The Earth Observer

An EOS Periodical of Timely News and Events

Vol. 3, No. 6

September/October 1991

EDITOR'S CORNER

Recommended Instruments for the Restructured Earth Observing System (EOS)

Berrien Moore III	University of New Hampshire
Jeff Dozier	NASA Goddard Space Flight Center and University of California, Santa Barbara
Mark R. Abbott	Oregon State University
Dixon M. Butler	NASA Headquarters
David Schimel	University Corporation for Atmospheric Research
Mark R. Schoeberl	NASA Goddard Space Flight Center

INTRODUCTION

At a workshop in Easton, Maryland from October 21-24, the Payload Advisory Panel for NASA's Earth Observing System (EOS), responding to directions from the EOS Engineering Review Committee [Frieman, 1991] and the Congress, proposed a restructured EOS to address high-priority science and environmental policy issues in Earth System Science. Comprised of the EOS interdisciplinary investigators, the Panel is chaired by Berrien Moore of the University of New Hampshire. In setting priorities, the Panel was guided by studies conducted by the Intergovernmental Panel on Climate Change [1990], the Environmental Protection Agency [Lashof and Tirpak, 1990], and the Committee on Earth and Environmental Sciences [1991].

The recommendation now goes to the EOS Program at NASA Headquarters and the EOS Project at Goddard Space Flight Center for further analysis of costs and accommodations. Lennard Fisk, NASA's Associate Administrator for Space Science and Applications, will make the instrument selections by the end of the calendar year.

Recommended instruments for flight in the "Early" EOS period (1997-2001) and beyond are summarized in Tables 1 and 2. The strategy of the mission combines high-priority new measurements with continuation of critical data sets begun by missions that precede EOS. The need for continuity in Earth observations and the urgency of environmental questions require launch of some EOS elements as soon as possible, collaborative arrangements with international partners, and maintenance of consistent 15-year records. For implementation, the Panel recommends a set of similar, moderate-sized platforms, a suite of Earth Probes and additional free flyers, and an essential dependence on international instruments and platforms for which definitive commitments should be sought.

Table 1. Recommended EOS Instruments for Early Period (1997-2001)
(Details about instruments may be found in the EOS Reference Handbook [NASA, 1991].)

	Source	Instrument	Team Leader
ACRIM	U.S.	Active Cavity Radiometer Irradiance Monitor (no orbital requirement other than solar viewing)	R. Willson
AIRS	U.S.	Advanced Infrared Sounder (AIRS, AMSU-A, & MHS are a synergistic package that should fly on same platform)	M. T. Chahine
AMSU-A	U.S.	Advanced Microwave Sounding Unit-A	H. Tsu
ASTER	Japan	Advanced Spaceborne Thermal Emission and Reflection Radiometer	H. Tsu
CERES	U.S.	Cloud and Earth's Radiant Energy System (on multiple satellites in morning, afternoon, and inclined orbit)	B. R. Barkstrom
EOSP	U.S.	Earth Observing Scanning Polarimeter (subject to review by EOS Atmospheres Panel)	L. D. Travis
HIRDLS	U.S./U.K.	High-Resolution Dynamics Limb Sounder	J. Barnett & J. Gille
LIS	U.S.	Lightning Imaging Sensor (on TRMM)	H. J. Christian
MHS	Eumetsat	Microwave Humidity Sounder	
MIMR	ESA	Multifrequency Imaging Microwave Radiometer	TBD
MISR	U.S.	Multi-Angle Imaging Spectro-Radiometer	D. J. Diner
MODIS-N	U.S.	Moderate-Resolution Imaging Spectrometer - Nadir (in both morning and afternoon orbit)	V. V. Salomonson
MOPITT	Canada	Measurements of Pollution in the Troposphere	J. R. Drummond
NSCAT-2	U.S.	Scatterometer (needed for continuity of NSCAT-1 data on ADEOS, which start in 1995)	M. H. Freilich
SAGE	U.S.	Stratospheric Aerosol and Gas Experiment (in both sun-synchronous and inclined orbit)	M. P. McCormick
SeaWiFS	U.S.	(Continuation of 1993 mission until launch of second MODIS-N)	
SOLSTICE	U.S.	Solar Stellar Irradiance Comparison Experiment (no orbital requirement other than solar viewing)	G. J. Rottman
TOPEX/ Poseidon-2	France/U.S.	(Continuation of 1992 mission needed to avoid data gap)	
Assumptions			
GLI	Japan	Global Imager (on ADEOS-2)	
MERIS	ESA	Medium-Resolution Imaging Spectrometer (on POEM-1)	

Table 2. Recommended New EOS Instruments for Period Beyond 2001

	Source	Instrument	Team Leader
ALT	U.S./ Europe	Altimeter (requirement needs to be reviewed in light of other ocean altimeters)	L. L. Fu
GGI	U.S.	GPS Geoscience Instrument	W. Melbourne
GLRS-A	U.S.	Geodynamics Laser Ranging System - Altimeter	B. Schutz
HIRIS	U.S.	High-Resolution Imaging Spectrometer	A. F. H. Goetz
LAWS	U.S./ intl	Laser Atmospheric Wind Sounder (requires separate platform and adequate funding from international or domestic partner)	W. E. Baker
MLS	U.S.	Microwave Limb Sounder (possible future selection)	J. W. Waters
MODIS-T	U.S.	Moderate Resolution Imaging Spectrometer - Tilt (needed if GLI and MERIS do not meet adequate levels of performance for measurement of ocean biota)	V. V. Salomonson
SAFIRE	U.S.	Spectroscopy of the Atmosphere Using Far Infrared Emission (possible future selection)	J. M. Russell III
SAR	U.S./ intl	Synthetic Aperture Radar (requires separate platform, Congressional new start, and adequate funding from international or domestic partner)	C. Elachi
TES	U.S.	Tropospheric Emission Spectrometer	R. Beer

The recommended instruments will study:

- Clouds, radiation, water vapor, and precipitation, including diurnal variations;
- Oceanic productivity, circulation and air-sea exchange;
- Sources and sinks of greenhouse gases and their atmospheric transformations, with emphasis on the carbon cycle;
- Changes in land use, land cover, primary productivity, and the water cycle;
- Polar ice sheets and sea level;
- The coupling of ozone chemistry with climate and the biosphere;
- Volcanoes and their role in climate change.

Omitted from the recommendation are measurements of the middle and upper stratosphere and those associated with solid Earth geophysics.

While this recommendation focuses on the science program associated with instruments to be launched by NASA and international partners in the period 1997-2001 and beyond, EOS will build on progress from satellite missions that have now begun and will continue in the 1990s. EOS will provide follow-on measurements to:

- Earth's radiation budget from ERBE (Earth Radiation Budget Experiment) and Nimbus-7;
- Precipitation, snow and ice cover, and atmospheric water from TRMM and SSM/I, part of DMSP;
- Scatterometer observations from NSCAT, to fly on the Japanese ADEOS;
- Ocean color from SeaWiFS, which continues measurements begun by CZCS;
- Altimetric measurements begun by TOPEX/Poseidon;
- Land surface measurements from Landsat, AVHRR, and SPOT programs;
- Operational meteorological satellites;
- Stratospheric chemistry from UARS;
- Ozone from TOMS, SBUV-2, and SAGE II.

Although the Panel's recommended EOS program remains ambitious, it is reduced from the original plan proposed last year. While EOS will retain its emphasis on collecting observations over a 15-year period, many important measurements are cancelled, deferred or proposed for provision by international partners. For many measurements, EOS will now rely on international or domestic instruments that are less capable than those originally selected. Some risk is associated with such reliance, and continuity may be endangered.

ENVIRONMENT AND CONTEXT FOR EOS

The programmatic environment for EOS has changed since instruments were selected early in 1990 for the launch of the "EOS-A" satellite in 1998. The run-out budget through fiscal year 2000 was capped by the House-Senate Conference Report at $11 billion, down from about $17 billion. The Congress imposed a $44 million cut on the President's budget in FY 1991 and a $65 million cut in 1992, leaving an allocation for FY 1992 of $271 million. The Senate also suggested that the 1993 increment will be no more than $200 million, thus constraining the availability of funds in the near term.

The reduced funding profile for 1992-94, coupled with a $6 billion decrease in the budget for the first decade of EOS, requires that NASA pursue only the highest-priority science and policy issues. Pursuit of these issues requires the U.S. to exploit fully the current operational satellites, Earth Probes, and international space missions, and to use a more phased implementation of the EOS program. This phasing is consistent with placing the EOS instrument configuration on moderate-sized platforms and associated smaller free flyers, as recommended by the EOS Engineering Review [Frieman, 1991] and subsequently as directed by the House-Senate Conference Report. The recommended reconfiguration leads to a flexible sequence of instruments and satellite payloads to measure the most important variables, without delaying the launch of NASA's first EOS satellite beyond 1998. The strategy can adapt to reordering of scientific priorities as our knowledge of the Earth improves. The lower budget, however, dictates increased reliance on our Japanese and European partners in the international Earth Observing System, and on instruments furnished and operated by domestic partners, NOAA, DoD, and potentially DoE.

Table 3 summarizes the Panel's ordering of science and policy questions. Table 4 identifies the most important instruments in each category.

IMPLEMENTATION

The recommended implementation of the EOS measurement suite builds on the investment made in Earth observations in the 1990s and provides additional capability for observing critical Earth system processes. Tables 5 and 6 summarize the Panel's recommendations for NASA-flown payloads and NASA-provided instruments for flights on free flyers or international satellites. Synergistic instrument clusters have been identified that attack specific scientific problems (e.g. cloud feedbacks). To the extent that instrument clusters can be accommodated on the same spacecraft, errors caused by temporal variability in observed phenomena are minimized.

In constructing payloads to address the key EOS science issues, the Panel has assessed technical and

Table 3. Science and Policy Priorities

Based on recommendations from the Intergovernmental Panel on Climate Change [1990], the Environmental Protection Agency [Lashof and Tirpak, 1990], and the Committee on Earth and Environmental Sciences [1991], the Payload Panel links EOS instruments to the following science and policy categories listed in priority order. Within each category, Table 4 lists the most important instruments (see page 6).

Water and Energy Cycles:

- cloud formation, dissipation, and radiative properties, which influence response of atmosphere to greenhouse forcing;
- large-scale hydrology and moist processes, including precipitation and evaporation.

Oceans:

- exchange of energy, water, and chemicals between ocean and atmosphere and between upper layers of ocean and deep ocean (includes sea ice and formation of bottom water).

Chemistry of troposphere and lower stratosphere:

- links to hydrologic cycle and ecosystems, transformations of greenhouse gases in atmosphere, and interactions with climatic change.

Land surface hydrology and ecosystem processes:

- improved estimates of runoff over surface and into oceans;
- sources and sinks of greenhouse gases;
- exchange of moisture and energy between land surface and atmosphere;
- changes in land cover.

Glaciers and polar ice sheets:

- predictions of sea level and global water balance.

Chemistry of the middle and upper stratosphere:

- chemical reactions, solar-atmosphere relations, and sources and sinks of radiatively important gases.

Solid Earth:

- volcanoes and their role in climatic change.

fiscal feasibility, given constraints imposed by budgets and size of launch vehicles. The Panel also has considered effects on the size and implementation schedule of the EOS Data and Information System (EOSDIS). Where instrument clusters do not need to fly on the same spacecraft, the Panel considered launch dates of NASA and international platforms. Throughout, they attempted to minimize science risks that would result from programmatic disruptions or delays.

The instruments on the recommended NASA afternoon platform allow study of cloud formation, precipitation, and radiative properties. A subset of these instruments (MIMR, AIRS/AMSU-A/MHS, and MODIS-N), in concert with vector wind stress measurements from a scatterometer (recommended for consideration for Japan's ADEOS-2), are needed for global-scale studies of air-sea fluxes of energy and moisture. MIMR, MODIS-N, and AIRS contribute to studies of sea-ice extent and heat exchange with the

Table 4. Science Questions and Instruments
(Instruments recommended for flight in 21st century delimited by brackets [ ].)

Water & Energy Cycles	Oceans	Tropospheric Chemistry	Land-Surface Hydro/Eco
AIRS/AMSU-A/MHS CERES [LAWS] MIMR MISR MODIS-N	AIRS/AMSU-A/MHS [ALT/GGI] GLI & MERIS MIMR MODIS-N STIKSCAT	HIRDLS [MLS] MOPITT SAGE III [TES]	ASTER [HIRIS] MIMR MISR MODIS-N [SAR]

Ice Sheets & Glaciers	Stratospheric Chemistry	Solid Earth
[ALT] ASTER [GLRS-A/GGI] MODIS-N [SAR]	HIRDLS [MLS] [SAFIRE] SAGE III [SOLSTICE]	ASTER [HIRIS] MISR MODIS-N [SAR]

atmosphere. Flight of this platform during the operational lifetime of TRMM will allow assessment of the utility and accuracy of precipitation estimates based on MIMR data. MODIS-N and MIMR will allow mapping of snow water equivalent and the monitoring of variability and change of the climate and hydrological systems.

The recommended NASA morning platform includes a suite of sensors (CERES, MODIS-N, and MISR) focused on cloud and aerosol radiative properties. Measurement of the diurnal properties of clouds and radiative fluxes requires measurements on the NASA a.m. and p.m. sun-synchronous orbits as well as the inclined orbit provided by TRMM. Another cluster on the NASA a.m. platform (MODIS-N, MISR, and ASTER) will address issues related to air-land exchanges of energy, carbon, and water, a task that is addressed now only qualitatively by AVHRR. MOPITT, SAGE III, and HIRDLS provide critical data related to tropospheric and lower stratospheric chemistry, including troposphere-stratosphere exchanges.

Measurements of the external solar forcing of the Earth System will be provided by ACRIM and SOLSTICE; however, they need not fly on any specific platform or in any particular orbit, other than sun-viewing. CERES and LIS in an inclined orbit will improve the diurnal coverage and could be implemented on TRMM-2. EOSP and SAGE III in an inclined orbit will similarly improve coverage.

Variations in ocean absorption of solar radiation caused by changes in bio-optical properties can be investigated using yet another set of instruments (MODIS-N and GLI, with SeaWiFS-2 providing continuity of ocean color measurements until both MODIS-N instruments are flying). Along with vector winds from a scatterometer, this cluster will allow more accurate estimates of ocean-atmosphere exchanges of carbon.

The recommended NASA-supported or -flown EOS initial suite consists of 20 instruments on approximately seven platforms to be launched in the 1997-2001 time frame (Table 5). Investigation of key IPCC priority areas and continuation of crucial time series (first established in the early 1990s) will be carried out using both intra- and inter-platform instrument groupings.

The recommended payload scenario for the years 2001 and beyond focuses on altimetric, ice sheet, and tropospheric chemistry instruments on various free flyers, and reflying the basic clusters from the early AM and PM platforms (Table 6.)

Table 5. Early Instrument Clusters (1997-2001)

NASA A.M. Cluster	NASA P.M. Cluster	Free Flyers
ASTER CERES (2) MISR MODIS-N	AIRS AMSU-A CERES MHS MIMR MODIS-N	SeaWiFS-2 TOPEX/Poseidon-2 TRMM-2
Polar Flight of Opportunity	**Inclined Flight of Opportunity**	**Other Flight of Opportunity**
EOSP* HIRDLS MOPITT NSCAT-2† SAGE III	CERES EOSP LIS SAGE III	ACRIM SOLSTICE

* Subject to recommendation from EOS Atmospheres Panel
† Would need to be considered for NASA platform if not accommodated on ADEOS-2

SUMMARY

The recommended EOS platforms and instruments assure continuity of important time series of climate measurements, address high-priority science and policy issues identified by the IPCC, and are consistent with technical, budgetary, and schedule constraints. While the program as proposed will advance our understanding of climate processes and change, it is neither sufficiently extensive to solve all identified climate problems nor is its implementation without some risk.

Cost savings result from the following changes in implementation from the program as it was proposed a year ago.

1. Fewer instruments and changes in launch schedules have affected both the size and development pace of EOSDIS.

2. Several instruments have been eliminated from the program.

3. Some instruments have been deferred until later in the mission, thus reducing the number of instrument copies. Similarly, some instruments should transition to the operational NOAA series.

4. Increased reliance has been placed on international partners for critical measurements, again reducing the number of NASA-provided instruments or instrument copies or platforms.

Table 6. Instruments for Early 21st Century

NASA A.M. Cluster	NASA P.M. Cluster	Free Flyers
CERES HIRIS MISR MODIS-N	AIRS AMSU-A CERES MHS MIMR MODIS-N	LAWS SAR TRMM-3
Altimetry Cluster	**Chemistry Cluster**	**Flights of Opportunity**
ALT GGI GLRS-A	TES HIRDLS SAGE III MLS or SAFIRE †	ACRIM EOSP MODIS-T SOLSTICE Scatterometer

† Subject to recomendation by EOS Atmospheres Panel

What Has Been Lost

The removal of instruments to measure stratospheric wind and solar-terrestrial fields instruments and the cancellation of either MLS or SAFIRE will lose characterization of the stratosphere during a period of rapid anthropogenic chemical change. We will also reduce our ability to monitor and characterize the near-space environment, including particle fluxes and magnetic field measurements.

The deferral into the 21st century of sensors that collect complete spectral information (visible spectral coverage by MODIS-T and HIRIS, shortwave infrared coverage by HIRIS, and thermal infrared interferometry by TES) will impair our study of the exchange of trace gases between the ocean, land, and atmosphere, and increases the chance that observations of unanticipated environmental problems will be missing.

Descoping of GLRS to remove laser ranging eliminates measurements of solid Earth processes that precede and follow earthquakes and volcanic eruptions. This capability should be pursued through development in other NASA programs, as well as with the collaboration with other agencies or international partners.

Determination of whether the polar ice sheets are growing or shrinking is deferred until the 21st century. Changes in ice sheet volume are indicators of multi-year climate change, and monitoring ice sheets is needed to understand and predict sea level change.

What Is At Risk

Continuity of data is at risk: scatterometer data if NSCAT-2 is not selected for ADEOS-2; continuity of ocean color data without extension of SeaWiFS purchase; continuity of ocean topography data without TOPEX/Poseidon follow-on; long data gap in ERBE-quality radiation budget measurements if SCARABE (France/USSR) or DoE instruments are not available before the launch of TRMM; and continuity of precise measurements of the ozone profile without flight of SAGE III on satellites in mid-inclination orbits.

Global measurements of the tropospheric wind field and the determination of the transport of moisture and trace gases are at risk without the flight of LAWS. Without a multi-frequency synthetic aperture radar, we miss global studies of structural vegetation characteristics such as biomass, along with soil moisture and snow properties. Finally, we have not yet been able to identify flights of opportunity for solar irradiance measurements made by ACRIM and SOLSTICE.

REFERENCES

Committee on Earth and Environmental Sciences, Our Changing Planet: The FY 1992 U.S. Global Change Research Program, 90 pp., Office of Science and Technology Policy, Washington, D.C., 1991.

Frieman, E., ed., Report of Earth Observing System (EOS) Engineering Review Committee, 63 pp., NASA, Washington, D.C., 1991.

Intergovernmental Panel on Climate Change, Climate Change: The IPCC Scientific Assessment, 364 pp., Cambridge University Press, Cambridge, 1990.

Lashof, D. A. and D. A. Tirpak, eds., Policy Options for Stabilizing Global Climate, United States Environmental Protection Agency, Washington, D.C., 1990.

NASA, EOS Reference Handbook, 147 pp., NASA Goddard Space Flight Center, Greenbelt, MD, 1991.

Jeff Dozier
EOS Project Scientist

5th EOS IWG Meeting Takes Place in Seattle

The University of Washington in Seattle was host to the fifth meeting of the EOS Investigators Working Group held on August 28, 29, and 30, 1991.

The lead-off speaker for the plenary session on the first day was Shelby Tilford. He discussed the changes in the EOS budget and the consequent need for a "restructuring" process. The immediate difficulty facing EOS is a likely reduction in the EOS budget for the decade ending in 2000 from a requested amount of $16-17 billion to $11 to 12 billion. A revised EOS budget plan is to be available by December 15. EOSDIS is to be maintained on its planned budgetary track at least for the next few years because there is a Congressional requirement to be able to handle the Pathfinder data sets plus data from the ADEOS, TRMM, and EOS precursor missions.

Bob Watson addressed the need and means for establishing EOS science priorities in view of the prospect of a severely reduced budget. He proposed that EOS base its priorities primarily on those recently formulated by the Intergovernmental Panel on Climate Change (IPCC). With this lead, and speaking for himself and not necessarily for NASA, he listed six high-priority objectives for EOS observations and studies: greenhouse gases, clouds, oceans, land-surface hydrological processes, polar ice sheets, and ecological processes. In the spirit of the U.S. Global Change Research Program, climate change on the scale of decades-to-centuries provides the governing framework. He argued that observations of the atmosphere should concentrate on the region near the tropopause, with lesser focus on the upper stratosphere.

Watson gave the study of clouds and radiation plus precipitation as the number one priority question to be addressed by EOS. Second priority was the study of oceans, including greenhouse gases, and third was the study of tropospheric chemistry. He advocated a "building block" approach wherein, at a minimum, one of these problems would be investigated thoroughly as opposed to making less-than-definitive studies of several problems.

Stan Wilson gave an action schedule to provide the basis for the EOS portion of the President's budget message to Congress. The action schedule shows the EOS Payload Panel meeting on October 21-24, and passing its recommendations to NASA HQ on October 28; it shows approval of the restructured EOS program by the NASA administrator on about December 1; and it ends with the restructured program being included in the President's FY 1993 budget on about December 15.

Wilson also proposed issues that should govern the make-up of the restructured program: fifteen-year continuity of observations should be maintained; there should be a modular approach; EOS plans should be integrated with World Climate Research Program/International Geosphere Biosphere Program plans; non-NASA sources of instruments should be addressed; and the support of the traditional Earth-science community should be sought.

Dixon Butler described the current status of "foreign instruments" in the overall context of Earth observations. The "International Earth Observing System" includes Canada, ESA, and Japan as primary partners with the U.S. The international program starts formally with the launch of the Japanese ADEOS in the first quarter of 1995.

The first day's meeting ended with a charge to the EOS science panels by Stan Wilson to prioritize the science in their areas of concern and then the corresponding instrument complement. He also asked that the panels specify their preferred time of day for equator crossing.

At the second plenary session the science panel chairmen reported on the findings of their panels. Bob Dickinson (Modeling Panel) said that the Panel has concluded that 4-D data assimilation will be the key EOS "technology," and that AIRS and LAWS will provide the main inputs to the assimilation. Their data will be crucial for the clouds and radiation problem and will also be needed for the determination of surface fluxes. Bidirectional Reflectance Distribution Function (BRDF) data are important for the determination of the surface albedo, which is a key parameter for global climate modeling.

Mark Abbott (Oceans Panel) discussed the key instruments from the oceans perspective and expressed the Panel's concern that the overwhelming majority of key measurements are to be made by non-EOS entities. The Panel urges the EOS Program Office to take the lead in assuring the availability of the non-EOS data. The Panel advocates the retention of the MODIS-T instrument in the EOS payload for its greater coverage of the world's oceans and its more complete spectral coverage than will be possible with any of the proposed alternatives.

Bryan Isacks (Solid Earth Panel) said that his Panel would like to see a scenario in which the first EOS launch carried ASTER, MODIS-N, MISR, and GLRS-A (the altimetry portion of GLRS). Jay Zwally added that an exact-repeat orbit would not be needed for the ice sheet measurements by GLRS-A, which could then provide an absolute calibration for the 3-D topographic modeling effort accomplished by ASTER.

Mark Schoeberl (Atmospheres Panel) said that the Panel felt that there should be early flights of MOPITT with AIRS and early flights of TES as well to address tropospheric chemistry. The Panel also recommended that AIRS, MODIS-N, an aerosol measuring instrument, and CERES should fly within five to ten minutes of each other; LAWS should be flown for its contribution to assimilation; and the decision on whether to fly a stratospheric chemistry package should be held off until UARS data have been available for a year. [Dennis Hartman was elected chairman of the Atmospheres Panel, taking office in January 1992.]

Piers Sellers (combined Terrestrial Biosphere/Biogeochemical Cycles Panel) said that the Panel had concluded that "clouds," as referred to in the IPCC priorities, really includes energy and water cycles, clouds and radiation, and hydrology and moist processes. John Barker, in a brief presentation, made the case for a high spatial-resolution imager, with 5 to 30 meters desired. Such an imager would be needed to identify and model changes over land as an adjunct to the MODIS-N products. In another brief presentation, Alan Strahler affirmed the utility of MISR, also as an adjunct to MODIS-N, to determine BRDF.

Eric Barron (Physical Climate and Hydrology Panel) reported the findings of a workshop held earlier in the summer at Penn State University. The Panel feels that the IPCC priorities are not an adequate blend of critical science issues and information needed for policy issues. They will be examining this question further and also be examining the merits of possible payload choices for the restructured EOS.

George Parks (Solar/Terrestrial Panel) gave a brief review of the science involved with the mechanisms whereby charged particles from the sun can lead to processes that destroy atmospheric ozone.

The final session was basically a roundup of the developments and understandings that had been developed through the events of the previous days. The Seattle payload for the first two launches is as follows (although the order of launch is yet to be determined) — the instruments are listed in alphabetical not priority order:

10:30 a.m.	1:30 p.m.	OTHER
ASTER—>HIRIS	AIRS/AMSU/MHS	ACRIM
MISR	CERES	SOLSTICE
MODIS-N	HIRDLS	ALT+
MOPITT	MIMR	TES
SAGE	MODIS-N	SeaWiFS

As footnotes to the above table: HIRIS would be a replacement for ASTER on the second flight of the first payload grouping; NOAA might pick up AIRS/AMSU/MHS as an operational suite.

Renny Greenstone
Hughes STX Corporation

EOS Restructuring Process and Schedule

Following the actions of the U.S. Congress this past summer, pointing to a considerable budget cut for the EOS program, NASA is responding by considering a formal restructuring of the EOS program. The intent is to establish a restructured program that will be resilient to the likely changes in the EOS budget and yet make significant contributions to the U.S. Global Change Research Program.

The schedule for the elements of the restructuring process follows. It starts with the meeting of the EOS Payload Panel in Easton, Maryland of October 21 - 24. The process ends with the NASA Administrator's approval of the restructured EOS program and its inclusion in the President's 1993 budget submission to the Congress.

1991 EOS Restructuring Process Schedule

October 21 - 24	Payload Panel Meeting
October 28	'98 Platform Instrument IWG Response/Definition
November 4 - 5	Post Payload Panel ESAD Retreat
November 7	Review by Associate Administrator (Fisk)
November 8 - 14	Program/Project Final Options Definition
November 14	ESAD Review of Program Options
November 18	Rebaseline Approval by Associate Administrator
November 21, 22, 25 - 27	Program Restructuring Review
November 27	Review Chairperson Presentation to Associate Administrator
December 4	Administrator's Approval of Rebaseline
December 15	Submit '93 Budget

Panel Reports

Science Panel on Physical Climate and Hydrology

The Science Panel on Physical Climate and Hydrology sponsored a four-day workshop entitled "Science Foundations for the EOS Era: Physical Climate and Hydrology" July 22-25 at Penn State University. Whereas much of the previous panel activity has focused on the EOS program and planning, the intent of the meeting was to promote scientific interaction and collaboration among EOS and outside scientists. The workshop provided the first major opportunity for Co-I and graduate student participation within the larger EOS community. More than 80 scientists participated in the workshop, including 29 graduate students from across the United States. The extent of Co-I and graduate student participation was made possible by NASA funding for the workshop.

The abstracts given covered five major themes including the role of clouds, surface hydrology, land/atmosphere/ocean energy fluxes, ocean/atmosphere/cryosphere interactions, global analyses, and the coupled climate system. Most of the sessions began with a keynote talk, providing a broader perspective on the scientific questions to be addressed by EOS. The vast majority of the session speakers presented current research results, much of it a product of the initiation of EOS funding. A total of 45 thirty-minute talks were presented at the conference. In addition, the workshop included a longer presentation on GEWEX from Michael Couglin (GEWEX Project Office), with the intent of facilitating interaction and communication between GEWEX activities and the planned EOS physical climate and hydrology research.

The workshop was also an ideal opportunity for a Science Panel meeting, providing an opportunity for significant Co-I participation in addition to the PI and Team Leader input which normally occurs at panel meetings during the IWG. The panel reviewed its 40-page report entitled "EOS Science Priorities for Physical Climate and Hydrology: Key Measurements." The report outlines the major issues and uncertainties, presents key objectives for physical climate and hydrology, and lists the key measurements required to meet these objectives. For each of the required observations, the report outlines the importance of the physical or biological variable, current measurement capabilities and the contribution expected from EOS. During the meeting the report was finalized, and then was submitted to the EOS Program and Project Offices. The panel is now placing priorities on the elements in the report in preparation for the next Payload Panel Meeting.

The panel meeting during the workshop also focussed on future workshops and activities of the panel. The panel was in full agreement that science meetings such as the Penn State workshop should be a regular part of the Science Panel on Physical Climate and Hydrology and EOS in general. As a first meeting, the workshop covered a broad area of topics. The panel felt that future meetings should now focus on specific topics. The next topic proposed is "major data sets for climate and hydrologic research." The panel proposed to give longer speaking times to key contributors willing to describe data sets in detail, including associated algorithms and the spectrum of issues and problems associated with the measurements. In future meetings, the intent will be to publish contributions to the workshops in special volumes. Future Physical Climate and Hydrology Panel science meetings will rotate between different EOS institutions, to maximize involvement of Co-Is and graduate students.

Eric Barron
Physical Climate & Hydrology Panel Chair

EOS Modeling Panel Report

The EOS Modeling Panel, under the chairmanship of Robert Dickinson, held its 5th meeting on August 28, 1991 at the Seattle IWG meeting. The meeting was well attended (about 100 participants) because of little conflict with other such activities. In order to provide more continuity in membership and activities, it was decided that, in the future, official members of the panel would be designated by each Interdisciplinary Team, either the PI or a designated substitute.

It is essential that the activities of the Modeling Panel be integrated with community thrusts in global change modeling outside of the EOS community. These include UCAR's Climate System Modeling Program (CSMP), DOE's CHAAMP program, the modeling components of NSF's Arctic System Science Program (ARCSS), modeling evaluations by the Intergovernmental Panel on Climate Change (IPCC), and various modeling thrusts in the World Climate Research Program (WCRP).

Dave Schimel described the CSMP program, including current plans for a postdoctoral program and a series of workshops. The other programs were summarized more briefly by the chair and other panel members.

It was decided (no objections voiced) that over the next year, the Modeling Panel would focus on a report addressing the following issues:

- 4-D data assimilation in connection with EOS-related activities, plans, gaps, recommendations.
- Computational resources and networking (what's now in place for EOS-related modeling, plans, needs, recommendations).
- Where will global change models be in 5 years—in 10 years?
- How would current product lists be used in future models?
- How should global change system models be structured to best use EOS data?
- Thrusts of individual interdisciplinary projects in modeling (keeping above questions in mind).

The panel also received the following presentations:

- Wayman Baker presented the current status of the LAWS program;
- Ronald Errico described some current work in 4-D data assimilation for global models emphasizing difficulties to be overcome in tropical regions;
- Additional comments on this topic related to their research were provided by Ray Bates and Eugenia Kalnay;
- J. Zwally described current remote sensing issues in diagnosing the mass balance of large ice sheets.

Overall, a wide range of topics was discussed at the meeting. Importance of 4-D data assimilation for the improvement of global data sets was especially emphasized in many of the comments. For this, AIRS and LAWS would be the main inputs beyond current instruments. Improvements would be expected to be greatest in the southern hemisphere and over the oceans. These data sets are needed for determining surface fluxes and could be a critical input for determining formation processes for clouds.

Robert Dickinson
Modeling Panel Chair

Solid Earth Panel

Report of Panel meeting at IWG meeting in Seattle, Washington, August 28-30, 1991.

The Solid Earth Panel first discussed the critical roles of solid earth science in respect to the IPCC priorities, and, then, based on this discussion, prioritized relevant EOS sensors. The roles are summarized below. The Panel then developed a proposal for a feasible first platform, focused on land surfaces processes, that could possibly fly before 1998.

Role of Solid Earth Science in IPCC Priority Scheme

The IPCC priorities have been re-combined below according to the IWG presentation of Stan Wilson into five "focused topics": clouds and radiation balance, oceans, atmospheric chemistry, polar ice sheets, and land. The panel agrees with the priority ordering except that it would place "land" first instead of last. This is reflected in the numbering below.

1. <u>Land</u>

Land hydrology, biogeochemistry, and ecosystems are embedded in the framework of soil, rock, and topography of the "solid Earth". Volcanism, tectonics, weathering, erosion, deposition, and ground water flow all involve processes which occur over an enormous range of time scales that extends from relevant human scales to the long-term evolutionary trends that give an essential perspective on present and future climate change. Examples of rapidly acting processes relevant to global climate change and its impacts include volcanic eruptions, large wind-, water-, or ice-driven erosional or depositional episodes, erosion resulting from land-use changes, and land deformation related to earthquakes or fluid withdrawal or injection. A full understanding of the land surface system requires recognition and integration of the important solid Earth component.

From a broader perspective the Solid Earth Panel considers the land surface system as a whole (the integrated system is covered in its other essential aspects by three other IWG panels: Physical Climate and Hydrology, Land Biosphere, and Biogeochemical Cycles) to be of the highest priority for EOS, and in this respect disagrees with the priority ordering of the IPCC document. Of the major components of the Earth system, the land surface system is most complex, least understood, but most directly relevant to development of mitigation and adaptation policies.

The relevant EOS sensors for the solid Earth component of land surface studies include ASTER, MODIS-N, SAR, MISR, HIRIS, and GLRS-A. The splitting of GLRS into two separate instruments: (1) GLRS-A for the nadir-pointing laser altimeter and (2) GLRS-R for the pointable multi-color laser ranging instrument, was proposed as feasible by representatives of the GLRS team.

2. Clouds and Radiation Balance/
4. Atmospheric Chemistry

Emissions into the atmosphere from volcanic eruptions and wind erosion of arid regions are important solid Earth inputs to the atmospheric chemistry and particulate load that can be effectively studied and monitored with satellites. Besides the land surface sensors mentioned above, monitoring volcanic emissions requires TES, AIRS, SAGE III, MLS, EOSP, and GLRS-R.

3. Oceans

Earth rotation variations reflect integrated effects of mass and momentum transfers between the atmosphere, the oceans, and the solid Earth. Study of these interactions requires GGI, ALT, LAWS, and GLRS-R.

5. Ice Caps and Sea Level

The solid Earth component to the sea level/ice volume problem is essential and simple: control on the non-negligible motions of the solid Earth along ocean coastlines and near the margins of ice sheets is required to determine changes in ice or water volumes. These measurements involve primarily GGI and GLRS-R in conjunction with other space-based geodetic measurement systems such as GPS and the proposed FLINN networks. Measurements of the ice surfaces require GLRS-A, ASTER, SAR, and ALT.

Proposed First Platform

The Panel proposed that a first platform composed of ASTER, MODIS-N, MISR, and GLRS-A, flying with a 10:30 AM crossing time, could be launched as early as 1997. This would provide an early science return from a package with direct application to the development and validation of process models and detection of change in the critical land surface system and ice caps. In the detection of change, ASTER would provide valuable continuity in the high-resolution monitoring record that started with MSS imagery. The sensors would also provide essential information for calibration of nearly all of the down-looking EOS sensors.

Substantial reduction of the cost of the package is obtained because ASTER is provided by an international partner, Japan. However, significant delay in scheduling of this instrument on later EOS platforms is likely not to be possible according to ASTER team representatives attending the Panel meeting.

Additional priorities, proposed to fly when feasible, include the following: a simplified SAR, HIRIS, and GLRS-R. The panel noted that HIRIS does not simply replace ASTER but has distinct capabilities and products.

Bryan L. Isacks
Solid Earth Panel Chair

TEAM MEETINGS

HIRIS Science Team Meeting

The HIRIS Science Team met July 23-25, 1991 on the Caltech campus in Pasadena, California. The primary goals were to :

- Discuss functional requirements document (FR)
- Finalize science requirements document (SRD)
- Discuss upcoming draft RFP
- Hear progress reports from Team members.

Alex Goetz began the meeting with a review of old business and the previous minutes. There was a general discussion of the Wall Street Journal article concerning HIRIS and ASTER. The article was grossly inaccurate and a letter to the editor has been written. However, it did have the positive effect of raising the HIRIS level of visibility.

Curtiss Davis led a discussion concerning relaxing the NEDL around 410 nm. Some contractors found that the current requirement was driving the entire cost of the instrument, since there is so little net throughput at this wavelength (~30%). The team agreed to the proposed change.

Don Rockey reviewed the Science and Functional Requirements Documents. He reviewed in detail five issues: stray light; SWIR spectral dispersion; polarization around 1.0 micrometer; duration of moon viewing and calibration. The wording of the stray light requirement was pointed out to be ambiguous by some contractors. The team agreed to express the requirement in terms of absolute numbers. Hugh Kieffer is to be in charge of the wording, with JPL confirming the feasibility. The team agreed to alter the wording of the SWIR spectral dispersion requirement. The value is to be increased from +/- 3 nm to +/- 4 nm. In addition, a statement of required maximum sampling intervals is to be included (14.5 nm in the SWIR, 14.0 nm in the VNIR). Next, the team agreed to relax the polarization requirement in the 1.05 m region, +/- 50 nm about the dichroic beamsplitter crossover wavelength. The polarization requirement for the IR now reads <10% in the 1050-2450 nm range. The team, after some discussion, decided not to change the lunar viewing duration requirements for the draft documents. A review of this topic will be done before the final documents are prepared. The team then agreed to reword the calibration requirement. Now, one onboard method must be provided to calibrate to better than 5%.

A general discussion of the above issues followed. Roger Clark pointed out that the 0.5% band-to-band calibration requirement, previously in the document, was missing from the FR and SRD. This issue was not resolved. Hugh Kieffer asked for clarification on how error budgets are partitioned between JPL and the vendor. The Team has now signed off on the SRD, and it was agreed that the Team Leader was authorized to sign off on any future revisions, including those discussed above.

Terry Reilly reviewed the engineering effort. He is hoping to proceed with the contractor selection and to concurrently stabilize the instrument design. JPL will provide the focal plane assembly, and issue a contract to Rockwell for the SWIR detectors. Next he reviewed the increasingly difficult issue of the configuration of the A series of platforms. HIRIS has been asked to move its electronics, other instruments may introduce stray light, and radiators must have an unblocked view of space. The team discussed the importance of having the A platforms HIRIS-compatible. He then outlined the RFP. It will contain a specimen contract, exhibits to the contract, a product assurance plan and enclosures.

Neil Kuo reported on the EOS Operations Working Group and its HIRIS-related activities. The HIRIS-related issues include EOS data flow and standard and specialized products. He also reported that the highest priority data will be processed to level 1 in 4 hours or less. Curtiss Davis reported to the team on the EOSDIS interface with scientists. He feels that HIRIS may be further along in this process than other instruments.

Rob Green reported on AVIRIS status. First, he reviewed the 1991 maintenance, calibration, pre-European operations, European operations, and post-European operations. Then he outlined the planned 1992 deployments and scheduling. Gregg Vane reported that the Navy has some interest in AVIRIS. They may fund several changes and upgrades to the instrument including C-130 compatibility and new gratings. The team discussed production of compact discs containing example AVIRIS data sets. Alex Goetz agreed to form a working group of Curtiss Davis, Roger Clark and himself to address this issue.

Bryan Bailey reported on EROS Data Center's DAAC activity in the area of Land Processes. He covered three main topics. First, he reviewed the Version 0 Information Management System, using pre-EOS data including TIMS, NS-001 and AVIRIS. Secondly, he discussed the science support issues of algorithm development. Finally, he outlined his views on the HIRIS team interface.

Roger Clark presented some of his geologic mapping results using AVIRIS data and his spectral feature curve-matching algorithm. He illustrated how imaging spectrometry can be used to map surface mineralogy, to discriminate among different minerals, and even to map solid solution series variations within a single mineral species.

Sig Gerstl reported on work in progress to account for atmospheric and BRDF effects inherent in the HIRIS system. He is currently developing ABC models (Atmospheric and BRDF Correction). His associate, Chris Borel, showed examples of modeled atmospheric effects using a TM example. He also presented a radiosity modeling method which attempts to account for both surface and volume optical properties.

Bo-Cai Gao showed his work on atmospheric modeling and spectral curve fitting. The atmospheric transmission removal program now operates on a pixel-by-pixel basis for AVIRIS data and is self-contained. Transmission for water vapor is calculated for each pixel, while the CO_2 and CH_4 contributions are calculated for a mean elevation in the scene. Future versions will do all the calculations on a pixel-by-pixel basis. The current program takes 4 hours on a DEC Station 3100, but does not run faster on the DEC Station 5000. I/O is the problem, not CPU speed. The program will be available for beta-test in November with a full release in the first half of 1992. The program is written in C and Fortran and will eventually be incorporated in SIPS (Spectral Image Processing System). It is anticipated that this or a similar program will be a preprocessing step for all HIRIS data analysis.

Hugh Kieffer reported on HIRIS calibration methods. Stray light on the solar diffuser plate may be a problem. A ratioing radiometer may be needed. He suggests that the team develop test field sites for spectral and radiometric response characterization. Jim Conel reported on AVIRIS calibration efforts using surface reflectance and atmospheric optical characterization. He also mentioned some possible South American calibration sites.

Alex Goetz presented the SIPS being developed at CSES/CU. The software will be available for free distribution to team members this fall. It is broken into three packages: pre-processing routines; interactive visualization routines and batch-processing analysis routines. Joe Boardman presented the SIPS interactive analysis program on a SUN workstation. The program allows for full spatial and spectral access to imaging spectrometry data sets. Since it is coded in IDL it is portable between different machines. Currently it is running on IBM, SUN, and DEC Unix workstations. IDL version 2.1.1 or later and at least an 8-bit color display are needed. It is hoped that the team members will form a user group for SIPS software and both benefit from it and contribute to it. SIPS will be available to any EOS investigator, free of charge, after the beta-test phase.

Curtiss Davis and Mike Hamilton presented results of a study of Lake Tahoe using AVIRIS. Comparison of in-water radiance with atmospherically corrected AVIRIS data shows good agreement. Ken Carder presented results from an AVIRIS overflight of Tampa Bay.

Larry Rowan reviewed research efforts at the USGS in Reston. The highlights included the work of Jim Crowley mapping evaporites in Death Valley using AVIRIS and field spectrometry. Other work includes AVIRIS overflights of a geologic site in Spain; however, haze and D-spectrometer problems may limit the usefulness of these data.

David Landgrebe presented the current status of his efforts in modeling and extracting information from hyperspectral data. He illustrated methods of spectral feature design, decision tree analysis methods, system simulation software, and system implementation software.

The team had a general discussion of several questions. Will the EOS platform be broken up? If so, how does HIRIS fit into this new scheme? What instruments are really synergistic with HIRIS? How much will HIRIS really cost?

Curtiss Davis presented a comparison of the NEDL figures for a variety of instruments, showing how AVIRIS and HIRIS fit in with MODIS. The team decided that better contacts with the MODIS team are needed. HIRIS can complement MODIS in many ways including BRDF studies, atmospheric corrections, and analysis of ocean processes.

Alex Goetz reviewed the list of deliverable products for HIRIS and their status. The next meeting for the team was set for Wednesday through Friday, January 15-17 1992, in Boulder, Colorado.

Joe Boardman
CSES/CIRES, U. of Colorado

Alexander Goetz
HIRIS Panel Chair

LAWS Science Team Meeting

The LAWS Science Team met on July 15-17, 1991 in Aspen-Snowmass, Colorado. The meeting was attended by 12 science team members, one associate team member, one adjunct team member and 41 other people from NASA Headquarters, the NASA/Marshall LAWS Project Office, NOAA/NESDIS, France, and private industry. The following topics were discussed:

Richard Beranek and John Fikes (NASA/MSFC) presented the results of their detailed LAWS accommodations study. Their findings included the following: Both the Atlas IIAS and the Atlas IIA launch vehicles would have ample performance to deliver LAWS into either a sun-synchronous or a 55° orbit.

The scientific advantages and disadvantages of various orbits were discussed. A 525 km, sun-synchronous orbit would provide global coverage every seven days. An orbit as low as 460 km altitude would be possible, even for a 2001 launch near the maximum solar activity (and atmospheric drag). The 525 km orbit would have a slightly lower signal-to-noise ratio (SNR) but slightly wider swath than the 460 km orbit. On balance, the science favored an orbit with a 1:30 p.m. equatorial crossing. However, the size of the solar arrays would have to be significantly enlarged. Also, it was noted by Dave Emmitt (Simpson Weather Associates) that upper tropospheric thin clouds tend to be a maximum in the early morning, which would enhance the signal strength from an otherwise low backscatter region, thus favoring an orbit with a 6:00 a.m. equatorial crossing. The 525 km, sun-synchronous, 6:00 a.m. orbit was finally selected.

The results of the latest observing system simulation experiments (OSSE's) presented by Jim Pfaendtner (NASA/GSFC) and T. N. Krishnamurti (Florida State University), clearly showed the advantages of the sun-synchronous orbit compared to a 55° inclined orbit. Southern hemisphere high-latitude wind analyses were as accurate as those in the northern hemisphere with LAWS in a sun-synchronous orbit (as expected) although, surprisingly, the tropical wind analyses were not significantly improved in the case of the 55° orbit.

Ramesh Kakar (NASA Headquarters) summarized the 2 μm Technology Review, which included several laser experts outside of the LAWS program and was held in Washington, D. C., May 21-22, 1991. With a 1993 technology freeze required for a 2001 launch, it was concluded that the present CO_2 technology is the only choice.

Bob Jayroe (NASA/MSFC) emphasized the importance of strengthening the links between the science requirements and the LAWS instrument design specifications for the upcoming CDCR, tentatively scheduled for June 1992. Accordingly, a science validation plan was drafted to accomplish this in time for the CDCR, resources permitting.

Excellent progress on the Phase B design studies was reported on by the GE and Lockheed contractor teams. The contractors are also now underway with the breadboard (laboratory model of the laser system) program which is a key part of the Phase B effort. A critical objective is the successful demonstration that the laser system will meet the mission lifetime requirement of five years.

One of the highlights of the meeting was the discussion held during the evening of July 15 between CNES (France) and NASA representatives on potential CNES/NASA collaboration on LAWS. A delegation of LAWS program representatives plans to travel to CNES (in Toulouse, France) in November/December 1991 to begin detailed discussions.

The next LAWS Science Team Meeting is scheduled for January 1992 in Huntsville, Alabama.

Wayman E. Baker
LAWS Science Team Leader
NOAA/NMC

IGBP Proposes New High-Resolution Land Data Set Based On AVHRR

The Earth Observer *office recently received a report from the Land Cover Working Group of the International Geosphere Biosphere Program Data and Information System. We note that among contributors to the report are EOS investigators Joseph Cihlar, Chris Justice, and John Townshend, Chairman of the Working Group, and report editor.*

We present a brief summary of the report for consideration by scientists in the Earth-science community. (Our summary is drawn from the text of the Executive Summary.) The full report is being published as IGBP#20 and will be available from IGBP DIS, University of Paris VI, 4 Place Jussieu, 4th Floor. Paris, Cedex 05 75252, FRANCE

Improved Global Data for Land Applications:

A proposal for

a new high resolution data set

The report outlines a proposal to produce a global data set at a spatial resolution of 1 km derived from the Advanced Very High Resolution Radiometer (AVHRR), primarily for land applications. It outlines the characteristics of the data set needed to meet a number of requirements of IGBP's science program and suggests how it could be created. The report is intended to form the basis for the production of the data set through the cooperative efforts of various international and national agencies.

Scientific Requirements for a 1 km Data Set

Examination of the scientific priorities of IGBP reveals a requirement for global land data sets in several of the IGBP Core Projects and notably in the International Global Atmospheric Chemistry Project (IGAC), Biospheric Aspects of the Hydrologic Cycle (BAHC), Global Change and Terrestrial Ecosystems (GCTE), and Global Analysis, Interpretation and Modelling (GAIM). These data sets need to be at several space and time scales, and there will be a need to extrapolate between them. For example, Global Climate Models typically have cell sizes of 250,000 square km, whereas global models of hydrology and ecosystems are expected to require cell sizes at least as fine as 2,000 square km. In order to parameterize these cells, much finer resolution data are normally required.

Examples of the need for information on land attributes include investigations of:

- Climate through the need for variables describing surface roughness, albedo, latent and sensible heat fluxes;
- Biogeochemical cycles and atmospheric chemistry, through such attributes as land cover conversion and the rate, distribution, and type of biomass burning events; and
- Water-energy-vegetation studies for which information on soil moisture, land transformations, and evapotranspiration is required amongst others.

Remotely sensed data are increasingly regarded as an essential source of data, especially for those attributes requiring global or regional coverage and regular monitoring or updates.

Types and Uses of AVHRR Data

Among many types of remotely sensed data of the Earth's surface, data from the Advanced Very High Resolution Radiometer (AVHRR) of NOAA have been used most frequently for global land studies. This arises because its spectral bands are reasonably well suited to the detection of important terrestrial attributes, especially those relating to vegetation. But most importantly, it provides data with a high enough temporal frequency that global data sets can be compiled in which cloud cover is substantially reduced. Hence, regular monitoring of almost the entire global land surface becomes feasible. The AVHRR has significant limitations especially relating to calibration, but international efforts are being made to ameliorate this particular problem.

Numerous studies involving the use of AVHRR data have demonstrated their value in the estimation of various attributes of vegetation cover, including leaf area index, green leaf biomass, net primary productivity, and photosynthetic capacity. Estimates of evapotranspiration have been made as well as surface temperature and the distribution and areal extent of fires.

One of the largest problems relating to the data from the AVHRR are their availability. Although the whole global land surface is sensed on a regular basis, global data sets at the basic sensed resolution of 1.1 km are not centrally archived due to limitations of onboard tape recorders (producing Local Area Coverage [LAC] data) and ground reception facilities. However, sampled global data are acquired regularly through onboard processing to generate Global Area Coverage (GAC) data with a nominal nadir resolution of 4 km. Even these data are not currently available in a form suitable for use at a global scale for land applications.

Currently, the availability of AVHRR data is limited to the following:

- The Global Vegetation Index (GVI) data set created by NOAA with a spatial resolution of 15-20 km. This data set has been a most important spur to the use of global data sets, but it is now recognized that it has a number of significant limitations. Revised, improved forms of this data will shortly be available.
- A NASA data product (the Global Inventory Monitoring and Modeling — GIMMS product) from the Goddard Space Flight Center, based on the GAC data product, is being generated with a spatial resolution of about 8 km produced on a continent-by-continent basis. However, it has not yet been produced on a globally uniform basis. Related efforts are underway at the European Community's Joint Research Center, Ispra.
- Local 1 km archives of varying spatial extent and length of historical record are available, such as through the NOAA LAC archive and from various national and regional reception facilities. Areas for which data sets are most readily accessible include the North American continent from the USGS EROS Data Center and the Canadian Center for Remote Sensing, Europe and northwest Africa through ESA, and some European research groups.

Future important efforts in generating global data sets include:

- The joint Pathfinder activity of NASA and NOAA, which will lead in the next few years to a complete retrospective AVHRR data set from 1981 onwards at a spatial resolution of 9 km and a frequency of once every 10 days.
- Data from various new sensors, the most important of which are likely to be the Along Track Scanning Radiometer, particularly the version to be placed on the European ERS-2 from 1994 onwards, with a spatial resolution of 1 km though with a lower temporal frequency than the AVHRR, and the new sensors of the Earth Observing System, notably the US MODIS and the European MERIS.

There are no current plans for the creation of regular global data sets at spatial resolutions finer than those described, but it is apparent that for several IGBP activities a spatial resolution of 8 km or coarser will be insufficient for their needs. Given the fact that data with a nadir resolution of 1.1 km are obtainable for the whole land surface of the Earth, it is appropriate to explore the possibility of compiling such a data set.

Required Characteristics of a Global 1 km Data Set

Data should be provided to users in a form which minimizes pre-processing by users. The global 1 km data set should contain: (i) radiometrically corrected radiances for all five channels, (ii) the normalized vegetation index derived from the corrected radiance, and (iii) the date and look angle for each pixel selected. These data sets should be well registered spatially.

High repetitivity of data improves the chances of acquiring a cloud-free view of every location within a finite time period. Because of the high cloud cover in many parts of the world, it is necessary to plan for the collection of data from every orbit. These data will then need to be composited to form synthetic products relating to minimum time periods as long as 10 days for global coverage, though at higher latitudes the frequency could be increased to once every 5 days. Composite data sets in which cloud is sufficiently removed for many applications may have to be generated for periods as long as 30 days and in some humid tropical regions, large amounts of cloud may still remain.

Multi-temporal global coverage of data, achieved through a mixture of recorded data and data from ground receiving stations, is required, though there may have to be some pragmatic concentration on priority areas.

The minimum length of record should be a year, and ideally a system should be put in place which leads to the continuous acquisition of 1 km data, providing a baseline data set prior to EOS towards the end of the decade.

Preprocessing Procedures

Substantial effort will be required in the preprocessing of the data set to make it suitable for the extraction of information. It is essential that a set of procedures is established, for which there is general agreement from the IGBP community. The main stages in preprocessing are radiometric calibration, atmospheric correction, geometric correction, and temporal compositing.

In terms of radiometric correction, AVHRR data from bands 1 and 2 pose particular problems because of the absence of onboard calibration. Calibration is essential because of drift of instruments and differences between the AVHRR sensors. Hence, several groups are involved in attempts at vicarious calibration. International coordination, possibly through IGBP-DIS, with a regular means of communicating information to update calibration coefficients needs to be established. The 1 km data set should use the best available ancillary data to improve the usefulness of the data for long-term investigations.

For some aspects of atmospheric correction, procedures are reasonably well established, as in the case of the Rayleigh scattering and ozone corrections. But, for water vapor and aerosols there is no general agreement on common methods, and in the next few months a decision will have to be made on whether or not to apply one of the available methods. Close liaison with the NASA/NOAA Pathfinder activity is recommended since this group is also actively considering and researching into these matters.

Data need to be corrected geometrically so that uniform fields of well-registered data are created using an equal area projection.

Several aspects of preprocessing still require additional research to optimize procedures. For example, better procedures for compositing images need to be developed to minimize cloud effects for both the individual channels and the vegetation index.

Availability of Current AVHRR 1 km Data

LAC data recorded onboard the NOAA platform provide images of a substantial proportion of the Earth's surface, but global coverage cannot be achieved. The main gaps in coverage are in southwest Asia and northern Siberia. Also, priorities other than scientific requirements mean that data are often not collected in a manner to optimize global data collection.

Ensuring that data from ground stations regularly and reliably supplement the LAC data will require international coordination. Preliminary discussions between space agencies have already started to assess the feasibility of such a plan.

Data Management Recommendations

A global facility will be required to ensure the creation of a uniform data set, which is made readily available to the whole IGBP community.

It is recommended that information on availability of the 1 km data set and other data sets relevant to IGBP activities is made through the IGBP Directory, which will be based on the NASA Master Directory.

Long-term archiving needs to be established, and it is recommended that this could be carried out within the framework of the World Data Center system.

A review of the available media for the data set suggests that CD-ROMs may be the most suitable for distribution purposes.

Consideration of the various issues raised in defining the AVHRR 1 km data sets raises a number of generic issues relating to data management:

- The relationships between IGBP-DIS and various other activities such as the EOSDIS, the World Data Center system and the Global Climate Observing System need to be established.
- Mechanisms need to be established with key space agencies and major data suppliers such as the USGS in order to ensure that IGBP user requirements are properly represented through IGBP-DIS, so that AVHRR and other remote sensing data sets can properly support IGBP's activities.
- The relative roles of Core projects and IGBP-DIS in data management need to be established through consultations between these groups, and in particular through the mechanism of the IGBP-DIS Science Steering Committee.

First United Kingdom ERS-1 Image Released

The first image received and processed in the United Kingdom from the European Space Agency's (ESA) European Remote Sensing Satellite (ERS-1) is of an area in Estonia. The image shows the Baltic town of Narva lying to the north of a shallow lake fed by the river Narva. The Gulf of Finland lies to the north, and lake Chudskoye to the south. Copies of the image are available from National Remote Sensing Centre Limited (NRSC Ltd.). The image was processed at the United Kingdom Earth Observation Data Centre — £20 million facility equipped to process, archive and distribute data from ERS-1 and future satellites. The EODC has been developed by the Defence Research Agency (DRA), Farnborough, for the British National Space Centre (BNSC) and ESA.

British Aerospace Space Systems Limited was prime contractor for building and equipping the EODC, together with Data Sciences Limited, SD-Scicon, Logica and Serco. NRSC Ltd., under contract to DRA as agents of BNSC, is responsible for the technical and operational management of the EODC and will operate the Centre on a commercial basis.

The ERS-1 satellite acquired the image from an altitude of 785 km, using its Active Microwave Instrument — a specialized radar instrument which can observe the Earth through clouds. This "all-weather" observation ability is a major asset to Europe's Earth observation capabilities. ERS-1 was launched into polar orbit by Ariane, from Kourou, French Guiana, on July 17, 1991 (0246 hrs BST). Following the switch-on of the spacecraft's instruments on July 27, the image was transmitted to Earth and received by the United Kingdom ERS-1 ground station at West Freugh, in Scotland. The data were transferred to the EODC and processed to produce digital and photographic images.

ERS-1 is the first of a new generation of environmental satellites planned for the 1990's. During its three-year mission, it will study key aspects of the global environment, such as oceans and sea-ice, providing information which will help us to better understand the complex relationships which shape our environment.

For further information please contact:

Neil Pattie
Public Relations Manager
National Remote Sensing Centre Limited
North Gate Road, Farnborough
Hampshire GU14 6TW
Tel: Farnborough (0252) 541464 • Fax: (0252) 375016

System Simulations of EOS Instrument Data

Realistic simulated EOS data will be required to develop and validate advanced science algorithms in the EOS era, to test all possible paths within the data product algorithms, to develop robust evaluations of alternative instrument configurations and groupings, and to get reliable estimates of the resource requirements of the algorithms. Because of our desire to study the Earth as a system, and to utilize extensive ancillary and correlative data, interdependencies between instruments are inevitable. As a result, the simulated data must be created in a consistent manner by these instrument teams. It is our intention in this article to demonstrate how system simulations can be used by EOS science investigators and instrument developers to each of the points outlined above.

EOS Data Product Algorithms

Algorithms developed for the generation of EOS-era data products will differ from precursor remote sensing algorithms in several fundamental ways. First, the complexity of the computations will increase. Atmospheric corrections will be employed to perform quantitative, rather than qualitative, remote sensing of the Earth's surface. More information will be extracted from the higher spectral and spatial resolutions, made possible in part by improved confidence in the instruments' calibration and characterization. The increase in complexity, along with the higher sampling rates caused by the greater resolution in space and frequency and increased duty cycle, will drive up the CPU requirements. The move to quantitative remote sensing will necessitate the ingestion of a greatly increased amount of ancillary data, from collocated and coincident measurements from other EOS instruments when possible. Finally, the increase in sophistication of the algorithms will often result in additional data-value-dependent branching.

Measurement Simultaneity Requires Consistent Data

The production of many EOS data products will require processing of EOS instrument data with timely or concurrent input from other EOS instruments as well as non-EOS data sources. For example, the proposed CERES objectives for determining the average and cloud-free Earth's radiation budget require global cloud retrievals and surface and top of the atmosphere (TOA) radiation balance components. In addition to the CERES data, these algorithms require MODIS-N high-resolution cloud image data, AIRS/AMSU vertical profiles of temperature and humidity, MIMR passive microwave liquid water, geostationary satellite radiance data, global snow cover, surface topography, surface albedo, global ozone, and sea surface temperatures. For the CERES instruments designated for the TRMM and POEM-M1 platforms, alternative imagers and sounders will be employed. Clearly, a full test of the algorithms to complete this product requires not only simulated CERES data, but data or simulated data from all of these other sources. Precursor satellite, aircraft, and *in situ* datasets, combined in a comprehensive CERES system simulation, present an opportunity to find many or all of these parameters concurrently, and to test the science algorithms developed to process these data sets. Alternatively, introduction of a time-dependent Earth model through a General Circulation Model (GCM) simulation affords the opportunity to introduce realistic temporal variability on top of spatial variability.

Measurement Synergism Requires Consistent Algorithms

HIRDLS is expected to yield more accurate stratospheric temperature profiles than AIRS, while AIRS will obtain more accurate tropospheric soundings. Consequently, the data from these two instruments may be combined for an improved temperature profile throughout the troposphere and stratosphere. Simulations must be performed to test this possibility, and thus standard definitions of both atmospheric variation and radiance routines will be required by the HIRDLS and AIRS science teams.

Both AIRS and MODIS-N have channels that can be used to detect atmospheric SO_2 at altitudes where it will occur after volcanic eruptions. It is likely that the relatively moderate resolution footprints of the MODIS-N detector elements (1 km at nadir) will produce more useful observations in the early stage of an eruption when the SO_2 is concentrated in a small region. As the eruption proceeds, the SO_2 is dispersed over a larger region and high spectral resolution becomes more important than a higher spatial resolution in detecting the presence of the SO_2. In this period, AIRS may be better suited than MODIS-N to follow the SO_2 cloud as it disperses. Again, determining the optimum approach to using the instruments will be facilitated by simulations using radiance routines and standard definitions exchanged between the respective science teams.

In addition, the EOS 4-D data assimilation algorithm requirements are bounded only by the total amount of independent input data products available.

A Possible Role for General Circulation Models

Numerical models may play an important role in supplying a reference Earth for the generation of simulated EOS instrument data. By utilizing a GCM to simulate the Earth, the following properties result:

- Realistic variability in time and space, including diurnal variations and vertical structure
- Realistic physical, dynamical, and thermodynamical relationships among atmospheric, oceanic, and land-surface variables
- The ability to simulate data taken from multiple platforms and probes in a variety of orbits, as well as *in situ* data

In addition, parameterizations to create consistent treatments of variables not presently modeled (i.e., trace gases, the land and ocean biosphere) could be added. Evolution of a comprehensive, early EOS science algorithm system simulation approach would permit the EOS instrument teams, in conjunction with realistic platform attitude and ephemeris data sets and using either community or instrument-unique forward models, to generate simulated instrument telemetry (essentially Level-0 data). Using the developing science algorithms, at first at the Science Computing Facilities (SCFs), but ultimately at both the SCFs and the Distributed Active Archive Centers (DAACs) for operational integration and testing, the Level-0 and ancillary data could be used to create the higher-level products. Self-consistency between the instrument measurements would be guaranteed. Ultimately, these simulated data products could be fed into Level-4 algorithms supplied by the interdisciplinary teams (e.g., to test 4-D assimilation concepts for candidate groupings of EOS instruments and data product algorithms).

Representative Present-Day EOS Instrument Simulations

At this time, a number of EOS instrument simulation activities are occurring in parallel. Each is designed to address specific sets of questions, and there has, as yet, been no need for extensive coordination between the teams. For example:

The LAWS science team has been conducting experiments at GSFC, the National Meteorological Center (NMC), and the Florida State University (FSU) involving GCMs, which provide realistic time-dependent 3-D descriptions of atmospheric winds, aerosols, and clouds. These simulations have unambiguously demonstrated the beneficial impact of LAWS tropospheric winds on analyses of the atmospheric state (e.g., 3-D fluxes of sensible and latent heat).

The CERES science team is beginning to simulate CERES/MODIS/AIRS/AMSU through the joint use of recent historical ERBE/AVHRR/TOVS data from NOAA-9. In addition, the team has been conducting measurement simulations over 6-day periods using EOS-A overflights over a temporally and diurnally varying Earth specified by ISCCP GOES fields to optimize CERES spatial and angular sampling characteristics.

The MODIS science team has simulated spatial characteristics of MODIS through application of the instrument MTF to Landsat TM data, coverage and other effects of possibly conflicting land Bidirectional Reflectance Distribution Function (BRDF) model and ocean sunglint avoidance operating modes, and ocean bio-optical algorithm sensitivity to finite accuracy and resolution of ancillary data sets. The team is working towards developing a "math model" to accurately represent both geometry and radiometry in simulating MODIS-N and MODIS-T scenes.

The AIRS science team is evaluating alternative candidate profile retrieval algorithms through the use of line-by-line atmospheric transmittance simulations. In addition, the AIRS team is

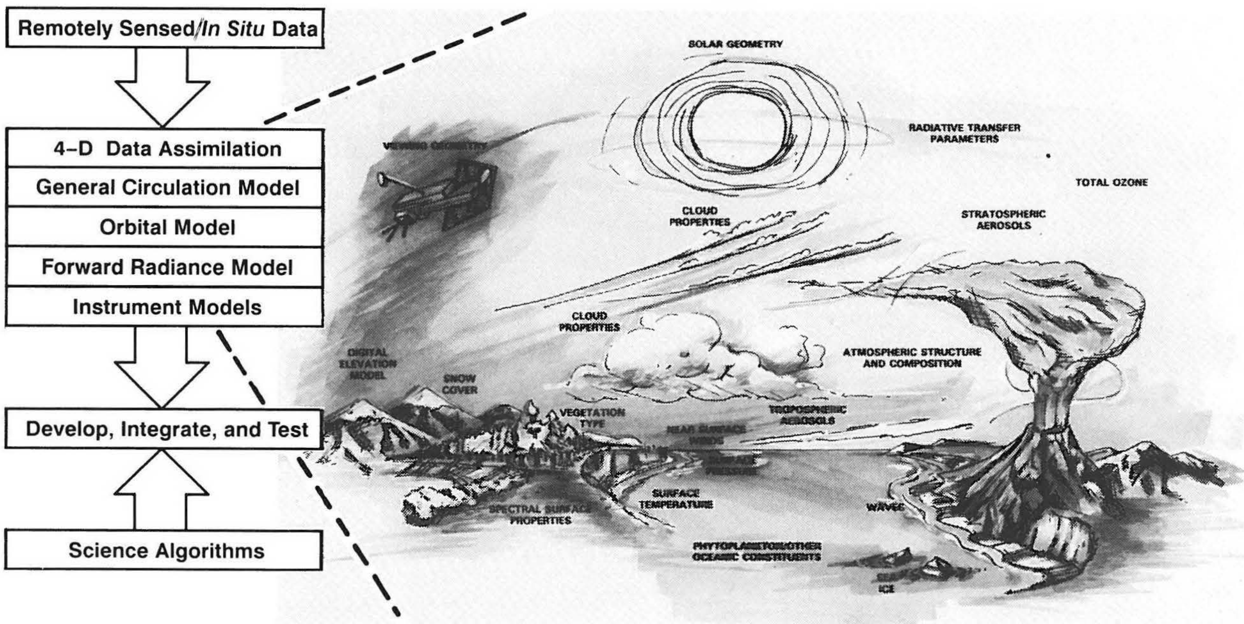

Figure 1. Conceptual view of the Earth as observed by EOS, a generalized set of variables that must be considered, and the relationship among science algorithms, data, and models needed to perform a general system simulation.

considering the use of an embedded mesoscale model inside of a GCM to generate high spatial resolution simulation data sets.

At FSU, observations from LAWS, AIRS, SSM/I, and STIKSCAT are being simulated for both the EOS and TRMM platforms. The simulation of these instruments is providing a diverse set of tests of the concept of using a GCM to provide a simulated Earth. In addition, this set of experiments will define the magnitude of improvement that could be expected from these instruments' data products in determining the state of the atmosphere. An important aspect of this modeling strategy is a set of simulation experiments with most of the above instruments included, followed by the elimination of one or more to successively assess their impact to the 4-D data assimilation. The experiments will also benefit science by providing insight into high resolution numerical forecast modeling with the addition of EOS instrument data products of the coming decade.

An End-to-End Concept for EOS System Simulations

Figure 1 provides a conceptual view of the Earth as observed by EOS, as well as a generalized set of variables that must be considered in a system simulation. In the atmosphere, the radiative effects of liquid water and ice clouds must be realistically treated, along with tropospheric and stratospheric aerosols, ozone, other trace gases, and the thermodynamic structure. Over the oceans, the sea surface temperature, optically active organic and inorganic oceanic constituents, and sea ice must be described, along with near-surface winds, wave spectra, and sea ice. Over land, the topography, snow and vegetation cover, along with spectral surface properties must be specified. Finally, the solar and platform positions and viewing geometries must be specified, along with the forward radiative transfer models needed to create incident spectral radiances at the instrument apertures.

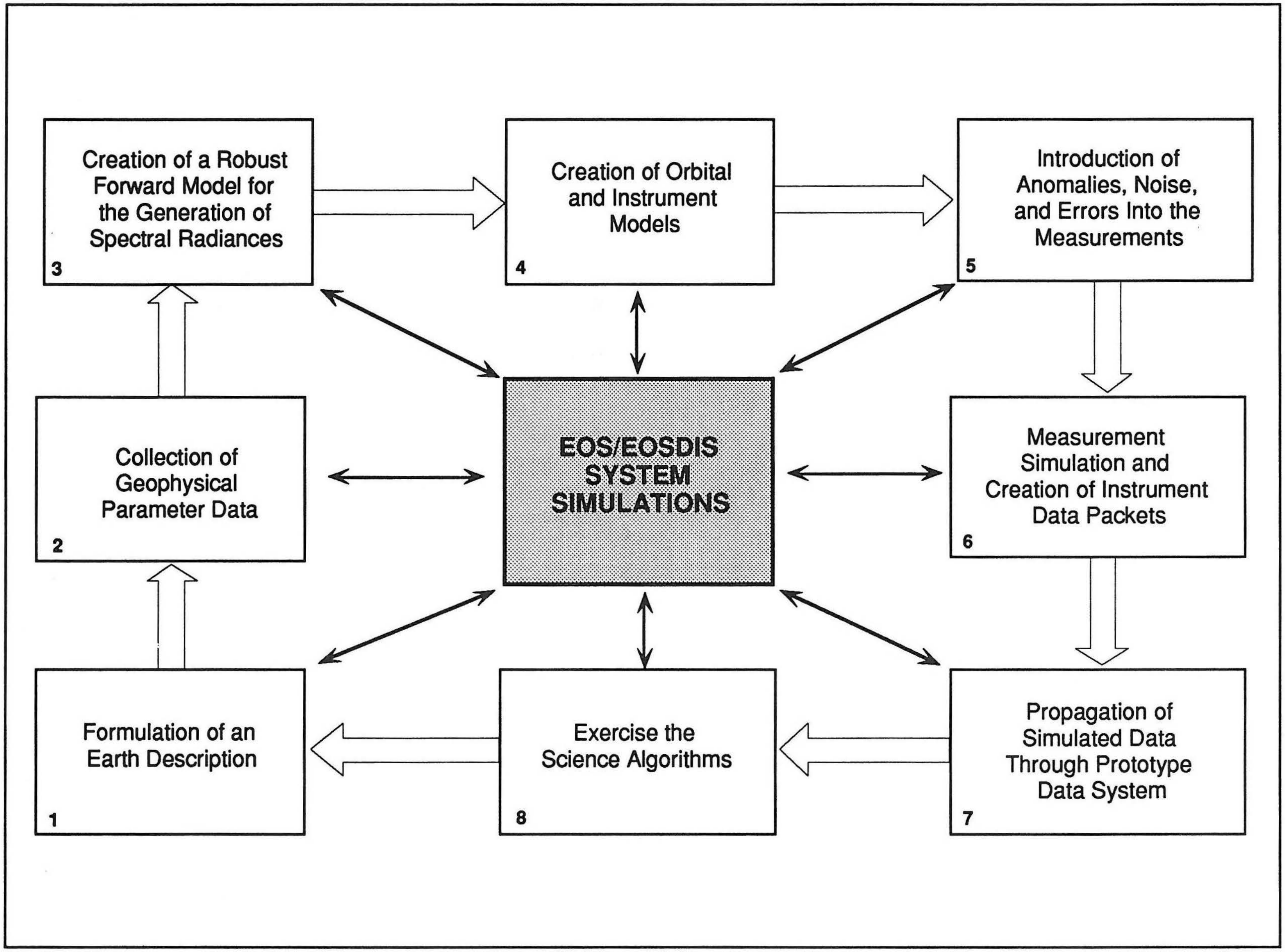

Figure 2. Eight steps in the simulation of EOS data, beginning with an Earth description, the generation of spectral radiances, the propagation of the radiances through orbital and instrument models, and finally the science algorithms to create simulated data products.

In such a simulation, the Earth description and the associated geophysical fields (either *in situ*, remotely sensed, and/or generated by a GCM) are used to generate spectral radiances (Figures 1 and 2), and then propagated through orbital and instrument models. Instrument errors and other artifacts are introduced into the observations at this point. The simulated data are then propagated through the science algorithms, and the data processing system, to exercise the science algorithms and create simulated data products. The process is iterated as early algorithm prototypes are improved.

Lessons Learned From UARS and Their Application to EOS

The obvious example of how such an approach may be used to best advantage is the UARS mission. The UARS project identified a multi-day period for which consistent simulations would be produced. For this period, the UARS PIs agreed upon a standard atmospheric model and were supplied with a project orbit/attitude simulation. Data file formats were defined and documented prior to the preparation of the simulated data sets. The UARS PIs then simulated each instrument's observations. These data sets were then integrated as a consistent UARS mission data set. An early version of a simulated UARS data and prototype system concentrated on the validation of the interfaces and updating of resource estimates. This first delivery was designed to be representative of the mission-ready software in terms of CPU and storage requirements. Evaluation of the processing requirements of this first processing system version led to a significant (factor of 10 in capacity) hardware augmentation. Later versions incorporated attitude and orbital artifacts to test the exception handling capability of the science and utility algorithms. The third software delivery was the mission-ready system.

A similar simulation activity should be considered for future EOS launches. However, as noted above, a difference in the science algorithms in the future generation of instruments is the interdependencies with respect to ancillary data, which may require coordinated activities among the teams and a true EOS system simulation. Beginning now, through collaboration between the EOS Modeling and other panels, and individual EOS investigators, the greatest amount of scientific benefit may be achieved. The interested community includes both users and providers of data, including those who deal with radiative transfer code, land, ocean, atmosphere, and biosphere models, EOS and Earth Probe instrument developers and modelers, orbit modelers, and more. Two outcomes from this effort may result:

1. The exchange of ideas, strategies, and lessons learned.
2. The development of a common Earth system simulation, or suite of simulation algorithms, available for use to all data product users/developers for developing, testing, comparing, and validating their code, science algorithms, radiative transfer, and Earth models, etc.

Acknowledgements

The author wishes to acknowledge Larrabee Strow for contributing the two examples for demonstrating measurement synergism, T. N. Krishnamurti for his insight into EOS and Earth Probe data impacts into numerical weather prediction, and Mitchell K. Hobish for his constructive suggestions in the preparation of this article. In addition, discussions with many EOS investigators, including Wayman Baker, T. N. Krishnamurti, Jan-Peter Muller, George Aumann, John Barker, Bruce Wielicki, Mark Schoeberl, Ricky Rood, and Ray Bates were helpful in formulating the discussion.

Philip Ardanuy
RDC

THE EARTH OBSERVER

The Earth Observer is published by the EOS Project Science Office, Code 900, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, telephone (301) 286-3411, FAX (301) 286-3884. Correspondence may be directed to Charlotte Griner at the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the meeting calendar should contain location, person to contact, and telephone number. Deadline for all submissions is the 20th of each month. To subscribe to *The Earth Observer*, or to change your mailing address, please call (301) 513-1613, or write to the address above.

Global Change Meetings

November 16-18	Sigma Xi Conference, Global Change and the Human Prospect, Washington, D.C. Contact Nancy Berry at (919) 549-4691.
November18-22	*The Global Change Research Program: Requirements, Technologies, and Opportunities,* Los Angeles, California. Contact J. Rosati (213) 813-7062.
November 19-22	8th Catalog Interoperability Workshop, Washington Plaza Hotel, Washington, D.C. Contact Angela Bland (Hughes STX) at (301) 513-1687 or Debra Williams (Westover Consultants) at (301) 220-0685.
December 2-6	*World Conference on the Chemistry of the Atmosphere: Its Impact on Global Change,* Baltimore, Maryland. Contact, CHEMRAWN VII, Secretariat, c/o American Chemical Society, 1155 16th Street N. W., Room 205, Washington, D. C., phone (202) 872-6286, FAX (202)8 72-6128.
December 5-6	Global Change Data Management Seminar, *From Desktop to Archive and Back,* Washington, D.C. Contact Lisa Bothwick, DEC, Executive Programs Office, 40 Old Bolton Road, Stow, MA 01775. Phone (508) 496-8444; Fax (508) 496-0146.
December 9-13	AGU Fall Meeting, San Francisco. Contact Carol Snyder, American Geophysical Union, 2000 Florida Ave., WAshington, D.C. Phone (202) 939-3205.
• 1992 •	
January 5-10	72nd American Meteorological Society Annual Meeting, Atlanta Georga. Write to: Meeting Department, AMS Headquarters, 45 Beacon St., Boston, MA 02108.
January 5-10	Third Symposium on Global Change Studies, sponsored by the American Meteorological Society, Atlanta, Georgia. Contact Eric J. Barron at (814) 865-1619; FAX (814) 865-3191; Omnet: E.BARRON.
January 14-16	Center for Global Change Science, Massachusetts Institute of Technology Symposium *The World at Risk: Natural Hazards and Climate Change,* Cambridge, Massachusetts. Contact Anne Slinn, (617) 253-4902; fax (617) 253-0354.
January 27-31	1992 Ocean Sciences Meeting American Geophysical Union, New Orleans, Louisiana. Contact Eileen E. Hofmann, Old Dominion University, Department of Oceanography, Norfolk, Virginia 23529; phone (804) 683-5334; FAX (804) 683-5303; Omnet: E..Hofmann.
February 7-10	AAAS '92, Chicago, Illinois. For meeting information write to: AAAS, 1333 H Street, N.W., Washington, D.C. 20005. Phone (202) 326-6462.
February 10-13	International Space Year Conference on Earth and Space Science Information Systems, Pasadena, California. Contact Arthur I. Zygielbaum, Jet Propulsion Laboratory, Fax (818) 354-8333; e-mail AZYGIELBAUM (NASAMAIL) or AIZ@EWOK.JPL.NASA.GOV (Internet).
February 16-17	Marine Technology Society, *Down to Earth Oceanography,* a workshop for teachers, administrators and science coordinators, Catalina Island Marine Science Center. Contact Sam Kelly (714) 758-3338.
March 4-6	1st Annual Conference on Carbon Dioxide Removal, Amsterdam, The Netherlands. Hosted by the University of Utrecht, Department of Science, Technology and Society, University of Utrecht,. Write to: ICCDR c/o KIvI, P.O. Box 30424, 2500 GK The Hague, The Netherlands.
July 19 - Aug 8	A NATO Advanced Study Institute, Remote Sensing and Global Climate Change, 7th Dundee Summer School in Remote Sensing, University of Dundee, Scotland, U.K. Contact Robin Vaughan at (0382) 23181 Ext. 4557/4912; Fax (0382) 202830; Telex 9312110826 DU G.
August 2-14	XVII Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Washington, D. C. Concurrent to the ISPRS Congress, two other meetings will be held nearby: the ASPRS and the American Congress on Surveying and Mapping (ACSM) will conduct a conference on Global Change; the International Geographical Union will convene its 27th International Geographical Congress (IGC) during the second week. For more information contact XVII ISPRS Congress Secretariat, P. O. Box 7147, Reston, Virginia 22091.
Aug. 31 - Sept. 3	COSPAR Symposium on Global Change and Relevant Space Observations, Washington, D.C., World Space Congress. Contact J. Fellous/OMNET; fax 33 1 45087867; telex 214674; phone 33 1 45087648. (Call for papers available from World Space Congress, AIAA, The Aerospace Center, 370 L'Engant Promenade, S.W., Wahsington, D.C. 20024-2518; phone (202) 646-7451; fax (202) 646-7508.
November 2-6	Sixth Australasian Remote Sensing Conference, *Remote Sensing and Spatial Information: the Functions...the Payback...the Future,* Michael Fowler Centre, Wellington, New Zealand,. Contact Stella Belliss, DSIR Physical Sciences, P. O. Box 31-311, Lower Hutt, New Zealand; phone 64(4)666-919, extension 8693, fax 64(4)690-067.

Future EOS Science Meetings

November 4-5	AIRS Team Meeting, Goddard Space Flight Center, Greenbelt, Maryland. Contact Hartmut Aumann at (818) 584-2934.
December 4-6	EO-ICWG Meeting, Montreal, Canada. Contact Dixon Butler at (202) 453-8522.
January 14-17	ASTER Science Team Meeting at JPL, Pasadena, California. Contact Anne Kahle at (818) 354-7265.
January 15-17	HIRIS Team Meeting , Boulder. Contact Alex Goetz at (303) 492-5086
January 28-30	LAWS Team Meeting, Huntsville, Alabama. Contact Wayman Baker at (301) 763-8005.
Spring, 1992	EOS Oceans Panel Topical Science Meeting on Air/Sea Interactions. Contact Mark Abbott, at (503) 737-4045.
Spring, 1992	EOS Atmospheres Topical Science Workshop. Contact Mark Schoeberl at at (301) 286-5819.

Code 900
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland
20771

Official Business
Penalty for Private Use, $300

Postage and Fees Paid
National Aeronautics and
Space Administration
NASA-451

U.S. MAIL