archiving and making available all science data products, models, algorithms, and documentation generated as part of the EOS mission. All products derived from EOS data provided for research purposes at the marginal cost of filling the user request, and which are the basis for refereed articles - including models, algorithms, and associated documentation - must be made available to the research community.

- EOSDIS will include and make available information about the data, such as quality assessments, supporting literature references, and catalog and directory entries.

- EOSDIS project management, in consultation with IWG, will establish protocols and standards to encourage and facilitate data software exchange and interoperability.

UNDERSTANDING THE EARTH SYSTEM

A great need exists for information that can help us evaluate our options to sustain the environmental conditions that have nurtured life on Earth. Mission to Planet Earth and the EOS will supply information needed to understand and predict climate changes from both natural and human causes. This information will allow for policy decisions that balance human needs and desires with protection of the Earth's environment.

Global change research will have practical benefits and will allow us to leave a legacy of responsibility. The practical benefits will include improvements in our ability to forecast climate, manage natural resources, protect public health, and plan for crops, forests, fisheries, wildlife, and human needs. The EOS will offer one means of fulfilling our moral and civic responsibilities as stewards of our home planet to future generations.

The wisdom of understanding life in harmony with the Earth can be seen in this quote from an early Native American:

> "This we know: the Earth does not belong to man, man belongs to the Earth. All things are connected like the blood that unites us all. Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself."
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> -Chief Seattle, 1852-

ACRONYM	*MEANING*	*ACRONYM*	*MEANING*
ADEOS IIa and IIb	Advanced Earth Observing Satellite IIa and IIb, Japan	IWG	EOS Investigators Working Group
ADEOS	Advanced Earth Observing System, Japan	LAGEOS-2	Laser Geodynamics Satellite
AMSU	Advanced Microwave Sounding Unit	Landsat-7	Land-Remote Sensing Satellite
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer	LITE	Lidar In-Space Technology Experiment
ATLAS	Atmospheric and Solar Dynamics Experiment	MIMR	Multifrequency Imaging Microwave Radiometer, Europe
CEES	Committee on Earth and Environmental Sciences	MOPITT	Measurements of Pollution in the Troposphere, Canada
DAAC	Distributed Active Archive Centers	MTPE	Mission to Planet Earth
DoD	Department of Defense	NASA	National Aeronautics and Space Administration
DOE	Department of Energy	NOAA	Department of Commerce/National Oceanic and Atmospheric Administration
DOI	Department of the Interior	NREN	National Research and Education Network
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite, France	NSCAT	NASA Scatterometer
Ecom	EOS Communications	NSF	National Science Foundation
EDOS	EOS Data and Operations System	POEM-ENVISAT	Polar-Orbit Earth Observation Mission Environmental Satellite, ESA
EO-ICWG	Earth Observations International Coordination Working Group	POEM-METOP Series	Polar-Orbit Earth Observation Mission-Meteorological Operational Satellite, ESA
EOS	Earth Observing System	SAGE	Stratospheric Aerosol and Gas Experiment
EOS-AERO Series	EOS Aerosol Mission	SCF	Science Computing Facilities
EOS-ALT Series	EOS Altimetry Mission	SeaWIFS	Sea-Viewing Wide Field Sensor
EOS-AM Series	Earth Observing System Morning Crossing Mission (Descending)	SSALT	Solid State Altimeter, France
EOS-CHEM Series	EOS Chemistry Mission	SIR-C	Shuttle Imaging Radar-C
EOS-COLOR	EOS Ocean Color Mission	TOMS/ ADEOS	Total Ozone Mapping Spectrometer, Japanese Spacecraft
EOS-PM Series	Earth Observing System Afternoon Crossing Mission (Ascending)	TOMS/Earth Probe	Total Ozone Mapping Spectrometer, NASA Spacecraft
EOSDIS	EOS Data & Information System	TOMS/ Meteor-3	Total Ozone Mapping Spectrometer, Russian Spacecraft
EPA	Environmental Protection Agency	TOPEX/ Poseidon	Ocean Topography Experiment
ESA	European Space Agency	TRMM	Tropical Rainfall Measuring Mission, Japan and NASA
ERBS	Earth Radiation Budget Satellite	TRMM-2	Tropical Rainfall Measuring Mission, Japan & NASA
GSFC	Goddard Space Flight Center	UARS	Upper Atmosphere Research Satellite
HIRDLS	High-Resolution Dynamics Limb Sounder	USDA	U.S. Department of Agriculture
IEOS	International Earth Observing System	USGRP	U.S. Global Change Research Program
IGBP	International Geosphere-Biosphere	WCRP	World Climate Research Program
IPCC	Intergovernmental Panel on Climate Change	X-SAR	X-Band Synthetic Aperture Radar