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Editor's Corner

A Validation Workshop was held at Goddard Space Flight Center on May 8-10 that focused on improving and enhancing the coordination between instrument teams, interdisciplinary science teams, and the NASA Research & Analysis (R & A) program. This workshop provided the first opportunity to compare and discuss the validation plans of individual science teams, both instrument and interdisciplinary, and to articulate both international and national networks, field programs, and schedules. The plans that will result from this workshop will be reviewed this fall as part of the Algorithm Theoretical Basis Document (ATBD) reviews, and will help define the NASA Research Announcement (NRA) for an EOS Correlative Measurement Program to be released later this year. This workshop followed an earlier Land Test Site Workshop, and is helping to further define and refine the EOS-wide validation program.

In addition to the validation program that is beginning to take shape, the National Institute of Standards and Technology (NIST) has begun to develop an extensive calibration capability for use throughout the EOS program (see March/April issue of *The Earth Observer*). NIST held an openhouse in May to showcase these facilities for a number of scientists and managers at NASA Headquarters and Goddard. Capabilities currently under development included an infrared transfer radiometer and thermal vacuum chamber (see pages 31-35), visible and shortwave infrared transfer radiometers based on SeaWiFS heritage, and a bidirectional reflectance laboratory for intercomparing artifacts (diffuser



plates and Spectralon™ plates) being used and measured by various instrument developers. This should enable the spectral reflectance characteristics of these diffusers to be intercompared when flown in space.

The Office of Mission to Planet Earth has now finalized the selection of proposals originating from the NRA (released September 22, 1995) for new investigations and investigators for the Earth Observing System. NASA received 309 proposals in response to this announcement, 77 of which were accepted. Details of the selection can be found on the World Wide Web at <http://www.hq.nasa.gov/office/mtpe/eosresul.html>, as well as pages 45-50 in this issue of *The Earth Observer*. The final selection results can be summarized as follows:

Landsat Team Member/Leader	14
MODIS Team Member	5
AIRS Team Member	2
TRMM Team Member	2
Passive Microwave Team Member	2
Interdisciplinary Investigation	31
New Investigator Program	21

Of these results, a subset of the interdisciplinary investigations will be considered EOS IDS investigations, while the remaining investigations will be managed under the NASA R&A program.

Recent additions or changes to the EOS program include the provision of the Humidity Sounder from Brazil (HSB) to replace the Microwave Humidity Sounder (MHS) on EOS PM-1, and the agreement between NASA and CNES (French Space Agency) to name the TOPEX/Poseidon Follow-On Mission (EOS Radar Altimeter-1) as Jason-1, after Jason and the Argonauts. Instruments and spacecraft for this mission are currently under development in the U.S. as well as in France. The latest EOS mission profile can be found on the World Wide Web at http://sps0.gsfc.nasa.gov/sps0_homepage.html.

There will be a Payload Panel meeting in Annapolis, Maryland on July 29-31. The meeting will focus on (i) the relationships between both the Earth System Science Pathfinder (ESSP) program and New Millennium Program (NMP), and EOS, (ii) the status of various implementation studies being planned or conducted (such as the EOS Chemistry-1 study discussed at the last Payload Panel Meeting, see page 15), (iii) plans for the implementation of the second series of sensors and missions (e.g., AM-2, Chemistry-2), (iv) the role of the National Polar Orbiting Environmental Satellite System (NPOESS) in partially fulfilling the long-term climate goals of EOS, and (v) plans for a federated EOSDIS, including the schema for governance, operational NPOESS processing, and how to ensure a broad range of participation.

—**Michael King**
EOS Senior Project Scientist

Minutes of the Eleventh EOS Investigators Working Group Meeting

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Monday, May 13, 1996

Morning Plenary Session

Michael King, EOS Senior Project Scientist, opened the Investigators Working Group (IWG) meeting and introduced Joe Rothenberg, Director of the Goddard Space Flight Center (GSFC), for a welcoming address.

Rothenberg discussed some developments in regard to Mission to Planet Earth (MTPE). There is good progress leading to the launch, as scheduled, of the AM-1 platform, and TRMM is on schedule for a fall 1997 launch. The protest that was lodged against the award for the contract on the “common spacecraft” has now been resolved. An Announcement of Opportunity (AO) to support the Earth System Science Pathfinder (ESSP) program is due to be released in June.

Rothenberg said that the FY 96 budget has now been signed and MTPE has suffered only minor cuts. Budget cuts are still threatened for FY 97. Finally, he said that the commitment to the 24 MTPE/EOS measurement sets remains firm.

Charles Kennel, Associate Administrator for MTPE, gave an overview of MTPE and EOS. He started with the “State of Health of NASA’s MTPE,” and said that “the patient is still in critical condition.” The approved FY 96 budget is set at \$1289.4 M, down by 6%. This is the first NASA budget to be passed since the Congress adopted the balanced budget goal. The FY 97 request is for \$1402.1 M. This shows an increase, but the outyear budgets are still ill-defined. Overall, the NASA budget is to decline by FY 00 from \$13.8 B to \$11.6 B. If this decline does, in fact, take place, MTPE will surely not go unscathed. Administrator Dan Goldin thinks this decline is negotiable. We have the dual strategy of hoping for the best, but planning for the worst.

The House Science Committee has subtracted \$373.7 M from the FY 97 budget. While this loss will not affect the 1998 launch of AM-1, it could lead to delay of the following missions starting with PM-1. The Science Committee added \$310 M to NASA’s Space Science Budget, but Goldin has said that this is irresponsible, and he opposes it.

MTPE has had a strategy that has gotten us through the last fiscal year reasonably intact:

- a. We have paid attention to House Science Committee concerns regarding downsizing spacecraft and providing opportunities for commercial activities.
- b. We have appealed to the appropriate House and Senate committees, emphasizing that this is a *science* program with short-term applications. (This is particularly important to the Senate.)

[On the day following the IWG meeting, May 16, there were to be MTPE presentations to the House Appropriations Committee and to the Senate Authorizing Committee.]

The National Academy of Sciences Board on Sustainable Development (BSD) in its report of last summer came out with spirited support of MTPE. The report said that MTPE science was strong, and that we should go ahead to implement the program without delay. Nonetheless, Kennel said, we can expect the pressures on the program to continue.

He explained that the New Millennium Program (NMP) was strongly directed toward the introduction of new *technology* and that ESSP is more directed toward the introduction of new *science* that could be supported by new technology.

There have been 760 downloads from the World Wide Web (WWW) of the draft AO for participation in ESSP. The plan is to choose one candidate each year and not maintain a queue of proposers for the AO. Instead there would be a new competition each year.

Kennel reported on the major challenges of the past two years, the period in which he has been the Associate Administrator for MTPE. It had not been possible to achieve a national consensus on the MTPE budget level, and this had been a chief goal. On the other hand we were able to maintain the 24 measurement sets as a goal.

A MTPE science plan is being developed, showing planned activities vs. time. Bob Harriss has had the lead on the plan, which shows the integration of MTPE's Research and Analysis (R&A) program, modeling program, and EOS. The plan outlines the expected short-term vs. long-term achievements in regard to understanding climate variability and change. It also articulates the science goals and brings out the interrelated network of science problems that are to be addressed. The EOS science plan, being developed by members of the IWG, will contribute to the articulation of the MTPE goals.

There has been an evolutionary approach to the implementation of EOS. The original plan was to have two repeat missions for each member of the first set of EOS missions. In this way there would be economies of scale, and the needed quality of measurements for monitoring of climate change would be maintained. Unfortunately, however, by following this approach, annual costs would have risen monotonically until 2010, and then there would have been a decrease.

A budget profile showing this relentless growth could not be supported. As a result it became clear that implementation of the second and third round could be different from the implementation of the first round. Despite changing the implementation mode, the commitment to the 24 measurement set categories could be maintained and it is up to the scientific community to guard the integrity of the measurement sets.

There has been a new focus on cost saving. Partly, this can be achieved by re-engineering the instruments to cut down on their mass and power requirements. In search of improved instruments, 80% of NMP funding is

going to the development of new, re-engineered instruments. The Advanced Land Imager (ALI) is the first example of a NMP development. It is to co-fly with Landsat. If ALI proves successful, then a copy could fly on the AM-2 spacecraft and thereby save system costs.

There are several areas in which we are achieving closer alignment with NOAA with potential for considerable overall savings. We are developing new technology for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). NPOESS is planned to have a 2008 launch. If it operates at a level of accuracy and precision needed for climate change purposes, it will offer an opportunity to save money for EOS. Related to this are plans for linking NOAA and NASA data systems. We are also considering new technology that would be applicable to the geostationary weather satellites. Incidentally, NOAA is still planning a move to the Goddard campus.

Following the BSD recommendations we are developing a new philosophy for data product generation. Creating an EOSDIS "federation" will be the first step toward providing greater flexibility, partly through introducing competitive forces. The federation should be in place by 1999.

MTPE is to have a new management approach — there will be a major implementation review every two years at Goddard. This will involve "all players," including Congressional staff members.

MTPE is now in the process of drafting a commercialization strategy and has an educational outreach philosophy that says: "teach the teachers." Unfortunately, the education budgets are limited.

An Integrated Global Observing Strategy (IGOS) is being formulated in conjunction with NOAA. The larger question is how would all the relevant agencies collaborate in monitoring the global environment. Currently, systems are being designed for *parts* of the global system — atmosphere, land, biodiversity, oceans — but these sets of programs have no coordinating body.

In March of this year the Committee on Earth Observations Satellites (CEOS) reviewed IGOS. The next step will be taken at the Global Climate Observing System (GCOS) meeting in Geneva, where there is the hope of building an international strategy group that would plan

for the post-EOS era. In fact, at this time there is no international plan to cooperate on Earth observing after the CHEM-1 mission has flown.

Kennel said that the “Critical Challenges” are:

- ◇ achieving consensus on a stable MTPE budget level;
- ◇ broadening the scientific constituency and reach of MTPE, which is still the largest science program in the world. Despite its size, there is still little awareness of MTPE in the science community at large. New collaborators, with new ideas, are needed.

Kennel added that relentless technical innovation demands close collaboration among the scientists, engineers, and administrators.

NASA Headquarters (HQ) is shrinking dramatically — MTPE program implementation has been transferred to Goddard, acting as the lead Center. NASA HQ retains responsibility for the peer review process and the *science* program. There has to be a proper balance of science and applications of MTPE research. Commercial interactions must be considered.

NASA has been given *expanded* responsibilities for the full range of related observations to solve its science problems — this means both space-based and *in situ* observations.

Kennel brought his presentation to a close with what he called “Personal Remarks.” He asked whether global change research is truly sustainable. He said that it is not clear whether we can sustain the program long enough. There surely is no clear-cut end to research. Domestic and international priorities can change drastically. There is an inherent potential for controversy. Research results can provoke anxiety and calls for change in the program. There is no easy road to public confidence; there is no crucial experiment; and there are no widespread economic payoffs foreseen as yet.

But, Kennel said, “global change research must be sustained!” In our generation human impacts on the environment have become quantitatively discernible. We owe it to the next generation to have the ability to think clearly about our global environment. The next generation will have to make the “tough calls” about sustain-

able development. Kennel’s concluding statement was that NASA’s basic role is to develop the sciences that require technology to achieve results.

Berrien Moore reported on the “NRC Review and Perspectives on MTPE/EOS.” Speaking without viewgraphs he discussed the La Jolla meeting of the National Research Council (NRC) Board on Sustainable Development (BSD) Committee on Global Change Research, which took place last summer. He also discussed the findings of the March of this year follow-on meeting.

At La Jolla there were seen to be four challenges of the USGCRP: seasonal to interannual variations of climate, chemical changes in the atmosphere, eco-terrestrial changes, and climate change on decadal-to-century scales. (Previously, USGCRP had been regarded as just a climate change program.)

The Committee urged that the federal government think about end-to-end information management. They noted that there had been a falling away of the mission agencies, such as Department of Agriculture, Department of Interior, and the Environmental Protection Agency, from participation in the USGCRP activities. At the March meeting they noted that their greatest concern was with the perceived lack of concern for terrestrial and marine ecosystems.

They stressed that the role of human dimensions in global change is essential. There should be a horizontal cut of social sciences across the four USGCRP objectives. There is a need to focus social science within each of the four USGCRP areas.

The Committee also noted that the international linkage is not well integrated in the USGCRP. The Integrated Observing Strategy was not deeply reviewed but it was felt to be extremely important. The status of Earth system modeling in the United States vs. the status of international efforts needs to be reviewed. The U.S. appears to be falling behind in this area.

As important as climate change has been perceived, atmospheric chemistry changes must now be recognized as being very important.

Issues that were summed up included these:

- ◇ NASA must contribute more to *in situ* observations, including airborne. There needs to be a healthy R&A program to do this.

- ◇ Overall, the USGCRP still needs a science plan, and the NASA plan will be an essential element.
- ◇ The CHEM-1 mission has shown considerable progress. There is still a need to integrate the space-based observations with *in situ* observations. The Committee has focused on TES. They believe that there should be tighter coupling of the TES observations with ground-based international monitoring of ozone and its precursors. The scientific community is not sufficiently involved with planning for tropospheric ozone observations.
- ◇ The Committee approves of NASA's approach toward flying smaller spacecraft.
- ◇ NASA is responding well to its recommendations for EOSDIS. The streamlining of the data downlink process was good. Critical issues must still be considered regarding the Federation of partners for EOSDIS. There can be a trade-off of savings between early implementation of the Federation and a more-effective system that could be achieved in the long run. A deliberate implementation approach should be adopted even though it could lead to delays. There should be a constitutional convention to establish governance of the Federation.

Robert Harriss, director of the Science Division of MTPE, reported on the "MTPE Science Plan and Planning." He referred to the critical challenges ahead that had been discussed by Kennel and said that there now is a logical MTPE plan with scientific substance. This plan is now available on the "net." The EOS plan that is to come will strengthen the MTPE plan by adding implementation insights.

He cautioned that there are still major problems with reaching outsiders — Congress, the White House, and the general population.

There has been an evolution of science and commerce from the Darwinian competitive world to the 21st-century world without competition. The winners will be those having a co-evolutionary and cooperative approach to problem solving. [He showed a sketch in which advanced technology, core research (R&A), EOS science (Interdisciplinary Science, IDS), academia, and regional applications all fed into sustainable use.]

There is a need to bring local and regional governments into the cooperative effort. Implications of global change for localities must be considered.

Assessments, such as the ozone assessment by the ozone community and the climate change assessments by the Intergovernmental Panel on Climate Change (IPCC), have taught us a lot. The IPCC Working Group II dealt with the climate consequences of global climate change, and Working Group III dealt with the economic consequences, but the quality of these studies is lower than that of Working Group I that dealt only with the assessment of scientific information on climate change.

The hydrologic cycle may be regarded as an instance wherein the relation of global to local change can be studied. There are enormous issues related to the problem of regional water supply. Elements that must be understood include:

- ◇ atmospheric sources — spatial patterns, trends, and variability;
- ◇ landscape/hydrologic interactions — recycling between the atmosphere and the surface;
- ◇ hydrologic flows and storages — synthetic aperture radar (SAR) can be used to determine surface and subsurface elements; and
- ◇ sustainability.

We are now building interactions with the Department of Agriculture and the U.S. Geologic Survey (Department of Interior) to pursue these questions, and we have already identified critical regions that should be studied.

We can see the relative impact of key changes in other countries, e.g., using a United Nations Environment Program (UNEP) study we can see the role of land degradation in arid and semi-arid areas that affects both water quality and quantity.

The World Bank looks at the price of water as the population increases in the megacities of the world. It expects the price of delivering water to double or triple in these places by the end of the century! Harriss believes that better science, and anticipating and ameliorating some of the foreseen changes, can lower the costs that may otherwise be incurred.

Around the world issues of the environment are becoming critical to national security in the developed world as a result of problems being encountered in the developing world. Increased environmental scarcity leads to conflicts. Worldwide, population is still increasing, but at a slowing rate.

In the Texas border region there has been a massive migration from Mexico to Texas. Thus about two million people are now living in an area where only about 200,000 people can be supported by the ground water. The wells there will be dry in a decade.

Considering factors like those just outlined, Harriss sees many regional applications for MTPE, and he listed just three of these, for which we can supply the needed data:

U.S./Mexico Borderland Initiative;

Middle East water; and

Impacts of seasonal-interannual climate variability on the Southeast U.S., Southeast Asia, and other areas based on our new understanding of El Niño Southern Oscillation (ENSO) dynamics.

As an example of what support MTPE might give, he said that we could provide Digital Elevation Model (DEM) data, coming from the Defense Mapping Agency, to Costa Rica. We would provide both slope and aspect data. The problem being faced in Costa Rica is a conflict between hydropower uses and other potential issues of land use. With the right data the hydropower users could have their needs satisfied and yet not infringe unnecessarily on the other users.

Soil composition mapping is another benefit that can be offered by MTPE. For example, he cited the flights of AVIRIS on the ER-2 aircraft. He pointed out that there will soon be AVIRIS-like hyperspectral technology on the Lewis satellite.

Within the EOS program as it stands we have these IDS studies relating to the hydrologic cycle: Sorooshian and Dickinson arid-lands studies, and Dozier's snow-melt study. All of these are relevant to the study of the Mexico/U.S. border region hydrology. The University of Texas at El Paso, under an Equal Opportunity contract, can also contribute useful hydrologic information.

The problem is that in Texas we don't know where the re-charge areas for ground water are located. However, our R&A program has relevant models for this.

The growth rates for regions like the Mexico/Texas border are so great that the available census data are invalid. Mark Imhoff has been using city lights from the Defense Meteorological Satellite Program (DMSP) as a basis for quantifying urbanization. He will be applying DMSP city light data to pursue water studies for the mid-East. Danny Rosenfeld of Israel will be using Tropical Rainfall Measuring Mission (TRMM) precipitation data to learn about water availability in the tropics.

Harriss said that there are to be two new NASA opportunities to engage in hydrology-related studies. Two NASA Research Announcements (NRAs) are now going through the approval process and will be on the street within about six weeks.

The first of these NRAs is for Land Use and Land Cover Change Research (LUCC) and will provide support for three years. It calls for:

new and improved regional data;

process and parameterization studies (hyperspectral data will be enormously useful here); and

coupled land-use and ecosystem process studies.

The expected outcome of these studies will be integrated assessments of the consequences of land-cover and land-use changes in globally important areas of rapid change. The second NRA provides for support of TRMM science in the period from 1997 to 2000.

Ghassem Asrar, EOS Program Scientist, presented "EOS Science Update: IDS Reviews and NRA Selection." Harriss reiterated his feeling that MTPE must do more than develop an understanding of the Earth system; rather we should also show how to apply the knowledge that we gain.

Asrar started by mentioning a recent NRA that had been issued in September of 1995. The focus was on increasing participation, enhancing educational outreach, and improving the communications aspects of the program. There were 328 proposals received, and 123 of these were for IDS investigations. As a result of the NRA, the following numbers of new Team Members have been

selected: MODIS - 5, Landsat - 14, AIRS - 2, Multifrequency Passive Microwave Radiometer (MPMR) - 2, and TRMM - 2. Five new investigators have been added to pursue atmospheric chemistry and climate modeling. Five new projects have been selected for education and communication.

Asrar said that the biennial site reviews began in 1990, a second review was held in 1992, and the latest review was held in 1995. He reviewed the mail- and panel-review process. As a result of the process IDS teams were scored in three categories, with these results: 7 teams were rated exemplary (category I); 18 were rated satisfactory (category II); and 4 were rated unsatisfactory (category III). One team did not submit a progress report. Category III investigations are to be phased out over two years, with their budgets reduced by 50%. There is to be a recompetition in the 2000 time frame.

Asrar remarked that there was some outstanding science in some of the category III investigations, but this work should be part of an R&A study and not an IDS study. As a result of the review it was felt that there should no longer be 10-year grants to the investigators. Rather there should be an allowance for re-adjustments every 4-to-5 years.

Plenary Session on Chemistry-Aerosol Climate Processes

Jerry Mahlman, Director of NOAA's Geophysical Fluid Dynamics Laboratory, reviewed "Challenges and Opportunities for Climate Research." He began by acknowledging Charlie Kennel's key role in refocusing NASA's MTPE to make it a science-based program. He then went on to discuss requirements for climate monitoring. He illustrated the problem by showing the equilibrium ΔT that should have been calculated as a result of greenhouse forcing and showing that it doesn't match what has been observed.

The role of water vapor in the troposphere is a very significant one that needs more study. There is good agreement between a general circulation model (GCM) experiment and measurements of upper troposphere water vapor. This confirms the notion that deep convection leads to moistening of the upper troposphere.

Mahlman devoted much of his to talk to the National Polar-orbiting Operational Environmental Satellite

System (NPOESS). Some relevant thoughts were that: climate change predictions must be evaluated; long-term monitoring is very difficult; "clean" monitoring is rare; monitoring from space is critical; and NASA expertise is essential. NPOESS will provide continual measurements over the next 2-to-3 decades.

Mahlman also listed some "barriers" to NPOESS success, including: the current operational focus of the program; the current organizational structure; the current sense of program ownership — the science community needs to be in there; the limited awareness on the part of key agencies — NOAA, DOD, NASA, and OSTP are not pushing for serious climate monitoring. NASA should "kick in" financially; and, finally, a research infrastructure is missing as is an arrangement for an "NPOESSDIS."

Mahlman discussed the findings of an integrating panel from an NPOESS climate needs workshop. Among the findings were these: NPOESS represents a major opportunity to obtain climate-relevant operational products; NASA, especially, is in a position to influence the choice of climate products; research support needs to be planned very carefully; a strategy is needed to incorporate new instruments and new technologies; and NPOESS needs to take advantage of EOS knowledge and developments.

Mahlman's conclusion was that understanding climate change requires an inseparable synthesis of appropriate observations, focused analyses, and careful modeling. Kennel added that the White House has to take the lead in adapting NPOESS for climate research.

Mark Schoeberl, Goddard Space Flight Center, described his research on "Comparison of Modeled and Observed Antarctic Ozone Loss." He started with data for the period August 17 to September 17, 1992 from the CLAES instrument onboard the UARS satellite. The intent of the research was to determine the mechanism for Antarctic ozone loss. He found that necessary conditions for the development of the Antarctic ozone hole include high levels of reservoir chlorine species, HCl and ClONO₂, sufficiently cold temperatures leading to the formation of polar stratospheric clouds (PSCs) made up of ice and nitrates and isolation of the air by the circumpolar vortex.

He said that his analyses can't explain the year-to-year

variations in the ozone hole but do explain the long-term trends. The use of “balanced” winds in his model may be the reason for the discrepancies he found.

Hugh Christian, Marshall Space Flight Center, described his observations with “The Optical Transient Detector (OTD): Initial Results from a pre-EOS Instrument.” The OTD was built in just eight months and was launched in April 1995 as a Pegasus payload, along with the GPS/meteorology (GPS/MET) payload. [GPS/MET is the subject of Michael Exner’s presentation, which is described later in these minutes.] OTD is a precursor to the LIS instrument, which is part of the TRMM payload. Thirteen months of data have now been obtained. Christian showed data for the one-year period from May 1995 to April 1996. OTD has the special advantage of being able to detect lightning both day and night.

Christian explained that three conditions are necessary to have lightning: a strong updraft is needed (> 13 m/s); there must be ice crystals; and there must be graupel.

Pat McCormick, Langley Research Center, discussed “LITE Cloud and Aerosol Measurements from the Space Shuttle.” LITE is the Lidar In-space Technology Experiment and was launched on September 9, 1994, providing data from September 10 to September 19 based on 2 million laser shots. LITE was a NASA Office of Space Access & Technology (Code X) program and flew in ten years from its inception.

LITE has a small footprint — 1 mrad divergence leading to 300 m at the surface from Shuttle altitude. There are 20 to 30 ns pulses, leading to 15 m vertical resolution. The fundamental wavelength is 1020 nm, and there are also doubled and tripled frequencies. Pulses hit the ground at 740 m intervals.

The goal of LITE was to demonstrate the utility of spaceborne lidar. Sixty groups in twenty countries participated in the experiment by providing correlative measurements. Six instrumented aircraft made underflight measurements.

Among visualization products were beautiful three-D images showing slices of observations of aerosols and clouds along the spacecraft path.

Jim Garvin, Goddard Space Flight Center, gave some “Preliminary Results from the Shuttle Laser Altimeter

Experiment: Implications for EOS Era Observations of Oceans, Land, and Clouds.” The experiment was the successful design and application of a 30 W, 30 kg lidar system for Shuttle mission STS-72. The lidar system is designed to study land cover and geodetic topography, globally. The particular application of the data from such a system is the establishment of ground elevation control points. The particular beneficiary of the work that has been done will be the GLAS instrument which will fly as part of the EOS laser altimetry mission. The next flight of the Shuttle Laser Altimeter is to be on a 57° inclination orbit in July 1997.

Michael Exner, University Corporation for Atmospheric Research, gave the last talk of the day: “GPS Sounding of the Atmosphere from Low Earth Orbit: GPS/MET.” GPS/MET went from concept to spacecraft flight in six months. It provides 500 atmospheric profiles per day for one receiving satellite. Not only does the system provide meteorological measurements, but also it provides electron density profiles, giving it a space-weather capability. The measurements that have been made show great variabilities in the ionospheric electron density profiles.

There are temperature profile errors in the system at altitudes greater than 50 km, which are due to ionospheric effects. Calculations of temperatures are made ignoring moisture variations. The system offers vertical resolution of about 1 km to within 500 m of the surface. The best resolutions are obtained near the tropopause. The horizontal resolution is 300 km.

Tuesday, May 14, 1996

Session on Global Productivity and the Carbon Cycle

Steve Running, University of Montana, led off a joint presentation (with Alan Strahler and John Townshend) on “Global Land Cover Products from EOS.” Running called his part of the presentation “Representation of Terrestrial Vegetation in Global Models.” In a series of viewgraphs he illustrated: abrupt changes in vegetation that take place as one crosses the Montana/Canadian border; the effects of land-use changes on plant canopy density; the reduction in evaporation/transpiration (E-T) — 50 % lower in some places than was expected; and the great differences in land cover classes vs. area covered, as defined by various authors. He noted that

terminology for vegetation classes is far from standard and that, until satellite measurements came along, direct measurements have been sorely lacking.

Running has been trying to straighten out the discrepancies in classification and has settled upon six clear-cut classes. He has found that surface temperature is a better classifier than is NDVI. The temperature thresholds he uses are based on maximum temperatures throughout the year and are consistent classifiers. He now has a global 8 km land cover map, based on AVHRR observations, but there is no way to verify the scheme that he used.

John Townshend, University of Maryland, presented the set of products that his investigation is to produce at launch.

Alan Strahler, Boston University, discussed his use of advanced classification technology involving neural nets and decision trees. He said that the IGBP is providing a 1 km database involving 17 "IGBP land cover units." Nine of the units fit the category "natural vegetation," three are in the category "developed lands," two are in "mosaic lands," and three are in "nonvegetated lands." He also pointed out that when MODIS data are available it will be possible to make use of surface reflectance and spatial texture.

As part of his advanced technology approach he illustrated the "change vector" technique. The presence of mixed cover in a 1 km pixel would appear to be a problem, but Strahler feels that it will not be a problem with 30 m pixels. It is subscale variations that are a problem.

Jim Collatz, Goddard Space Flight Center, discussed work on "Radiative and Physiological Effects of Doubled Atmospheric Levels of CO₂ on Climate." The goal of the investigation was to develop an Earth system model involving the modeling of the interactions among soils, vegetation, and the atmosphere. The Simple Biosphere Model Version 2 (SiBV2) shows the interaction paths of the canopy and atmosphere. The combined model uses SiBV2 and the Colorado State University general circulation model (GCM), a modified version of the University of California GCM. The FIFE and BOREAS campaigns have served as validation for the modeling efforts.

Collatz showed observations of NDVI from the NOAA satellites and commented that NDVI is affected by

changes in the sensors that have occurred during the succession of the satellites.

A question of interest to the investigation is how *plant physiology* and the atmosphere interact when CO₂ is doubled. Collatz pointed out that C3 plants are very sensitive to increases of CO₂, whereas, C4 plants are not sensitive.

A simulation of more than 30 years has been run and shows that the temperature effects vary with latitude. When physiology is introduced into the model there is substantial warming over and above the effects of radiative forcing attributable to the change in CO₂.

Milton Smith, Goddard Space Flight Center, spoke on the subject "Analyzing AVHRR Data Over Amazonia Using Fore-and Background Techniques to Minimize Cloud Effects on Surface Images." He was reporting on changes in Amazonia based on a ten-year AVHRR time series. He has been looking at biogeochemical fluxes derivable from remote-sensing measurements. Challenges to the analysts have been the uncertain instrument calibration and the variable scene illumination. Atmospheric effects are significant and must be taken into account. He has used a Finite Impulse Response (FIR) filter to find components of the observed mixtures. The filters were applied to a single image each day. He gave as his conclusions:

- ◇ The entire surface of the Amazon Basin can be revealed free of clouds using monthly mosaics of AVHRR images; and
- ◇ The 3.5 μm channel of AVHRR shows the response to photosynthesis and temperature.

Berrien Moore, as session chairperson, led a "Synthesis and Discussion" period. He said that the straightforward classification schemes of Running and Strahler gave confidence. The Sellers work (reported by Collatz) shows that doubling CO₂ shuts down evapotranspiration leading to warm tropics and cool high latitudes. The presentation by Milton Smith shows that some of the previous AVHRR data interpretations have been questionable. It is interesting to ask how much of the changes that have been reported in the past are due to changes in calibration. Will MODIS data get us out of the difficulties we have been having?

Dozier responded that MODIS would help by doing

atmospheric corrections directly, and Scolese pointed out that MODIS will still have clouds in its data set. Strahler added that his group uses multi-channel atmospheric correction and gets corrected surface reflectances. View angle effects can be taken into account by correcting to standard angles. Townshend pointed out that it is possible to go back to the old AVHRR data and apply the atmospheric corrections retroactively. His group will be doing this for both 1 and 8 kilometer data. The 8 kilometer data go back to the early 80's.

Moore said that there is an intercomparison group using CO₂ flask data to see whether land or ocean has the greatest effect on gross primary productivity (GPP).

Moore asked whether information on the bi-directional reflectance distribution function (BRDF) would be available from AVHRR or from MODIS. Strahler replied that the MISR/MODIS teams are converging on semi-empirical models for surface BRDF. POLDER will contribute as well. Global maps of BRDF have been created using AVHRR data, but no global seasonal maps are yet available.

Dozier pointed up the odd situation that as models have been improving the apparent uncertainties have been increasing! We need to be able to explain this to the Congress.

Session on Validation, Calibration, and EOSDIS

Vince Salomonson, Goddard Space Flight Center, led off with a review of some of the calibration/validation issues that he perceives. We have heard a lot about the sensor drift of AVHRR. The 24 EOS instruments have now become the 24 EOS measurement sets, and this allows openings for new instruments to be introduced into the program. The proposed smaller version of MODIS will have the disadvantage of losing some of its internal calibration/characterization devices. Looking to future developments, it is necessary to protect the quality/integrity of the EOS measurements.

David Starr, Goddard Space Flight Center, reviewed the status of validation planning for the early AM-1 timeframe. Recent activities include the October Airborne Instrument Workshop, the March EOS Test Sites Meeting, and May EOS Validation Workshop. The

May meeting had substantial Interdisciplinary Science (IDS) and NASA Headquarters (HQ) participation with 15 IDS teams and 12 Program Scientists participating. Starr noted that Jim Dodge has NASA HQ responsibility for calibration/validation activities.

Starr went on to review the Test Sites Meeting report and the Validation Workshop held the prior week. He also introduced the EOS validation homepage. In addition to documentation of validation activities and reports, the contents include the draft Validation Plans from the instrument teams and summaries of their plans, inputs from the IDS teams, and links to descriptions of test sites, field experiments and networks.

The schedule calls for revision of AM-1 timeframe validation plans with a formal review late in the year. There is also to be a NASA Research Announcement (NRA) for correlative measurements later this year. Validation planning activities for missions in the PM-1 timeframe will be initiated this fall.

A hierarchical approach to land test sites was established at the Test Sites Meeting. Five "tiers" were defined as follows:

- ◇ Tier 1: Intensive Field Campaigns such as the Boreal Ecosystem-Atmosphere Study (BOREAS) and the proposed Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA).
- ◇ Tier 2: Super Sites having extensive instrumentation with application to multiple data products and disciplines.
- ◇ Tier 3: Biome Tower Sites having a limited but standard complement of key land surface instruments.
- ◇ Tier 4: Globally Distributed Test Sites with limited instrumentation. These sites will likely include various existing networks and sites.
- ◇ Tier 5: Calibration Test Sites comprised of highly specialized (simple) targets.

It was recommended that the EOS Validation Program NRA emphasize support for the Tier 3 and Tier 4 sites. A balance between enhancement of existing sites and development of new sites was also recommended.

A major focus of the Validation Workshop was further cooperation and integration among activities of the Instrument and IDS teams and with NASA R&A Programs, as well as to identify potential interagency and international partnerships in support of EOS Validation. A unifying theme here is that the overall scientific productivity, quality, and comprehensiveness of EOS validation will strongly benefit from cooperative community efforts. Utilization of common test sites and field experiments, where appropriate, is essential to this end.

Starr summarized the Validation Workshop and highlighted some important issues that had been identified. Working groups considered validation of fundamental geophysical products (radiances) including vicarious calibration activities (joint ASTER/MODIS/MISR activities are underway), atmospheric correction algorithms, and standards and protocols for validation measurements. Validation of higher order geophysical products including radiation, cloud, ocean, land and atmosphere products was also considered.

Issues included the need for well-defined measurement protocols and calibration. An accessible secondary calibration facility is required. Development of a unified EOS Master Aircraft Schedule is needed to facilitate planning and allocation of resources. Efforts are needed to define a standard instrument package for the Tier 3 sites, to determine the suitability of existing tower sites around the globe, and to document existing test sites and networks. Archival of validation data is another key issue that must be addressed. A policy must be implemented that is consistent with providing data access to facilitate progress but is realistic in terms of resources. The role of the DAACs should be clarified. In addition, specific information is needed about the NASA R&A programs and what activities are planned that might provide opportunities for coordination with other validation activities.

Barry noted that the National Snow and Ice Data Center (NSIDC) will look after the Surface Heat Budget of the Arctic (SHEBA) data; the DOE has an archive program for ARM data; and the other discipline DAACs can do more.

Running said that four classes of data sets have been identified, but none of the 50 to 60 existing towers that were cited collect all four classes of data. He asked whether we could send sensors of our selection to the

tower managers. Murphy replied that long-term loans have been made in the past.

Goodison asked whether sites like BOREAS will be maintained for the duration of MTPE. He wondered whether Canada was expected to provide the funding.

Jim Butler's subject was "EOS Calibration: Status and Plans." He began by discussing the use of ultra-stable transfer radiometers for radiometric measurement comparisons. A set of four targets has been used as standards for artifact measurement round robins. After each measurement the target was returned for checking to the National Institute of Standards and Technology (NIST). Butler stressed that calibration, validation, and quality analysis are *all* significant steps in the process. Fritz Hasler and K. Palaniappan, Goddard Space Flight Center, gave the final presentation of the morning: "Visualization and Analysis of MTPE Datasets Using the Interactive Image Spreadsheet." This was a live presentation involving images that were both static and animated and could be brought up in spreadsheet fashion for manipulating the contents of the various images. Hasler remarked that techniques such as the one demonstrated for dealing with overwhelming amounts of data had been described by Vern Suomi as those that "help us to drink from the fire hose."

One of the examples of visualization had to do with animated renditions of Hurricane Luis. Using the new techniques it has been possible to bring out the previously unrecognized intensification that took place in the northwestern corner of the hurricane "eye."

Palaniappan emphasized that in the future the hardware elements that are used to make sophisticated visualizations work will be essentially "free." The significant costs will be associated with the software elements.

Breakout Sessions on Science Implementation Plan

The afternoon was devoted to breakout sessions on the various discipline chapters of the plan.

Wednesday May 15

Yukio Haruyama, NASDA, gave an invited presentation on "NASDA Future Earth Observation Plans." He began by showing plans for the Japanese meteorological

satellites including the GMS series and then showed the plans for TRMM and the Advanced Land Observing Satellite (ALOS). TRMM is to be launched in November 1997, and ALOS has a target launch date of 2002. ALOS will feature an L-band SAR called PALSAR. ADEOS is to be launched on August 17 this year, and ADEOS II will be launched in 1999. The JERS-1 satellite was launched in 1992.

Longer-range developments include ADEOS III and ADEOS IV. TRMM follow-ons could be ATMOS 1,2, and 3. ADEOS III may be launched in the 2001 time frame. Its mission concept is described as providing a better understanding of global change. It will include sensors for both atmosphere and ocean characteristics.

Atmospheric measurements will include cloud characteristics, temperatures, water vapor, cloud water, precipitation, radiation budget, aerosols, and ozone.

ATMOS-1 could include three versions, A, B, and C. The goal would be to determine seasonal and annual global water cycle elements. With a 55° inclination angle and 400-kilometer orbit, ATMOS will give approximately 95% coverage of the world. A dual-frequency precipitation radar (PR) on ATMOS-A will measure lower rain rates than will be possible with the single-frequency version on TRMM. ATMOS-B will carry a cloud lidar.

Session on Seasonal and Interannual Climate

Ted Strub, Oregon State University, addressed "Comparative Studies of Eastern Boundary Currents in the Ocean: A Multi-sensor Approach." Four out of five major bio-activity areas occur in eastern boundary currents. They are rich systems for fisheries and have large fluctuations. Strub discussed a program called Global Ocean System Eco-Dynamics (GLOBEC). He pointed out that there is a natural cycle of about sixty years for sardine/anchovy catches. It is also interesting that there is an out-of-phase variability between Alaska salmon vs. Pacific Northwest salmon.

In studies of the ocean circulation off the coasts of both North and South America he has used satellite altimetry and AVHRR to survey patterns of the formation of a "jet," and the appearance of eddies as the jet moves off shore. In turn he has studied both the California current and then the Chile current. In doing this he has found

different patterns between the two currents. He has also taken advantage of CZCS color sampling in these studies. Studying the dynamics of the maxima in the counter currents he has analyzed the relative influence of local wind frequencies vs. large-scale/basin-scale currents. Strub has not established whether ocean topography affects the observed motions of the jet, such as the pattern of separation from the coast. He will be adding Atlantic upwelling regions to his studies. His models do produce *meandering jets*.

Eric Wood, Princeton University, gave the final plenary session paper, "Strategy and Initial Testing of the EOS/HPC Large Scale Terrestrial Water and Energy Balance Algorithms." (HPC refers to hydrologic processes and climate.) Wood's studies cover small, medium, and large scales, going from 10² to 10⁴ to 10⁶ km². He uses process models, coupled models, and budget analyses. In his mesoscale hydrologic model he uses four vertical models to account for the water and heat fluxes, including the effects of soil moisture. He makes soil porosity estimates for the underlying bedrock and uses texture data, porosity, and conductivity relations to analyze the first few meters of soil depth. His model for runoff does not include water quality/geochemical content.

Wood said that his group has found errors in reported ground heat fluxes, but has been able to correct them. There is a wide variation in reports of runoff vs. evaporation from many groups. Often there is either too much or too little soil moisture compared to observations. Other errors that he has encountered have to do with modeled sensible heat fluxes. Moore remarked that precipitation-temperature data are needed globally to use as standards for studies such as this.

Wood's strategy for calibration/validation is to work with large-scale data sets, in particular, data from the Red-Arkansas Basin. It was pointed out that the available global precipitation data do not include precipitation in the form of snow, and this could affect studies like Wood's.

Pierre Morel pointed to the need to promote cooperation between the various IDS investigations. For instance, the land surface hydrology people should improve their connections with the CERES Earth radiation team. Wood responded that CERES just offers monthly data and his approach requires daily data. Also, it will be hard to get the necessary 1°-to-1.25° data from

CERES. There are also problems in matching up grids and projections. Similarly, Wood is unable to use GEWEX data, as the data are monthly and suffer from too many inconsistencies. Moore concluded that there is clearly a great need for a technique to down-scale data.

Payload Panel Meeting, Wednesday, May 15, 1996

Following the plenary sessions of the IWG there was a meeting of the Payload Panel, chaired by Mark Abbott. See page 15 for Abbott's full report on that meeting.

Mark Abbott, Oregon State University, in his "Opening Remarks," traced the flow of MTPE elements through science, technology, and requirements as manifested in the R&A program, ESSP, and NMP and on through EOS and NPOESS. In all of these the focus has been on climate research. He said that we can see the EOS focus on technology being adapted by the NPOESS program. There has been rapid evolution in the MTPE climate research programs, but slow evolution in the developments leading to NPOESS. There is a need to keep science insights in mind. He concluded his introductory remarks by referring to the role of new technology in MTPE with its potential for both scientific benefits and possible risks.

The next few lines of this report indicate just the nature of the other presentations made to the Payload Panel.

Al Diaz, Deputy Director, Goddard Space Flight Center, addressed "Chemistry-1 Study: Objectives." In his talk he described the nature and findings of the NASA Headquarters study that had been headed by Sam Venneri toward the end of last year. The study looked at possible cost savings vs. possible science accomplishments for the Chemistry-1 mission.

Rich Zurek, Jet Propulsion Laboratory, described "Chemistry-1 Study: Results, Science Impacts, and Options." He gave the contents of the interim report of the study and then gave the purpose as addressing: resource reduction, new technology opportunities, and accelerated tropospheric chemistry measurements, all constrained by the need to maintain a 2002 launch schedule.

The various Chemistry mission instrument teams were asked what they could do to reduce costs by fifty percent. [ODUS was not included in this review.] The responses in brief, were as follows:

- ◇ MLS could adopt millimeter wavelength Monolithic Microwave Integrated Circuitry (MMIC) to reduce the instrument size. [It was noted that MLS is the largest instrument of the mission.]
- ◇ HIRDLS proposed a reduced aperture size, which would have science impact for the stratospheric and mesospheric measurements.
- ◇ TES could not reduce much beyond reductions already made.

Zurek showed five potential mission scenarios plus the one he called baseline. In some of the options the launch date for CHEM-1 could be advanced. With the MMIC array, MLS could incorporate vertical profiles in multiple azimuth directions in addition to the baseline along track scanning. Among the three instruments, only MLS is in a position to infuse new technology.

Robert Price, Goddard Space Flight Center, Director of the Mission to Planet Earth Program Office, led a final session devoted to "Chemistry Project Assessment of Technical Risks and Options." Five options, in addition to the current baseline, were presented and are given in the Payload Panel report on the CHEM-1 study in this issue.

Peg Luce, Goddard Space Flight Center, Flight Manager for the CHEM-1 mission, gave the Project assessment. She said that there is only a small cost difference between 200 kg/300 W and 500 kg/500 W payloads. All the options that have been considered will advance the launch dates over the baseline launch date of December 2002.

Abbott brought the Payload Panel meeting to a close, saying that he would have a draft report available in a week or two to be ready for the planned July 29-31 meeting of the Payload Panel. ■

Report of the EOS Payload Panel on the GSFC CHEM-1 Study

— **Mark R. Abbott** (mark@oce.orst.edu), Chair

Introduction

NASA continues to search for ways to reduce the size, cost, and development time for its flight missions, to increase the rate of satellite launches, and to develop new technologies. These initiatives have helped to reshape NASA flight missions in all areas of science, including the post-2002 series of spacecraft in the Earth Observing System (EOS). These initiatives are interrelated in that smaller missions may be more cost-effective and provide more-frequent access to space. Reductions in the volume, mass, and power required by science payloads enable the use of smaller spacecraft and launch vehicles. The challenge is to achieve the needed reductions in spacecraft resources without jeopardizing the measurement capabilities required to achieve mission science objectives. The infusion of new technologies into the design and building of instruments and the spacecraft that carry them offers one means of meeting this challenge.

In response to these NASA initiatives, the Mission to Planet Earth (MTPE) Office at the Goddard Space Flight Center (GSFC) undertook a study to assess the feasibility of using new technologies and a new approach to implementing the EOS Series 1 Chemistry (CHEM-1) mission. The launch of CHEM-1 is baselined for December 2002, and its experiment teams are just starting detailed design and fabrication of the science instruments. Thus, there was time to consider whether an aggressive approach to infusing new technology could significantly reduce the resources required by the CHEM-1 instruments and so achieve substantial cost savings, possibly through multiple launches on smaller spacecraft. Investigating alternative launch scenarios was deemed particularly valuable because, at the start of the study in February 1996, the legal challenge to the contract award for procuring a common spacecraft for both the EOS PM-1 and CHEM-1 missions had not been adjudicated.

The GSFC CHEM-1 Study lead was Charles Vanek of GSFC, who was supported by the GSFC directorates and the EOS (CHEM-1) Project Staff. Science participation included: the Science Investigator Teams of the three U.S.-funded instruments (one funded jointly with the UK); Jim Gleason (CHEM-1 Project Scientist), Rich Zurek (Chair of the IWG Atmospheres Panel), P. K. Bhartia (TOMS Project Scientist), and Mark Schoeberl (EOS IDS PI). Preliminary results of the study were presented in late March to the GSFC management and in early April to the NASA MTPE (Code Y) Management. Mark Schoeberl also made a presentation to the Code Y Earth System Science and Applications Advisory Committee (ESSAAC) on April 19.

The GSFC CHEM-1 Study results were presented to the EOS Payload Panel on May 15, 1996, at a meeting appended to the Investigators Working Group Meeting, May 13-15, in Greenbelt, MD. Overviews of the study objectives, the impacts on science, and possible mission scenarios for deploying the CHEM-1 instruments were given by Al Diaz (GSFC Deputy Director), Rich Zurek (Atmosphere Panel Chair), and Peg Luce (EOS Chemistry and Special Flights Project), respectively. These were followed with presentations by the Principal Investigators of the instruments involved: John Gille and John Barnett, High-Resolution Dynamics Limb Sounder (HIRDLS, a US-UK collaboration); Reinhard Beer, Tropospheric Emission Spectrometer (TES), and Joe Waters, Microwave Limb Sounder (MLS). The Ozone Dynamics Ultraviolet Spectrometer (ODUS), provided by NASDA to NASA in exchange for the flight of the SeaWinds instrument on ADEOS-2, was not reviewed in this study, although it was necessarily included when considering various spacecraft options.

Study Guidelines and Methodology

The study guidelines were to aggressively pursue new technology options and to achieve substantial resource

reductions, while maintaining the essential scientific measurement capabilities and a launch date no later, and possibly earlier, than the original December 2002 date.

Instrument teams were challenged to meet targets of 50% reductions in cost, weight, and power requirements. Teams were encouraged to embrace new technical approaches where feasible, to remove excess margins, and to streamline and shorten development schedules. When instrument costs were assessed, allowance for the cost of technology development was included. The instrument measurement capabilities were scrutinized for duplicate capabilities and were judged against the suite of specific observations required to meet the EOS science objectives for the CHEM-1 mission.

CHEM-1 Science Objectives

The EOS CHEM-1 science objectives are derived from requirements addressing five areas of the EOS 24 Measurements: (i) Tropospheric Chemistry, (ii) Stratospheric Chemistry (emphasizing ozone and its precursors), (iii) Atmospheric Temperature, (iv) Atmospheric Humidity, and (v) Aerosol Properties (stratospheric). These five areas map directly and indirectly into four themes for the EOS CHEM-1 mission: (i) Tropospheric Chemistry, (ii) Stratospheric Chemical Cycles, (iii) Transport and Dynamics, and (iv) Long-Term Trends. These themes place special emphasis on beginning a global survey of key tropospheric chemical species, on acquiring global measurements of meteorological fields, and on obtaining distributions of trace gases and aerosols in the upper troposphere and lower stratosphere.

Launch of the CHEM-1 instruments in or before 2002 is critical to establishing long-term trends in key chemical species, by shortening the gap with present measurements, such as those of the continuing, but aging, Upper Atmosphere Research Satellite (UARS). Furthermore, the peak in stratospheric chlorine concentrations is projected to occur at the turn of the century, and observations are needed to capture the possibly nonlinear response of the ozone layer to these high chlorine concentrations. The many policy issues involving tropospheric chemistry will benefit from an early global survey of key tropospheric trace gases, and understanding the potential links of stratospheric ozone and upper tropospheric water vapor to climate change requires observations with greater precision and spatial resolu-

tion than are currently available. Thus, the National Academy of Sciences (NAS) Board on Sustainable Development recommended that the CHEM-1 stratospheric and tropospheric measurements not be delayed [Ref: "A Review of the U. S. Global Change Research Program and NASA's Mission to Planet Earth/Earth Observing System, " NRC, 1995].

General Findings of the CHEM-1 Study

Major reductions in the cost of the CHEM-1 mission could be achieved only if at least one instrument were deleted from the CHEM-1 payload(s). However, this would result in an unacceptable loss of science. Given past scrutiny of the CHEM-1 payload, e.g., see the report of the November 1995 Payload Panel Meeting, it was not surprising that the present study confirmed that deletion of any instrument or any descope that significantly reduced any instrument's observational capability would result in an unacceptable loss of science. Each instrument contributes in a major way to at least one, and usually more than one, of the EOS CHEM-1 science themes. Furthermore, in those cases where more than one instrument measures a given field, e.g., temperature (T) or ozone (O₃), they do so with different spatial resolutions, coverage, instrument biases and sensitivities to clouds and aerosols, or they require nearly simultaneous and co-located measurements, e.g., T or water vapor, to retrieve other, instrument-unique fields.

For the Microwave Limb Sounder (MLS), rapid advances in the development of Microwave Monolithic Integrated Circuits (MMICs) at ever higher frequencies presents a real opportunity for reductions in the mass (380 kg \Rightarrow 255 kg) and power of one of the largest single EOS instruments. The use of these devices could permit a small array of detectors that would provide multi-azimuth limb scanning for some of the fields measured by MLS; microwave frequencies have the advantage that they are less sensitive to the ice clouds and aerosol layers in the upper troposphere and lower stratosphere. No such breakthrough is available for HIRDLS or TES, which observe infrared radiation. These instruments are incorporating the use of improved infrared detectors, coolers, and composite materials into their instrument designs. Some mass and cost savings were identified; these are discussed below in detail.

The major reductions in the weight of the MLS and proposed smaller reductions in HIRDLS (161 kg \Rightarrow 110 kg)

and TES (290 kg \Rightarrow 255 kg) do enable launch on smaller spacecraft. The use of multiple launch vehicles provides opportunities for earlier launch of some of the EOS CHEM-1 instruments. [Note: The original instrument masses quoted here already take into account reductions identified in preliminary design work.]

The proposed modifications to MLS, HIRDLS, and TES increase technical risk to the extent that new technologies are being considered for MLS, and all three instruments have less margin in weight and power. The study concluded that overall these risks could be managed appropriately. Furthermore, the benefits of technology infusion, e.g., enabling of cross-track limb scanning for MLS and the use of MMIC technology that will undoubtedly be used in later missions, and of potential deployment on small spacecraft, e.g., enabling earlier launches and protecting against loss of the entire payload due to a single launch failure, were considerable.

Instrument Changes Recommended

MLS would measure the same fields in the same spectral intervals as previously proposed. The higher frequency channels at 240 and 640 GHz would continue to use the planar diodes originally proposed, but the 112 and 190 GHz channels would use MMIC-based devices. The small size and weight of these devices permit, with little mass and power penalty, sparsely populated MMIC arrays to be used to provide five or more azimuths, greatly increasing the horizontal resolution of the MLS measured fields of T, P, H₂O, ClO, O₃, SO₂, N₂O (a long-lived trace gas), and HNO₃.

One of two technical approaches to implementing the MLS 2.5 THz channel which measures OH, involves a high-tech high T_c superconducting hot electron bolometer in conjunction with a solid state laser and photomixer local oscillator. These approaches were already being evaluated by the EOS project prior to this CHEM-1 study.

HIRDLS proposed to reduce its mass by removing the outer housing of the instrument, and downsizing the instrument by reducing its optical aperture (telescope and optical bench). The resulting lower signal-to-noise was originally thought to affect measurements mainly in the mesosphere and upper stratosphere, requiring more spatial averaging of measurements of these still important, but lower-priority, regions. The lower signal-to-noise would also degrade the vertical resolution of

measurements to be made in the upper troposphere and lower stratosphere, though HIRDLS would still achieve better resolution than that achieved by present instruments, e.g., on UARS. However, more-recent and detailed algorithm simulations indicate significant degradation in the precision of the retrieved temperature and some species concentration fields in the critical upper troposphere and lower stratosphere. Roughly 60% of the mass savings for HIRDLS are achieved by eliminating the outer shell; the factor of 2 in increased noise only saves about 20 kg in mass. Investigations reconfirmed that potential new material and detector technologies were not mature and would raise costs by requiring substantial development efforts.

This proposed downsizing of HIRDLS retains the innovative horizontal limb-scanning capability of the instrument and the complement of trace gases and aerosols that can be measured. A more-radical descope of the instrument would likely jeopardize the participation of the UK in this international collaboration. However, because of its loss of capability in the critical tropopause region, this option was rejected.

TES proposed to implement changes to its electronics assembly and to replace its dual coolers with a single cooler; these options had been identified in studies conducted in the previous year, as part of the assessment of the TES tropospheric capability [Ref: "Tropospheric Chemistry: Measurement and Modeling Strategy," Proceedings of the GISS Workshop, November 7-9, 1995]. As had been reported previously, more-severe modifications of the TES instrument, e.g., replacement of the Connes interferometer with a Michelson device, would jeopardize the central TES measurements of tropospheric ozone and nitrogen species. Thus, this option was rejected.

TES also proposed transferring some of its science budget to augment instrument development. This proposal raised the issue of whether the TES data production algorithms would be ready at launch, particularly if the instrument were launched as early as December 2001.

Recommendations by the Payload Panel: Instruments

- ◇ MLS should proceed with implementation of the MMIC technology in its lower frequency channels, with normal and full evaluation by the EOS Chemistry and Special Flights (C&SF) Project of technical

risk, including potential impacts on cost profiles and schedule.

- ◇ MLS should incorporate the proposed MMIC detector/spectrometer array (with 5 or more azimuths) to achieve multi-azimuth limb scanning for the lower frequency channels, subject to normal evaluation by the EOS C&SF Project. Because of the relative insensitivity of the microwave measurements to the presence of ice clouds and of (volcanic) aerosols, this high horizontal resolution scanning provides a new and desirable capability in pursuit of EOS science goals.
- ◇ HIRDLS should not implement the proposed aperture reduction as it will jeopardize key measurements in the upper troposphere and lower stratosphere, a region of high scientific priority. Mass savings due to removal of the instrument's outer shell appear to have minimal impact on science and are therefore acceptable.
- ◇ TES and the EOS C&SF Project should continue evaluation of the use of single or dual coolers, including impacts on instrument optical alignment and thus on the schedule for instrument delivery. The schedule and budget for delivery of TES data products should be reviewed by the EOS Project Science Office, and a strategy developed for accommodating potential early launch dates.
- ◇ The Panel agrees that there is unlikely to be significant cost savings associated with these instrument changes, given the redesign and technology development activities necessitated by the changes. The Panel concurs that deletion of an instrument or a major descoping beyond the changes recommended here would have a major impact on the CHEM-1 mission science and would result in an unacceptable loss to EOS science.
- ◇ The Panel notes that the major risk to the CHEM-1 science may not be technical, but programmatic, in that prolonged delay of the start of instrument fabrication and of algorithm development poses significant schedule risk. The EOS C&SF Project needs to ensure that cost profiles, as well as total cost and instrument delivery margins, are adequate. Furthermore, a decision is needed very soon on which spacecraft will be used to deploy the various CHEM-1 instruments (see below).

- ◇ The Panel strongly recommends that the EOS C&SF Project not perturb the risk-mitigation strategies now being pursued by the various instrument activities. This includes development of engineering models, test and delivery of processing software, pre-launch sensor characterization, etc. Attempts to save money in these critical areas should not be pursued at the expense of increased risk of sensor failure or poor performance on orbit.

Potential Mission Scenarios

The GSFC CHEM-1 Study identified several mission options, with different combinations of MLS, TES, HIRDLS, and ODUS deployed on various sets of the PM-1/CHEM-1 Common bus and/or smaller spacecraft. Additional options are still being considered and costed; one of these involves a smaller version of the Common spacecraft, discussed with TRW after the dismissal of the challenge to the procurement of the Common spacecraft. These options (still preliminary) are shown in Table 1. Cost data for the various mission scenarios are still being acquired and evaluated.

Table 1. Potential Mission Scenarios

Mission Option	Instrument Payload	Spacecraft & ELV Configuration	Launch Dates
Baseline	HIRDLS, MLS, ODUS, TES	Common S/C Delta 7920	12/02
1	HIRDLS, AMLS*, ODUS, TES [+400 kg, 250 W]	Common S/C Delta 7920	6/02
2	HIRDLS, AMLS, ODUS [+700 kg, 600 W] TES	Common S/C Delta 7920 Small/Taurus	6/02 9/01
3	TES, HIRDLS AMLs, ODUS	Small/Delta Small/Delta	9/01 6/02
4	HIRDLS, TES, ODUS AMLs	Common-Lite** Delta 7320 Small/Taurus	12/01 6/02
5	TES, HIRDLS, ODUS AMLs	Small/Taurus Small/Taurus Small/Taurus	9/01 3/02 12/02

* AMLS=MMIC-array version of MLS

** Common-Lite = smaller version of Common S/C bus (deck modules removed)

One consequence of the downsizing of the CHEM-1 instruments, through the infusion of new technology into MLS and through more-conventional descopes of HIRDLS and TES, is that the deployment of the CHEM-1 payload on the Common spacecraft bus leaves considerable mass and power resources for the flight of other instruments. These resources could be used to accommodate EOS instruments now slated for flights-of-opportunity or other instruments flown as part of other programs, including the Earth System Science Pathfinders (ESSP) or New Millennium Program (NMP). Inclusion of such instruments is not free, due to integration costs. The best use should be made of these "extra resources," which may be as great as 700 kg & 600 W additional capability; see Table 1. However, the EOS measurement capabilities must not be jeopardized, whether by driving spacecraft requirements, by imprudently severe reduction of margins, or otherwise diverting EOS resources.

Science Implications of Splitting The CHEM-1 Payload

In the past, the Payload Panel has opposed moving the CHEM-1 payload onto multiple spacecraft. Concerns typically focused on two issues: (i) the feared loss of measurement capability if one or more instruments did not fly in the same time frame, and (ii) the loss of nearly simultaneous coverage. It is important to note that the instruments would not have co-located fields-of-view, even if they were on the same platform. However, the CHEM-1 instruments would sample overlapping regions within minutes of one another's observations and would observe at similar local times, if deployed on a single platform.

The synergy between HIRDLS and TES is that the stratosphere is a source for tropospheric ozone and some nitrogen species. With its high-spatial-resolution observations, HIRDLS can capture much of the temporal variation of this influx to the troposphere, while TES observes the variation in the lower troposphere itself. The addition of ODUS, with its column measurements of ozone, together with the stratospheric ozone profiles provided by HIRDLS or MLS, also complements the TES measurements of tropospheric ozone. For HIRDLS and MLS, the synergism is that they measure different parts of the chemical cycles involved in ozone destruction. Experience with aircraft data and with UARS observations has relaxed some concerns that understanding atmospheric chemical processes requires essentially

simultaneous measurements of the key chemical species. Often, understanding the chemical processing of air requires knowledge of the environments encountered by the air parcel being observed, in addition to its present trace-gas composition. The ability to use available wind fields, derived from conventional meteorological data, to assess the effects of transport, together with the constraints provided by observing long-lived tracers, permits the chemical modeler to synthesize observations taken at different times and places. This at least holds true for the lower stratosphere at mid to high latitudes, where characteristic spatial scales and variability can be captured by fields mapped globally once or twice a day by the satellite. In the upper troposphere, changes may be more rapid and involve smaller spatial scales, but the horizontal and vertical resolutions provided by HIRDLS and the array-MLS are much improved over past and present capabilities, e.g., UARS. Finally, the measurement by both HIRDLS and an array-MLS of long-lived tracers, e.g., N_2O , with good horizontal resolution provides a standard of comparison for their uniquely measured species concentrations, e.g., NO_x for HIRDLS and ClO by MLS.

Deployment of the CHEM-1 instruments on multiple spacecraft has the advantage that earlier launches of some instruments are possible, if budget profiles allow, and different instruments could be deployed at different times of day. The TES, for example, would prefer a late morning, as opposed to afternoon, orbit to increase the number of cloud-free fields-of-view as it measures tropospheric trace gases in its nadir mode. Furthermore, formation flying of small satellites could provide adequate near-simultaneity of several minutes in orbits at the same local time.

Recommendations of The Payload Panel: Mission Implementation

The Payload Panel recommends:

- ◇ That the EOS C&SF Project evaluate various mission implementation options first on the basis of cost savings, provided that the implementation does not delay launch of any instrument beyond the 2002 baseline, and that all of the CHEM-1 instruments will operate simultaneously from orbit for at least a four-year period.
- ◇ That the possibility of formation flying of multiple

satellites carrying CHEM-1 instruments be evaluated as part of the various mission implementation studies. This evaluation should consider all costs and risks, including launch vehicle performance, platform pointing stability, etc.

- ◇ That TES be launched early, if feasible, to begin the high-priority global survey of key tropospheric chemical species. This assumes that the processing algorithm activity proceeds in step with the instrument development.
- ◇ That, in declining order of science preference, the mission options are: (i) all instruments on the same platform or in formation; (ii) TES, HIRDLS and ODUS on the same platform or in formation; or (iii) TES and HIRDLS together, whether on the same platform or on platforms flying in formation. These preferences should be weighed against potential cost savings and the desire for an earlier launch of TES (see above).
- ◇ That, should there be separate launches of HIRDLS and the array-MLS, there is preference for moving HIRDLS first, in part to provide some schedule margin for the development of the MMIC-based devices or terahertz technologies required by MLS and also to achieve an earlier pairing of TES and HIRDLS on orbit.
- ◇ That "divertible resources" not be created at the expense of jeopardizing, e.g., through reduced margins or instrument descopes, the approved EOS science measurements.
- ◇ That, if "divertible resources" are available, their use be based on the overall advantage to the EOS program, and first consideration be given to EOS instruments needing flights of opportunity, e.g., SOLSTICE, and second to the advantage of the MTPE program. This assessment must include the broader Earth science community, together with the Mission to Planet Earth Office at GSFC and NASA Headquarters.

Final Comments

The Payload Panel appreciates the efforts of the GSFC CHEM-1 Study team and, in particular, the contributions by the EOS Chemistry and Special Flights Project

personnel and EOS investigators. The need to respond to NASA initiatives attempting to preserve and enhance timely access to space and to provide the scientific observations vital to Mission to Planet Earth in an era of declining federal research budgets is understood. The present study has identified an infusion of new technology and instrument changes which enable launch on the Common (or derivative) bus with significant spacecraft margins or on multiple spacecraft, including small spacecraft, while maintaining and possibly advancing the launch date(s) and the overall science. Scrutiny of the technical risks associated with the recommended changes must continue to be evaluated by the Mission to Planet Earth Office. Close interaction of the science community and the GSFC engineering assessment teams will continue to be essential to the success of EOS. The Payload Panel further notes that a decision on mission implementation is needed soon to avoid further delays that may increase costs and risk, and possibly impact launch dates. ■

KUDOS

Wallace Broecker, Lamont/Doherty Observatory, Columbia University, and an MTPE/EOS colleague, was one of this year's recipients of the U.S. National Medal of Science and Technology, the nation's highest R&D prize, for his research on global climate change. He has also been chosen for the \$463,000 Blue Planet Prize, awarded by the Asahl Glass Foundation. Congratulations to Dr. Broecker on these outstanding accomplishments.

Minutes of the Stratospheric Aerosol and Gas Experiment III Science Team Meeting

— **Lelia B. Vann** (l.b.vann@larc.nasa.gov), SAGE III Science Manager, Aerosol Research Branch, NASA Langley Research Center

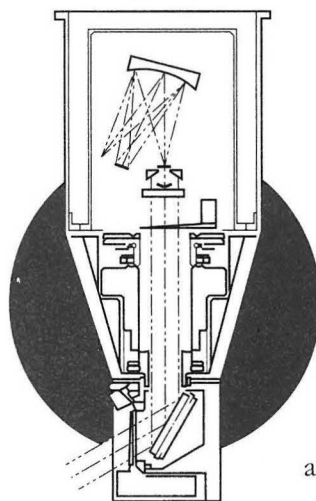
On May 7-9, a Stratospheric Aerosol and Gas Experiment (SAGE) III Science Team meeting was conducted at the Langley Research Center (LaRC) to begin formal discussion of the data validation approach and to finalize discussion of the algorithm theoretical basis documents (ATBDs).

M. Patrick McCormick, SAGE III Principal Investigator (PI), welcomed everyone and reviewed the agenda for the next three days. The first day was devoted to validation, and the remaining two days were devoted to ATBD discussions. McCormick introduced Dave Woods and Charles Trepte as the leads for coordinating the SAGE III Validation Planning.

Validation Discussions

Trepte discussed the preliminary plans for validation campaigns, and Woods discussed aircraft availability and possible airborne and balloon sensors. The focus was primarily on the 1998 Meteor-3M/SAGE III launch with the consideration that similar approaches would be used for the International Space Station mission in 2001 and the flight of opportunity (FOO) mission in 2005, with appropriate adjustments for the differences in orbits and launch times.

The SAGE III Standard Data Products were used as a guide for determining validation requirements. The proposed approaches included a combination of airborne campaigns, balloon flights, measurements at cooperative network ground sites, and comparisons with other satellite sensors. Candidate sensors for validating each SAGE III data product were discussed as well.



The following two University of Wyoming balloon packages were discussed:

1. The dustsonde, used for previous SAGE validations, measures vertical profiles of aerosol size distribution. The package also provides ozone and water vapor profiles.
2. The backscattersonde measures aerosol backscatter at two wavelengths and also provides ozone and water vapor profiles.

Either of these balloon systems can be deployed from one of several high-latitude sites (Northern Finland, Sweden, or Alaska).

The proposed aircraft flight options included: a late fall or early spring deployment from Poker Flat to observe a quiescent region; a late winter deployment from Thule in search of polar stratospheric clouds (PSCs); or flights to Canada or Alaska anytime.

The following aircraft are being considered for service as validation platforms:

- ◇ The ER-2 or WB-57, primarily for high-altitude *in situ* measurements, but with lidar on board if possible [either the Lidar Atmospheric Sensing Experiment (LASE) or Goddard's cloud lidar].
- ◇ The DC-8 for mid-altitude long-range flights with multiple lidars and other remote sensors as well as *in situ* measurements.
- ◇ The P-3 and C-130 are limited to altitudes less than 30,000 ft, where weather systems may interfere with measurements. However, they do have plenty of cargo capacity (can support multiple lidars) and very good range capability.

Because of their altitude limitations, they are viewed as possible backups in case the DC-8 cannot be made available.

- ◊ The University of Washington's Convair-580 with a large suite of instruments equipped for studying clouds and tropospheric aerosols and gases.

McCormick strongly emphasized that the initial planning of validation campaigns should be driven by the science requirements.

Volker Mohnen stated that the validation should focus on aerosols and ozone in the upper troposphere and lower stratosphere (8 - 12 km) because this is the region of greatest need and greatest scientific challenge. Phil Russell agreed with Mohnen, but pointed out that this altitude region is much more difficult to study than the stratosphere because of spatial inhomogeneities. Mohnen advised considering the use of Mike Profit's UV-Absorption method for ozone on all aircraft flights because it is the best *in situ* method available for ozone.

Peter Hobbs pointed out the importance of knowing the lower detectable limits of each SAGE III product because this determines the range over which SAGE III can measure that species. He also mentioned that FIRE III will be conducted in Alaska in 1998. Since the ER-2 will be involved, this could potentially be an opportunity for us to work in some SAGE III validation flights while the aircraft are in Alaska.

Mohnen stated that we should use ozone sondes at the southern tip of Argentina because of their low cost and low risk. He did not think it was important to do an airborne campaign in the southern hemisphere. Jack Kaye mentioned a workshop in November in which sondes will be one of the main topics of discussion.

Derek Cunnold pointed out that a southern hemisphere campaign might be necessary to resolve differences in SAGE response between sunrises and sunsets.

Dave Rind made the point that we should always fly two water vapor sensors on aircraft for intercomparisons.

Albert Chernikov and Nikolai Elansky presented discussions on a proposed Russian network that will include several high-latitude ground stations with measurements

of aerosols, nitrogen dioxide, ozone, and water vapor. Phil Russell presented some data on the Altus remotely piloted vehicle (RPV), which is capable of reaching 65,000 ft., but is very limited in payload capacity.

Validation Conclusions

The validation portion of the Science Team meeting closed with the Science Team in general agreement on the approach of planning three aircraft campaigns within the first year after launch. Assuming an August 1998 launch, the first campaign will involve deploying the DC-8 from Fairbanks in the November/December time frame. This will be followed in January/February with the DC-8 and ER-2 or WB-57 deployed out of Thule in search of PSCs. A third campaign in the summer of 1999 will be deployed over either Canada or Alaska and will involve the DC-8, ER-2, or WB-57, and perhaps the Convair-580.

ATBD Discussions

The next two days (May 8-9), were devoted to the ATBDs and to spectroscopy requirements. The SAGE III team members are to complete and submit the ATBDs to the Mission to Planet Earth (MTPE) EOS Project Science Office in July of this year. The ATBDs will be externally peer reviewed, with written comments, followed by two weeks of oral presentation to a visiting committee.

To support this effort and reach group consensus on the content and quality of the documents, the Team focused on the review and revision of the documents with particular attention to the science justification, algorithm description, and quality (error budget) of the SAGE III products. Four subgroups were formed and focused on specific topics (aerosol, cloud, gases, and temperature). Plenary sessions were held to provide time for criticism, group discussion, and consensus.

Each subgroup focused on written revisions of the ATBDs and was requested to review the following areas:

Summary of issues:

- ◊ Science rationale:
 - Justification
 - Historical context and why SAGE III was selected for this measurement

- ◇ Algorithm:
 - A clear and concise connection between the instrument measurements and the output products
 - Justify the choice of algorithm (building on the SAM/SAGE heritage, and expected to evolve with experience with SAGE III)
- ◇ Quality of the Products:
 - Error discussion
 - Systematic error sources and discussion
 - Implications for trend studies and validation

During the last plenary session of the day, it was suggested that since our products are closely related it made sense to combine all nine ATBDs into one document. McCormick discussed this approach with Michael King, the EOS Senior Project Scientist, and the decision was to keep all ATBDs separate so as to ease the review process.

Spectroscopy Discussions

Following the discussions at the January 1996 SAGE III Science Team meeting, the Team has reached consensus on the necessity and priority of laboratory spectroscopy measurements of key gaseous species. Eric Shettle prepared a detailed assessment of the current databases and provided recommendations.

The SAGE III Science Team examined the systematic uncertainties that will occur in the SAGE III measurements resulting from the quality of laboratory spectroscopic measurements and recommended that priority and funding be given to the following molecular-constituent determinations:

1. improved oxygen spectroscopy in the A band region (with a strong desire for simultaneous measurements of the B and C bands);
2. improved water vapor spectroscopy in the 940 nm band (870 to 1000 nm);
3. improved ozone spectroscopy at 940 nm and in all 'aerosol-only' channels (1550, 1020, 872, 757, 675, 525, and 385 nm), especially at stratospheric temperatures, (down to 180 K);
4. improved nitrogen trioxide spectroscopy, 580 to

680 nm, including the temperature dependence over the range of stratospheric temperatures.

Some further considerations regarding the laboratory determinations are as follows:

1. Given the wide range of the various measurements of the intensities and line widths for the oxygen A band, it was agreed that additional measurements are needed to have confidence that the oxygen A band absorption cross sections are known to within the 2% needed to meet the SAGE III accuracy requirements.
2. Given the 50% uncertainties applied to the weakest water vapor lines when integrated over the 2 nm resolution of the SAGE III detector, the water vapor absorption is known to about 10-15%. To achieve greater accuracy for water vapor retrievals will require new measurements of the water vapor spectroscopy in the near infrared.
3. Since ozone absorbs at most of the wavelengths used for the retrieval of the other species, its contribution must be removed from the transmission measurements at those wavelengths. Particularly in the IR, the uncertainties in the ozone cross sections (especially at stratospheric temperatures) can impact the retrieval of water vapor, aerosols, and to a lesser extent oxygen.
4. The uncertainties in the NO₂ absorption cross sections are 10-15% at room temperature and 20-40% at stratospheric temperatures. Improved measurements are needed, given these uncertainties. ■

Lidar In-space Technology Experiment Science Team Meeting

— **Lelia B. Vann** (Lelia_Vann@gmgate.larc.nasa.gov), Executive Secretary for Lidar In-space Technology Experiment Science Team Meeting

A Lidar In-space Technology Experiment (LITE) Science Team meeting was conducted at the Langley Research Center (LaRC) on Friday, June 7, 1996. The purpose of this meeting was to share and discuss the LITE research activities, data processing and analyses, and future plans.

Principal Investigator, M. Patrick McCormick, welcomed everyone and briefly summarized the agenda and the objectives of the meeting.

NASA Headquarters (HQ) Program Manager for LITE, Robert Curran, stated that the LITE proposal for data validation and processing received excellent reviews and therefore would be partially funded this fiscal year (FY 1996). Curran was not sure that the funding would continue into FY 97, but he will strongly advocate HQ funding for at least one more year to ensure adequate data validation prior to public data release.

The LITE Science Team members in attendance presented their on-going work as summarized below.

Edward Browell, Co-Investigator from LaRC, introduced William Grant, who presented their work on global distributions of tropospheric aerosols as observed by LITE and an airborne lidar during NASA's global tropospheric experiment (GTE) from 1981 to 1994.

Jim Coakley, Co-Investigator from Oregon State University, presented the vertical structure of cloud systems as deduced from simultaneous LITE and multispectral satellite imagery data.

Chet Gardner, Co-Investigator from the University of Illinois, presented the validation of LITE stratospheric temperature and aerosol measurements which he submitted to *Applied Optics* in May 1996. He has obtained excellent agreement of the LITE temperature

profiles from 5 to 35 km with balloon observations after compensating for aerosols, using both the 532 and 355 nm channels. Temperature residuals in the 15-30 km altitude range were as low as 2° C. The results suggest that it may be possible to recover the tropopause altitudes from the LITE data at least in regions where the aerosol loading is not severe.

George Papen, also of the University of Illinois, presented preliminary design and modeling results for an all diode-pumped master oscillator power amplifier for water vapor DIAL systems.

Raymond Hoff, Co-Investigator from Environment Canada, presented LITE observations of anthropogenically-produced aerosols. He has detected over 50 urban area and regional aerosol haze sources in the LITE data (largely nighttime observations). The aerosol plumes from these areas agree well with air trajectory information. It is believed that aerosol mass information can be estimated for the LITE data.

Geoffrey Kent, Co-Investigator from Science and Technology Corporation, presented analyses of LITE data showing upper tropospheric aerosol (at altitudes greater than 6 km) in the southern hemisphere. It is known from previous studies of the SAGE II data set, that this aerosol exhibits seasonal variations with a maximum aerosol optical depth in local spring. A marked feature was the geographical distribution in which the aerosol was found to occur over the ocean at large distances from land. Similar behavior is found in the LITE data set, where distinct upper tropospheric layers are seen with optical depths ranging up to 0.1. The aerosol extinction-to-backscatter ratio is found to lie between 50 and 90, compatible with the hypothesis that the aerosol source lies in the seasonal burning of biomass material in the savannah regions of southern Africa and the other southern hemisphere continents.

Harvey Melfi, Co-Investigator from the University of Maryland Baltimore Campus, could not attend but three colleagues attended the meeting and presented their ongoing studies. Geary Schwemmer from the Goddard Space Flight Center presented the comparison of Planetary Boundary Layer (PBL) statistics as derived from the LITE data and Large Aperture Scanning Airborne Lidar (LASAL) data. LASAL was the lidar system that flew on the P-3B during the LITE correlative measurement campaign. Steve Palm and Mohan Karyampudi from Science Systems & Applications, Inc. (SSAI) presented the derivation of water vapor and temperature profiles using airborne lidar and radiometer data collected during the LITE correlative underflights. The statistics of the boundary layer height is used with the radiometric sea surface temperature to derive the profiles. Similar PBL statistics derived from LITE data in the same regions were compared with the LASAL statistics and were also used to derive the temperature and moisture profiles. The profiles were compared to dropsonde observations.

David Randall, Co-Investigator from Colorado State University, presented comparisons of the LITE data with General Circulation Model (GCM) results. The GCM produces excessive total cloudiness, but realistic cloud forcing, which suggests an excess of optically thin clouds, e.g., thin cirrus. Therefore, the distribution of thin cirrus in the model is being investigated.

John Reagan, Co-Investigator from the University of Arizona, presented an assessment and applications of LITE surface returns from selected land surface standard target areas.

Dave Winker, Deputy Project Scientist from LaRC, presented the LITE saturation database and global cloud statistics.

Kathy Powell from Science Applications International Corporation (SAIC) presented an update on the current status of LITE data processing and discussed the future LITE data processing plans. The current version of the LITE data is LITE Level 0, version 3. This version was released in March 1996. The format of version 3 is the same as version 2, but there are 2 major differences between version 2 and 3. First, time was corrected for all known latencies. The time correction resulted in changes to all latitude, longitude, and profile backscatter altitude values. Second, the approximation to mean sea level has been improved. The version 3 geoid is formed

by combining undulations from the OSU91A potential coefficient model with the corresponding reference ellipsoid. The version 2 Earth model was an ellipsoid. This change gives better approximations to the altitude values assigned to each backscatter return.

Preliminary work to determine the amount of error in the reported footprint locations and backscatter altitudes was performed. The Space Shuttle position and attitude data extracted from the Postflight Attitude and Trajectory History (PATH) product were used to calculate footprint location and profile altitude values. The PATH product reports errors of approximately 250.0 m in position and a 3 sigma uncertainty in body-axis attitude data of approximately 0.2 degrees per axis. Applying these errors to a typical Shuttle position and attitude vector, one axis at a time, results in altitude errors of 45.0 to 190.0 m and footprint location errors of approximately 160.0 to 900.0 m. The LITE data surface elevations were compared to elevations from the Earth Resources Observation Systems (EROS) Digital Elevation Map. A section of LITE data from orbit 82 over California and Nevada with much variety in terrain was used in the comparison. The surface elevations of LITE data and the EROS digital elevations at the LITE footprint locations were in good agreement.

The next LITE data product will be Level 1, version 1. This data product will be released in January 1997 and will be available to the public. The process to create Level 1 from Level 0 includes: removing the fixed-phase baseline shape for each profile, removing the random-phase baseline oscillation for low-gain data, performing background subtraction for each profile, and truncating the profile altitude range from -5 to 40 km. Parameters to remove fixed and random phase corrections will be provided.

Paul Crain from SAIC demonstrated the LITE data access web site (<http://arbs8.larc.nasa.gov/LITE/litehome.html>). He showed how it could be used to access color-modulated plots, metadata, and instrument status data. He also discussed future plans for both the LITE data access page and the LITE home page.

Mary Osborn from SAIC presented a summary of the support given to participants in the LITE Correlative Measurements Program. Lidar scattering ratio profiles were analyzed and sent to over 60 ground sites. Unanalyzed high-rate data have been made available to

Science Team members, correlative aircraft investigators, and selected ground sites. The European LITE (ELITE) correlative measurements program was particularly successful. The Proceedings of their Final Results Workshop were published in March and show excellent agreement with the LITE data.

Osborn also presented the results of a study to determine the LITE system constant(s) for use in the calibration of LITE data. A plot of calibration factors for several LITE orbits was presented and revealed, in many cases, variations greater than 10% over an orbit. Also, the magnitude of the calibration factors decreased over the time of the mission, indicating a decrease in optical throughput. The cause of these variations is still under investigation.

Charles Trepte, from SAIC, showed a LITE video tape that was created at LaRC under his leadership. It was constructed with the FAST visualization software and highlighted LITE observations along orbits 14, 117, and the series 145-150. Copies of the video will be available in September of this year.

For the record, Robert Menzies and Martin Platt were not able to attend but have provided summaries of their ongoing research.

Menzies, Co-Investigator from the Jet Propulsion Laboratory, provided charts on the use of LITE landmark track measurements to link directional reflectance to surface wind speed.

Platt, Co-Investigator from the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, has been working on studies in collaboration with Winker and Mark Vaughan and validation studies in collaboration with Stuart Young, CSIRO DAR, and with Osborn.

Everyone was thanked for a job well done and the meeting was adjourned. ■

NASA Announces 1996 Software of the Year Award Recipients

— **Dwayne C. Brown**, NASA Headquarters, Washington, DC. (Phone: 202/358-1600)

Computer software that helps scientists better examine geophysical and climatological data and software that provides solutions to aerodynamic problems in designing new aircraft are the winning entries for NASA's 1996 Software of the Year Award.

Sponsored by NASA, the award is granted to individual(s) that develop software to enhance NASA's mission and assist the U.S. aerospace industry in maintaining world-class technology.

This year's recipients are the Linked Windows Interactive Data System (LinkWinds) software developed by the Jet Propulsion Laboratory, Pasadena, CA, headed by Dr. Allan "Bud" Jacobson; and the Tetrahedral Unstructured Software System (TetrUSS) developed by NASA's Langley Research Center, Hampton, VA, headed by Dr. Neal Frink.

LinkWinds is the world's most powerful viewer for scientific examination of geophysical and climatological data retrieved from satellite remote sensing. This software is a visual data analysis and exploration system that grew out of a research program to apply computer graphics to interactive science data analysis.

TetrUSS is an aerodynamic analysis and design system that is widely used throughout U.S. industry, government, and universities to study aerodynamics and other problems in spacecraft, rotorcraft, automotive, turbomachinery, and medical analysis and design.

NASA will present the awards at the Technology 2006 Conference to be held in Anaheim, CA, this October. Recipients will receive a plaque and a substantial monetary award.

Further information about this software is available by calling 202/358-2279 or via the World Wide Web at: <http://www.hq.nasa.gov/office/codei/codeic.html> ■

Land Processes DAAC Science Advisory Panel Meets

— **G. Bryan Bailey** (gbbailey@edcserver1.cr.usgs.gov) USGS, EROS Data Center, Tel. (605) 594-6001; FAX (605) 594-6567

The Land Processes DAAC (LPDAAC) Science Advisory Panel held a regular meeting at the USGS EROS Data Center (EDC) on May 6-8, 1996. Attending were a quorum of Panel members, as well as meeting participants and interested observers from EDC, NASA, and EOSDIS Core System (ECS) contractor Hughes Information Technology Systems (HITS).

Panel Co-Chairman, Tony England, opened the meeting with some reflections on certain events and developments of the past year. He noted that the Panel had gone a full year since its last meeting, opting to postpone the meeting scheduled for last fall due to confusion and uncertainties stemming from EOSDIS federation efforts and proposed recompetition of the DAACs. He also challenged the DAAC and the Panel to recognize that there yet remains a great deal to be accomplished in two years to get to the point where the DAAC hopes to be by launch of AM-1.

Following a tour of the new EDC building addition, where the LPDAAC will be located, Panel members reviewed outstanding action items from the April, 1995, meeting. Notably, DAAC Manager, Lyn Oleson, reported on the anticipated role in DAAC development of the ESDIS Project IV&V contractor and on the DAAC's interaction with the EOSDIS Ad Hoc Working Group on Production; Mike Abrams clarified current plans for ASTER data acquisition request (DAR) allocations; Darrel Williams reported that there will be an X-band antenna in Alaska for real-time downlink of Landsat-7 data and that NOAA has embraced the concept of Landsat DARs for individual users; and LPDAAC Project Scientist, Bryan Bailey, reported substantial progress in preparing a DAAC Science Support Requirements and Activities document. Review copies were distributed to Panel members in anticipation of further discussion later in the meeting.

Dixon Butler presented information about, and led a discussion on, NASA's current concepts for creating a

federated EOSDIS. He presented his ideas in the context of a hierarchy of data priorities and the relationship between environmental information and Earth system science. He called for the establishment of an environmental information economy, and he noted that a federated EOSDIS would be one step in that direction. He went on to define and describe what an environmental information system federation is and what Earth science information partners (ESIPs) are, and he explained NASA's ideas for establishing three types of ESIPs. Butler concluded by presenting current NASA plans and tentative schedule for implementing their EOSDIS Federation concepts.

The opening day of the meeting concluded with EDC Satellite Systems Branch Chief, R. J. Thompson, clarifying some of the similarities and differences between Landsat-7 ground system development activities and other LPDAAC development activities underway at EDC. The discussion also addressed the role of the international ground stations (IGS) in Landsat-7 data acquisition plans. Panel members expressed the point-of-view that cooperation, and even partnerships, with the IGS is needed to enhance Landsat data access by the international science community, and they expressed concern that charging the IGS large station access fees will hurt enhanced data access.

The second day of the meeting opened with a spirited discussion of EOSDIS IMS status and plans, by Lyn Oleson, who characterized the "IMS of today as the client of tomorrow." He acknowledged that there are not as many users of the X-windows version of the IMS as anticipated, partly because it may be too complex for the casual user. Someone else observed that "it is too slow for the knowledgeable user, so who is it for?" Dave Skole pointed out that part of the problem is that some users are expecting more from the Version 0 IMS than ever was intended. He also stressed the need for stronger involvement of the user community in various IMS prototyping activities and its development process.

It was noted that the ECS Evaluation Package 7 (EP-7) will be released this summer. The Panel assigned the DAAC an action to sponsor a "client workshop" this summer to examine existing IMS implementations, both operational and prototypical including EP-7, and develop a list of recommended ECS system functionalities that would be of particular use to the land science community.

Separate from related reports provided by Panel members associated with ASTER and MODIS Science Teams, DAAC staff summarized certain specific DAAC-ASTER and DAAC-MODIS activities. Jim Lacasse reported on ASTER beta science software integration and test (SSIT) activities at the LPDAAC. He provided an overview of the ASTER standard data product development strategy, identified the higher level ASTER products currently undergoing SSIT at the DAAC, reviewed the recent SSIT activities and their results in some detail, and outlined planned activities. Bryan Bailey reported on the status of efforts to implement the Japanese ASTER Level 0 to 1 processing software at the LPDAAC, implement an expedited ASTER data processing system at the DAAC, and to implement an ASTER precision processing capability at the DAAC. Glenn Kelly reviewed the ASTER DEM standard data product software procurement status. He discussed details of the requirements analysis that precedes release of any Request for proposals (RFP), as well as the current schedule for procuring the Commercial Off The Shelf (COTS) software for Digital Elevation Model (DEM) generation from ASTER data.

Jeff Eidenshink reviewed for the Panel various coordination activities ongoing between the LPDAAC and the MODIS Project. He characterized coordination responsibilities as: representing requirements and concerns of the LPDAAC to the MODIS Science Data Support Team (SDST), ECS, and the ESDIS Project; providing various and specific V0 experiences to ECS development; and representing traditional user requirements to the MODIS Science Team. Coordination is accomplished through regular participation at meetings (also telecons) of the SDST, MODIS Science Team, and MODIS Land Science Team (MODLAND), and through participation in major activities, such as developing plans and identifying requirements.

Eidenshink also summarized various MODIS-relevant "lessons learned" from the Global Land 1-km AVHRR Project. In the area of data processing, standards and documentation are critical for production staff and data

users, and benchmarks are necessary to validate algorithm performance and quality assurance. Benchmarks should be run on a routine schedule. As relates to data distribution, tape media are the overwhelming choice for product delivery; networks are not sufficient for large data volume transfers to a majority of users; and spatial, spectral, and temporal subsetting are necessary. Other general lessons learned include the fact that tools are needed by users for such things as facilitating use of multiple map projections, and reprocessing is difficult because of the data volume of the total data set.

Jay Feuquay reported on the DAAC's high-speed communications activities with MODIS. These include an experiment to investigate high-speed networks for large-volume data transfers where 60 GB of AVHRR data are transferred to the MODIS Science Team. Ten gigabytes of data have been sent to the team, so far. Feuquay reviewed the physical and logical connections involved in the data transfer, and he reported results of 1.25 Mbytes/sec average throughput with a peak throughput of about 3 Mbytes/sec. Plans for future work also were noted.

During the reports from Instrument Team members, Chris Justice identified the new members on the MODIS Team and briefly explained their roles. He also provided updates or commented on the MODIS validation plan, QA system design, common processing requirements, inter-instrument data dependencies, MODIS processing design, and various DAAC-related issues. In addition, Barbara Putney drew attention to recent increases in MODIS data processing and archiving loads, and she noted certain efforts being undertaken to deal with problems created by such increases. Putney also reviewed certain MODIS-related issues from the recent ECS critical design review (CDR).

Mike Abrams provided an ASTER activity report, covering developments in the areas of systems engineering, algorithm and software development, operations and mission planning, future plans, and management. Highlights from ASTER include the fact that Moshe Pniel has taken over as JPL ASTER Project Manager, replacing Dave Nichols, who accepted a Radarsat Project management position; the beta version of science processing software was successfully implemented at the LPDAAC; first-year funding for a new airborne ASTER/MODIS simulator (MASTER) was approved; and a major cal/val field campaign will be held in Nevada in June. Diane Evans provided an update on SAR activities. She

reported that the National Research Council (NRC) SAR review stressed the importance of frequency and polarization diversity, endorsed the proposed Shuttle Topographic Radar Mission (SRTM), and generally came to many of the same conclusions as the Interagency *Ad Hoc* Working Group on SAR. Evans also noted that NASA appears to be moving toward a potential new start for a LightSAR in FY 1997, and she encouraged the DAAC to remain proactive in assessing potential involvement with current and future SAR missions.

Landsat Project Scientist, Darrel Williams, provided a crisp status report on Landsat Project activities. Topics covered included status of Landsat-7 image assessment system development, addition of Level 1 processing for Landsat-7, approval of a second X-band receiving station, plans to synchronize the orbits of Landsat-7 and EOS AM-1, activities related to the definition of and selection by NASA's New Millennium Program (NMP) of an advanced land imager as the first instrument to be developed by the NMP, and the process of selecting a new Landsat Science Team, the members of which were announced in June.

The balance of the meeting's second day was spent reviewing status and plans of LPDAAC activities, with different DAAC staff presenting information and responding to Panel member questions. Mike Benson covered DAAC User Services and data distribution topics. He noted that the workload for the User Services staff has increased dramatically since the beginning of the 1996 calendar year, and, if the workload continues to increase, an additional full-time person will have to be added in FY 1997. He also reviewed selected user profile statistics and summarized DAAC outreach activities. In addition, Benson reviewed LPDAAC data distribution statistics by product, as well as by media, and he presented information that helped to characterize the users of various LPDAAC products.

Lyn Oleson reviewed DAAC data ingest status and plans. Data and products currently available from the DAAC include: TIMS, NS-001, and TMS aircraft scanner data; Landsat Pathfinder (MSS & TM) data; 1-km AVHRR orbital segments; global 10-day AVHRR and normalized difference vegetation index (NDVI) composites; 1-km DEMs for most continents; SIR-C Survey and Precision data; and SIR-C Educational CD-ROMs. Currently, only the aircraft scanner and some Landsat Pathfinder data are searchable and orderable through the system-wide Version 0 IMS. However, all of these data sets are

orderable through the EDC DAAC WWW home page. Efforts will continue to populate the Version 0 IMS with the additional Landsat Pathfinder data and SIR-C Precision data planned for release to the IMS in July and August. Additional data sets planned for DAAC ingest over the next year or being considered for ingest, include AVIRIS, ASAS, SEASAT, AirSAR, MASTER, and others.

John Dwyer summarized status and plans of mission support activities, which include development of the global 1-km AVHRR, global 1-km topographic, aircraft scanner, SAR, and Landsat Pathfinder data sets. Notably, orbital stitching of the global AVHRR 1-km data has been completed for the April, 1992 through December, 1993 acquisition period, and the global 10-day composites are on schedule for completion by the end of FY 96. Global data acquisition has been extended to October, 1996. The 1-km digital topographic data sets for Africa, North America, Europe, Asia, and Antarctica have been completed and are staged for FTP access; the South America data are expected to be completed in June. Demand for the SIR-C Survey and Precision data remain high, and the Survey data have been loaded onto digital linear tape for FTP access from the DAAC data distribution system (DDDS). Planning is underway to transfer the SIR-C processor from JPL to the LPDAAC in September. Generation of the Humid Tropical Forest Project (HTFP) Landsat Pathfinder products continues, and previous problems with the Instituto Nacional de Pesquisas Espaciais (INPE) TM data have been resolved.

DAAC Systems Engineer, Tom Kalvelage, briefed the Panel on engineering and development activities, specifically Version 0 sustaining engineering, design, and development of the DAAC's new information server, DDDS status and upgrade plans, and DAAC support of ECS development. Notably, recent sustaining engineering activities have included installation and test of multiple versions of V0 IMS client and communications software and developing software to upgrade DAAC servers to support new client versions. The DAAC is moving from a server shared with USGS functions to a dedicated DAAC IMS server. A prototype has been built with WWW access. The DDDS has experienced some minor problems, but solutions have been effected. DDDS short-term plans include increasing storage capacity to 2.6 TB, and long-term plans call for increasing capacity to more than 9 TB. DAAC support of ECS development has been extensive through participation in many reviews and other meetings, working groups,

workshops, and telecons.

The final day of the LPDAAC Science Advisory Panel meeting started with the DAAC's ECS Science Liaison, Saud Amer, presenting an overview of ECS prototyping activities. Primary purposes of ECS prototype activities are risk mitigation, enhancement of system functions, and technology assessment. Amer identified and described numerous specific prototype efforts that ECS is participating in with academic institutions and private organizations. He also discussed the relationship between various prototype efforts and the incremental inclusion of new capabilities in successive ECS Evaluation Package. Amer noted that the prototyping activities are the mechanisms through which: 1) the user community has the opportunity to impact the "look and feel" of the ECS system significantly in advance of implementation, and 2) the ECS contractor pursues the latest technologies and addresses key subsystem features that are important to the user community.

ECS contractor representative, Tom Dopplick, addressed the topic of V0-to-ECS data migration, as well as other related transition topics. Dopplick noted that the rationale for migrating selected data from V0 to ECS includes both preservation of scientifically important historical data and enhanced services to users wishing to access those data. Furthermore, ECS is contractually bound to effect data migration. Dopplick also explained that data format, specifically HDF-EOS, and metadata are related and important considerations in formulating a data migration plan. The DAAC, with advice from its science constituency, must decide not only which V0 data to migrate, but also whether or not to convert native formats to HDF-EOS and whether or not to enhance metadata attributes or provide only the minimal, mandatory attributes. Also, migrated data must be validated to ensure that the integrity of the original data is preserved during the migration process. Finally, Dopplick pointed out that it is important for ECS to "learn" about the migrated data and metadata before services can be provided to users. Simply placing the migrated data and metadata into an ECS archive at the DAAC results in NO services. The ECS "learning" process requires that migrated data and metadata flow through both the ECS ingest and data server subsystems.

The Panel concluded its meeting with summary discussions that included a review of action items and Panel recommendations. The next meeting of the LPDAAC

Science Advisory Panel will be held in the September/October time frame.

Imagery, GIS and Government Leaders Talk Standards at SPOT

— Colleen Hanley (703) 715-3137

Reston, VA — On April 1 and 2, 1996, over 40 representatives from software, data, government and non-profit organizations convened at SPOT Image Corporation for the second annual conference on standardizing geographic raster data formats and applications. Participants included software vendors and developers such as ESRI, Intergraph, ERDAS, Bentley Systems, and E-Systems; data providers such as SPOT Image, SSC/Satellitbild, Space Imaging, OrbImage, Earth Watch, EOSAT, and Vargis; and government/non-profit organizations such as U.S. Geological Survey, Defense Mapping Agency, Open GIS, Jet Propulsion Laboratory (JPL), and MITRE.

As a result of the SPOT/JPL-initiated effort, GeoTIFF 1.0 was endorsed as an industry standard for geographic raster data formats. Groups are also committed to developing the following elements:

- ◇ Support for very large (multi-gigabyte) image files through a "supertiling" structure
- ◇ Support for multiple projection spaces
- ◇ Increased capabilities of public domain software libraries
- ◇ Augmentation of the geodesy components to make more use of datum information
- ◇ Support for digital elevation models using the GeoTIFF image structure
- ◇ Recommendations for hyperspectral tiling protocols
- ◇ Deep (lossy) compression which preserves georeferencing properties upon decompression

An open forum discussion is currently taking place on the Internet with links from the SPOT Image home page. To obtain additional information, see "What's New" on <http://www.spot.com> (in the U.S.) or <http://www.spotimage.fr> (outside the U.S.).

A NIST Thermal Infrared Transfer Standard Radiometer for the EOS Program

— **Joseph P. Rice** (rice@garnet.nist.gov) and **B. Carol Johnson** (cjohnson@enh.nist.gov), Optical Technology Division, National Institute of Standards and Technology, Gaithersburg, MD 20899

A program to establish radiometric traceability between the National Aeronautics and Space Administration's (NASA's) Earth Observing System (EOS) instrument calibration facilities and the National Institute of Standards and Technology (NIST) radiance scale is underway [1,2]. Currently, flight instruments intended to measure Earth's radiance are calibrated before launch against working standards such as lamp-illuminated integrating spheres (for visible, near-infrared, and short-wavelength infrared channels) and 200 K to 400 K blackbody sources (for "thermal-infrared" channels in the spectral range of roughly 2 μm to 20 μm). Such a working standard provides an extended-area, approximately Lambertian source that overfills the entrance pupil of the radiometer, so that radiance responsivity is determined. To ensure the high accuracy required for instruments used in the EOS program, the output of the working standards will be compared to the radiance scale maintained at NIST. A practical way to verify the scales in the EOS program is to use a portable transfer radiometer that is first calibrated at NIST, then shipped to the location where the working standards reside. Such an approach has been used successfully in NASA's Sea-Viewing Wide Field-of-view Sensor (SeaWiFS) calibration community [3]. Here the transfer radiometer provided by NIST, the SeaWiFS Transfer Radiometer (SXR), had six narrow-band channels in the visible and near-infrared part of the spectrum, and was used to view integrating spheres and plaques. Plans are in place for NIST to provide similar radiometers for the EOS program: the Visible Transfer Radiometer (VXR), the Shortwave Infrared Transfer Radiometer (SWIXR), and the Thermal Infrared Transfer Radiometer (TXR) [2].

This article focuses on the TXR. The purpose of the TXR is to compare the radiance scales of the cryogenic

blackbody working standard sources used for EOS calibrations. Currently, a breadboard version of the TXR is being built and characterized. In this article, the design and calibration plans for the TXR are described, and the planned measurement program for the TXR is outlined.

EOS Thermal-infrared calibration facilities and sources

A typical facility used to calibrate such EOS instruments as the Moderate-Resolution Imaging Spectrometer (MODIS), the Clouds and the Earth's Radiant Energy System (CERES), or the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) consists of a large vacuum chamber fitted on the inside with a light-tight, nitrogen-cooled shroud. The shroud is cooled to near 77 K, providing an infrared background that is low compared to a 200 K to 400 K blackbody source. During its calibration, the flight instrument views an extended-area blackbody source in this low-background, vacuum environment. The blackbody sources used as working standards are typically of a cavity design having a black coating on the inside. The shape of the cavity varies. Mathematical models of the effective cavity emissivity typically yield emissivity values close to 1. Typical aperture diameters range from 4 to 10 cm. Heating is often done electrically. The cavities are usually fitted with a number of temperature sensors such as platinum resistance thermometers (PRTs) for measuring the temperature of the cavity walls. Because of the unavailability of a convenient thermal infrared transfer radiometer for making a direct radiance scale tie to NIST, separate radiance scales are currently established at the EOS instrument calibration facilities. These scales are generally based on use of the Planck radiation formula

with the modeled emissivity and the NIST-traceable temperature of the PRTs. Several issues have been raised regarding the accuracy of these contact-thermometry-derived scales. They include, for example, changes in the PRT calibration upon being fixed to the cavity walls, reliance on modelling for emissivity, cavity loading, and spatial uniformity of radiance across the output aperture. When the TXR is available, it can be used to verify these contact-thermometry-derived radiance scales radiometrically by comparing against the detector-based radiance scale maintained by NIST.

Optical layout of the breadboard version

The TXR has two channels based on filtered semiconductor photodetectors that share a common telescope. Channel 1 has a center wavelength nominally at $5\ \mu\text{m}$ and Channel 2 has a center wavelength nominally at $10\ \mu\text{m}$. The bandwidths of the channels are each nominally $1\ \mu\text{m}$, defined primarily by bandpass filters. All internal optics are cooled to near $77\ \text{K}$ to reduce background. Thus, the radiometer is packaged in a portable liquid nitrogen cooled cryostat, which can be mounted in the cryogenic vacuum chambers at EOS instrument calibration facilities. It has its own vacuum, nitrogen fill, nitrogen vent, and pressure-relief lines, so that it can be evacuated and cooled independently of the calibration chamber.

A layout of the optical design is shown in Fig. 1. The telescope consists of the planar fold mirror and the two off-axis parabolic mirrors. It is focused at infinity so that the TXR views the working standard sources in the same way as the flight instruments. Two apertures, one near the entrance of the cryostat (aperture stop, $20\ \text{mm}$ diameter) and one at the

foci of the mirrors (field stop, $6\ \text{mm}$ diameter), define a 2° full-angle field of view. A tuning-fork chopper immediately behind the second aperture deflects rays into the beam dump when closed, or allows them to pass onto the second parabolic mirror when open. This provides background subtraction and enables ac measurements (frequency nominally $42\ \text{Hz}$) for narrow electrical bandwidth detection using a lock-in amplifier on each channel. After the second parabolic mirror, a dichroic beamsplitter at 45° splits the beam into two by reflecting short-wavelength rays (wavelengths less than about 7 to $8\ \mu\text{m}$) and transmitting long-wavelength rays. From there the beams pass through individual bandpass filters that define the $1\ \mu\text{m}$ bandpass for each channel and non-imaging concentrators to the detectors. An InSb detector is used for the $5\ \mu\text{m}$ channel and a HgCdTe (MCT) detector is used for the $10\ \mu\text{m}$ channel. The beamsplitter, filters, concentrators, detectors, and cooled pre-amplifiers are mounted on a common, temperature-controlled stage designed for an operating temperature near $78\ \text{K}$. Additional details of the optical design are discussed in Ref. 4.

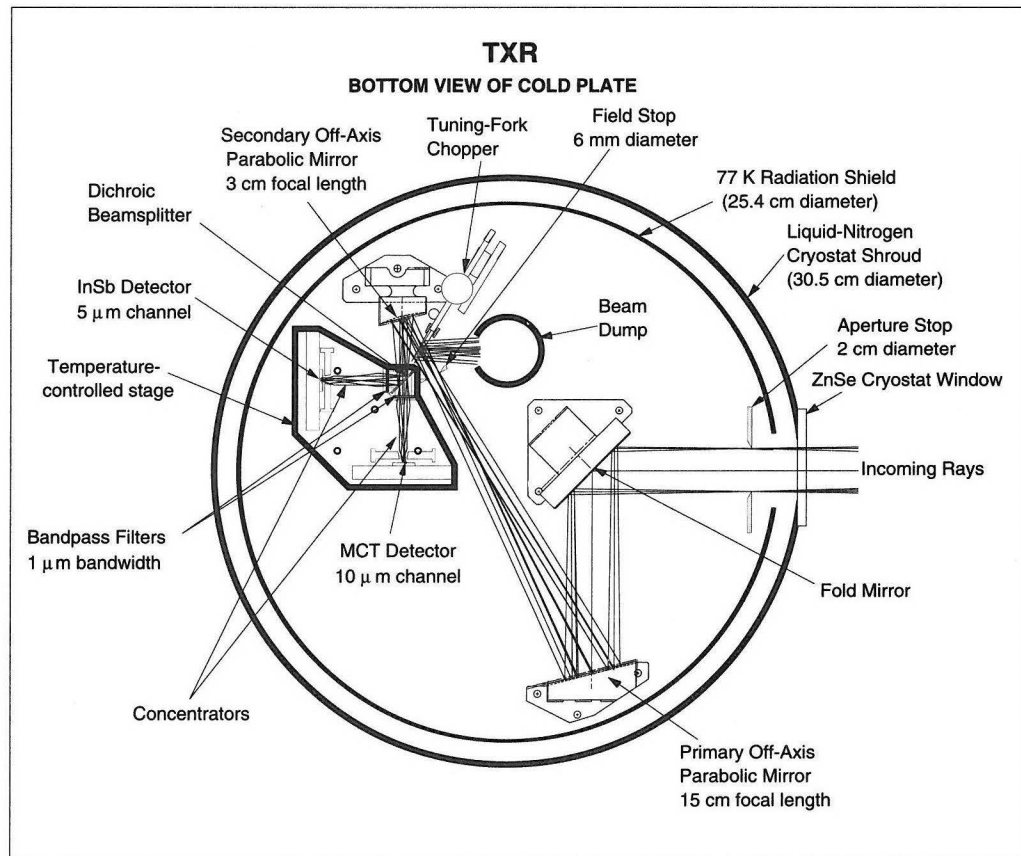


Figure 1. Plan view of the TXR optics mounted on the cold plate of the cryostat. This is a view from the bottom of the cryostat.

Field of view

The purpose of the telescope is to provide a narrow field of view so that the source overfills the entrance pupil of the radiometer, as required for radiance measurements. A ray trace was performed on the system to aid in laying out the optics. Marginal and central rays are shown in Fig. 1. The geometrically-determined full field of view, measured at the aperture stop, is 2° . Thus the diameter of the viewed source area with source placed a distance 30 cm in front of the aperture stop is 3.2 cm. For radiance measurements, this diameter must be less than the diameter of the exit aperture of the source to be tested. Of the candidate working standard blackbody sources that exist at this time at the EOS instrument calibration facilities, the source having the smallest aperture appears to be the Narrow Field Black Body used for the CERES instrument. This source has an elliptical aperture having minor and major diameters of 3.8×4.7 cm, respectively. Thus the TXR field of view is small enough for radiance measurements on at least one spatial point on this smallest-area source. On larger sources, there is enough resolution for spatial mapping of the radiance across the exit aperture.

Signal and noise

For each channel i ($i = 1, 2$), the signal in volts at the output of the preamplifier is estimated by integrating the product of the absolute spectral responsivity and the spectral radiance,

$$S_i(T) = \int R_i(\lambda) L_\lambda(\lambda, T) d\lambda \quad (1)$$

where the absolute spectral responsivity is estimated by

$$R_i(\lambda) = A_i \Omega_i \tau_i(\lambda) G_i R_{Di}(\lambda) \quad (2)$$

and $L_\lambda(\lambda, T)$ is the spectral radiance of a source of radiance temperature T . Here A_i is the area of the entrance pupil (which in this case is the aperture stop), Ω_i is the projected solid angle of the field of view at the entrance pupil, G_i is the pre-amplifier gain, $\tau_i(\lambda)$ is the transmittance within the field of view, and $R_{Di}(\lambda)$ is the responsivity of the bare detector. An estimate of the signal and noise levels expected for blackbody temperatures over the range 200 to 400 K can be found in Ref. 4. The minimum signal/noise ratio (200 K blackbody) for in-band, in-field measurements is expected to be of order 3000 to 4000. Thus, the TXR noise-equivalent radiance is low enough that it is not expected to limit the accuracy of the scale transfer.

Calibration

The complete calibration of a filter radiometer such as the TXR consists of measuring the absolute spectral radiance responsivity $R_i(\lambda)$ for each channel i . In principle, this could be done in one step by using an extended area (nominally 5 to 10 cm diameter) Lambertian tunable monochromatic infrared source of known radiance. However, such a source does not exist at NIST presently, even at visible wavelengths. Of the sources that do exist, the extended area Lambertian sources are not monochromatic, and the monochromatic sources are not extended-area Lambertian ones. Thus the measurement of $R_i(\lambda)$ will be split into two parts: the relative spectral responsivity $\rho_i(\lambda)$ and the absolute radiance responsivity K_i , where

$$R_i(\lambda) = K_i \rho_i(\lambda) \quad (3)$$

A monochromatic source will be used to measure $\rho_i(\lambda)$, followed by a separate measurement of K_i using an extended-area Lambertian source. By substituting for $R_i(\lambda)$ from Eq. (3), the radiometric performance equation, Eq. (1), becomes

$$S_i(T) = K_i \int \rho_i(\lambda) L_\lambda(\lambda, T) d\lambda \quad (4)$$

The monochromatic source that will be used to measure $\rho_i(\lambda)$ is part of the newly-developed Infrared Detector Comparator Facility [5]. With this facility, NIST has the capability of measuring the relative spectral response of detectors over the wavelength range of 2 to 20 μm .

The extended-area Lambertian source for measuring K_i is a cryogenic cavity blackbody source (known as the Large-Area BlackBody, or LABB) currently under development at NIST. Its design is based upon that of a similar blackbody source developed previously [6]. The cavity consists of a thin aluminum shell having a cylindro-conical shape and a 10 cm exit aperture. The inside of the shell has an infrared black coating. Rhodium-iron temperature sensors (known as Resistance Temperature Devices, or RTDs) are embedded into the shell, and heaters are mounted against the outside of the shell. The sensors and heaters are used in conjunction with temperature control electronics to vary and control the cavity temperature over the nominal range 200 to 400 K. A liquid nitrogen cooled jacket surrounds the entire shell excluding the exit aperture.

Prior to using it for calibration of the TXR, the LABB will be characterized and calibrated against the NIST radiance scale at the Low Background Infrared Radiation (LBIR) Facility at NIST [7]. This facility features a 0.6 m diameter \times 1.5 m long vacuum chamber with a helium-cooled, light-tight inner shroud to provide a 20 K background environment for blackbody calibrations. An extension to the LBIR Facility, described in Ref. 6, will be used to provide the necessary vacuum housing for the LABB. In the LBIR Facility, a liquid helium cooled radiometer operating on the principle of electrical substitution serves as an absolute cryogenic radiometer (ACR) [8]. This provides measurements of radiant power in terms of electrical power, enabling the calibration to be traceable to electrical units. Using the ACR in combination with precision apertures in the LBIR chamber, broadband absolute radiant power measurements will be made on the LABB at selected RTD setpoints covering the 200 to 400 K range. The spectrally-integrated radiance temperature T at each RTD setpoint of the LABB will be derived from these measurements.

The absolute calibration (measurement of K_i) of the TXR will be carried out in the Medium Background Infrared (MBIR) Facility currently under development at NIST.

This facility features a 1.2 m diameter \times 1.8 m long vacuum chamber with a liquid-nitrogen-cooled, light-tight inner shroud surrounding a rollout-optical bench. This provides a nominally 77 K background in a vacuum of nominally 10^{-4} Pa (10^{-6} Torr), similar to that used in the calibration of EOS flight instruments. The TXR will be mounted along with the LABB on the optical bench in the MBIR. Alignment will be made so as to ensure that the radiation emitted from the exit aperture of the LABB overfills both the aperture stop and field stop of the TXR, enabling the measure-

ment of radiance. The absolute calibration of the TXR will then consist of measuring $S_i(T)$ for each channel i with the TXR viewing the LABB in radiance mode. During these measurements, the radiance temperature T will be known from the readings of LABB RTDs calibrated on the LBIR. Thus $L_\lambda(\lambda, T)$ will be known from the Planck formula and Eq. (4) can be solved for K_i in terms of known quantities,

$$K_i = \frac{S_i(T)}{\int \rho_i(\lambda) L_\lambda(\lambda, T) d\lambda} \quad (5)$$

Figure 2 summarizes the plan for transferring the NIST scale of radiance to EOS calibration labs. The starting point is the ACR of the LBIR Facility. This will be used to calibrate the LABB in the LBIR Facility. The LABB will then be taken to the MBIR Facility at NIST, where it will reside. The TXR will be calibrated for absolute radiance response against the LABB in the MBIR Facility. The relative spectral response calibration of the TXR will be done in a separate step using the Infrared Detector Comparator Facility at NIST. Having measured $\rho_i(\lambda)$ and K_i , the calibrated TXR will be sent in turn to the various EOS flight instrument calibration laboratories where it can be used to verify the radiance calibration of large-area blackbody sources.

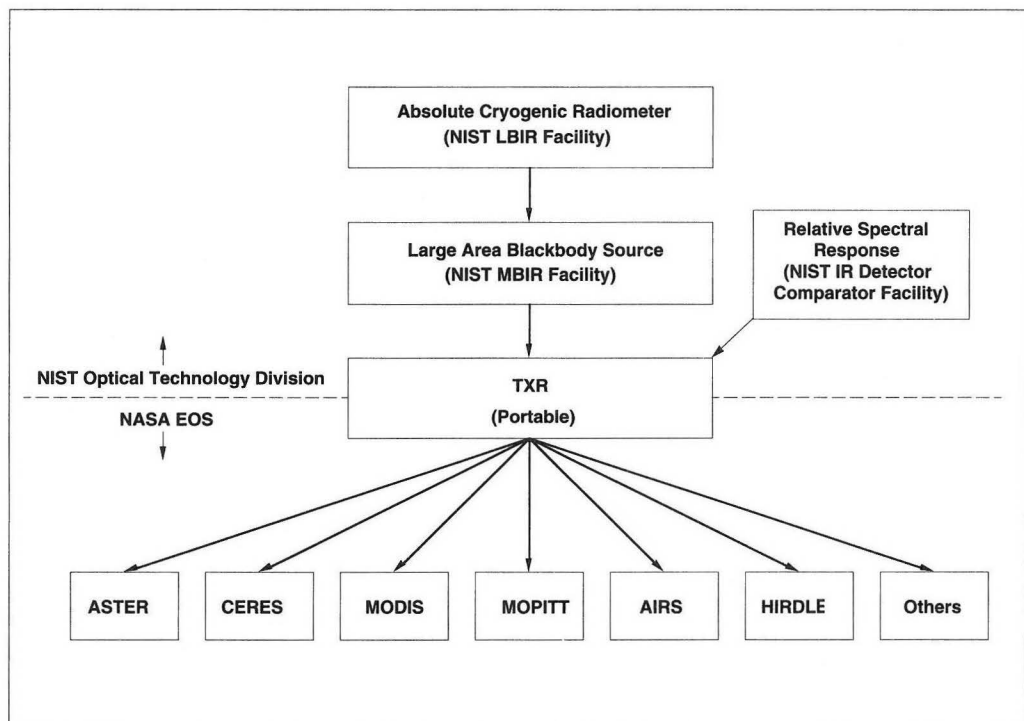


Figure 2. Summary of the plan for transferring the NIST thermal-infrared detector-based radiance scale to EOS flight instrument calibration facilities.

Use of the TXR at EOS instrument calibration facilities

To use the TXR, it needs to be mounted so as to view source X, representing any large-area blackbody source to be calibrated, in radiance mode. The quantity to be determined is $L_{\lambda,x}(\lambda, T_x)$, the spectral radiance of source X with its temperature setpoint at T_x . The TXR will measure signals $S_{i,x}(T_x)$ at each source setpoint. Thus, the measurement equation becomes

$$S_{i,x}(T_x) = K_i \int \rho_i(\lambda) L_{\lambda,x}(\lambda, T_x) d\lambda \quad (6)$$

It is then a matter of mathematics to determine the unknown $L_{\lambda,x}(\lambda, T_x)$ in terms of the known quantities $S_{i,x}(T_x)$, $\rho_i(\lambda)$, and K_i . Further details of how this might be done can be found in Ref. 4.

Conclusion

A thermal infrared transfer radiometer is being designed, built, characterized, and calibrated by NIST to provide radiometric traceability in the NASA EOS program. This radiometer will measure the spectral radiance of large-aperture blackbody sources having radiance temperatures from 200 to 400 K to provide a NIST-traceable radiance calibration of the blackbody sources. This will enable, for the first time ever, radiometric traceability of thermal infrared EOS flight instruments to the radiance scale maintained by NIST.

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Land Use and Land Cover Change (LUCC)

(Reprint from Global Change Newsletter, March 1996, No. 25)

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LUCC in the context of global change research

Over the coming decades, the global effects of land use and cover change (LUCC) may be as significant, or more so, than those associated with climate change. Moreover, land use and cover change are known and undisputed aspects of global change; it is an important human-caused global environmental change that is with us now. In addition to their central role in affecting climate, many facets of human health and welfare are directly connected with LUCC, including biological diversity, food production, and the origin and spread of infectious disease. Yet, we don't know enough about these important human-caused agents of global change. It is a testament to this paucity of knowledge that an accurate global map of agricultural activity does not now exist, nor do we have good measurements of agricultural expansion and the concomitant loss of natural ecosystems, particularly forests.

Classically, the empiricism of observation and measurement is the core of good science. An improved understanding of LUCC must begin with documenting the rate and extent of major changes worldwide. However, it is equally important to move the science from the assessment of pattern to the analysis of process. Hence, furthering our understanding of the complexities and dynamics of LUCC will require a comprehensive, interdisciplinary examination of its underlying causes. LUCC is sufficiently complex that research must include a wide range of scientific and scholarly disciplines, including demography, economics, political science, systems ecology, and other related fields.

The joint IGBP/IHDP Core Project on land use and land cover change (LUCC) has recently published its science plan. It covers complex issues that are not always easy to analyze. The Chair of the LUCC Scientific Steering Committee presents an overview.

The importance of an interdisciplinary perspective was recognized early in the development of the LUCC Core Project, and is manifested in its joint sponsorship by the IGBP and the IHDP. From inception, the planning and implementation of the project has actively engaged both the natural and social science communities,

and this will continue to be an important *modus operandi* in the future.

However, it is not prudent to engage these two communities separately. Rather, we should entrain the intellectual contribution of the interdisciplinary LUCC community itself — those scientists and scholars who are actively involved in the study of LUCC in its global change context. In this way, we will not only engage research teams comprising of members from both of C. P. Snow's "two cultures", but we will also engage those individuals who bridge the two cultures in their own research: the demographer who uses remote sensing to help elucidate the spatial orientation of settlement over time, or the systems ecologist who uses socio-demographic models to help elucidate the process of habitat fragmentation (as two simple examples).

LUCC as an agent of change

The contemporary state of the world's land cover is a constantly changing mosaic of cover types determined by both the physical environment and human activities. These changes in land cover can have profound global consequences. Here I will illustrate the various dimensions of LUCC as an agent of global change through three examples: the global carbon cycle, biological diversity, and infectious disease.

The Global Carbon Cycle

Understanding the global carbon cycle is central to our understanding of global change. The increase in atmospheric carbon dioxide is attributed to two anthropogenic sources: fossil fuel combustion and land cover conversion. Although the current net flux of carbon is dominated by the fossil fuel source term, biogenic net sources contribute approximately 25 - 30% of the total. However, over the last two hundred years the contribution from land cover conversion has been approximately equal to that of fossil fuel combustion. Reconstruction of the last two hundred years of land cover change will be an important part of carbon cycle

research. There are two ways to provide this long-term historical view. The first is to document land cover changes directly using historical reconstruction of changes in land use, particularly agricultural expansion. This would require the interdisciplinary efforts of historians and biogeographers. An example of this kind of work is the reconstruction of land cover change in South and Southeast Asia by John Richards and his colleagues and worldwide by Richard Houghton and his colleagues. Because of the nature of the data, reconstructions are usually spatially and temporally aggregated. Commonly, time steps are a decade or more and data are compiled at the country or province level.

The second approach is to use models to "backcast" the history of land cover change from current distributions of land cover. The current distribution could be ob-

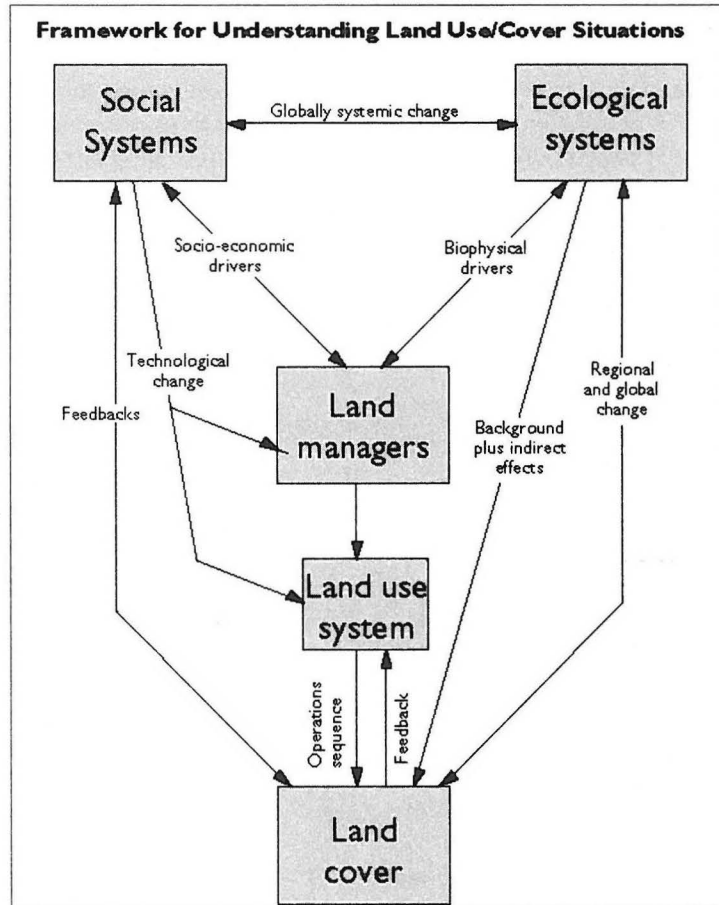


Figure 1. This diagram shows the fundamental structure of land use and cover change. Land managers (the farmers, loggers, etc.) are influenced by both the social and ecological systems in which they operate. Their activities, such as clearing forests, burning savannas, or building terraced paddies, constitute a specific land use system, which in turn changes natural land cover

tained from satellite remote sensing data, such as the global 1 km AVHRR land cover dataset being compiled by the IGBP-DIS. Integrated models, which utilize socio-demographic and economic information as forcing functions, could be used in conjunction with rule-based models and synoptic historical data at various intervals to derive spatially and temporally disaggregated analyses. In essence, such an approach which integrates actual observations, either for the current time period using satellite data or back in time using historical documents, with model-based estimates would be similar to the assimilation techniques, which climate and meteorological models often utilize.

While extremely valuable as a way to build the long-term datasets on

land cover transformation, such an approach falls short of providing a robust and dynamic understanding of the interrelationship between land use and land cover as it is occurring today. Dynamic Vegetation Models (DVMs), in which land use change and land cover change are interrelated in terms of processes and feedbacks offer an advanced approach to coupling the human driving variables with ecosystem response functions, hydrological dynamics, atmospheric conditions, and edaphic (fire related) factors. The development of LUCC-driven DVMs will require a truly interdisciplinary analysis and integrative modeling involving most of the IGBP Programme Elements.

Such models could, for instance, account for the role of transient states of secondary succession following disturbance. New evidence from satellite monitoring in

tropical forests suggests that a large fraction of disturbed areas are secondary growth. In the Amazon, approximately one-third of the deforested area is in secondary succession following abandonment of agricultural fields. Detailed multi-temporal analyses of satellite data show that deforestation is a highly dynamic process of clearing, abandonment and re-clearing, and the rates at which land is cleared or abandoned are related to the land use and management system the forest farmers employ. In one study I conducted with Brazilian colleagues from 1986 to 1993, approximately 35% of

disturbed sites were in active agriculture every year through 1993; these are sites in which the land use system is maintaining them as pastures or crops. Another 9% of the sites persisted every year as secondary growth, representing sites where long-term abandonment was occurring due to out-migration and severe losses of site fertility. But approximately 56% of the sites rotated between secondary growth and active agriculture throughout the period of observation, representing sites where the use and rotation of secondary growth is an explicit land use strategy. In some cases, deforestation

and secondary succession exist in tandem as a tightly coupled system in which secondary growth is continually recycled back into farmland. In other cases active land management maintains the land in agriculture, or the lack of active land management or population displacement results in long-term succession.

Thus, in the Amazon and elsewhere, land use change influences land cover change and is integrated with dynamics of ecosystem structure, function, and response. Within a focused research program on LUCC it will be important to frame such questions as: what human land use and land-management strategies are employed in different situations around the world, and how do they control, or interact with, the dynamics of ecosystem response to disturbance? Because deforestation and abandonment have opposite effects on atmospheric carbon dioxide, *e.g.*, uptake *vs.* release, we can restate the aforementioned general question in terms specific to the carbon cycle: over time, what land use strategies determine the abundance and spatial distribution of secondary growth, how do they determine the balance between clearing and regrowth rates, and how are these land use strategies in turn influenced by ecological conditions?

Finally, it is worth noting that the current global carbon budget is not balanced. There are good reasons to suspect that there is an unaccounted "missing sink" in undisturbed forests of the world, and hence some importance is placed on

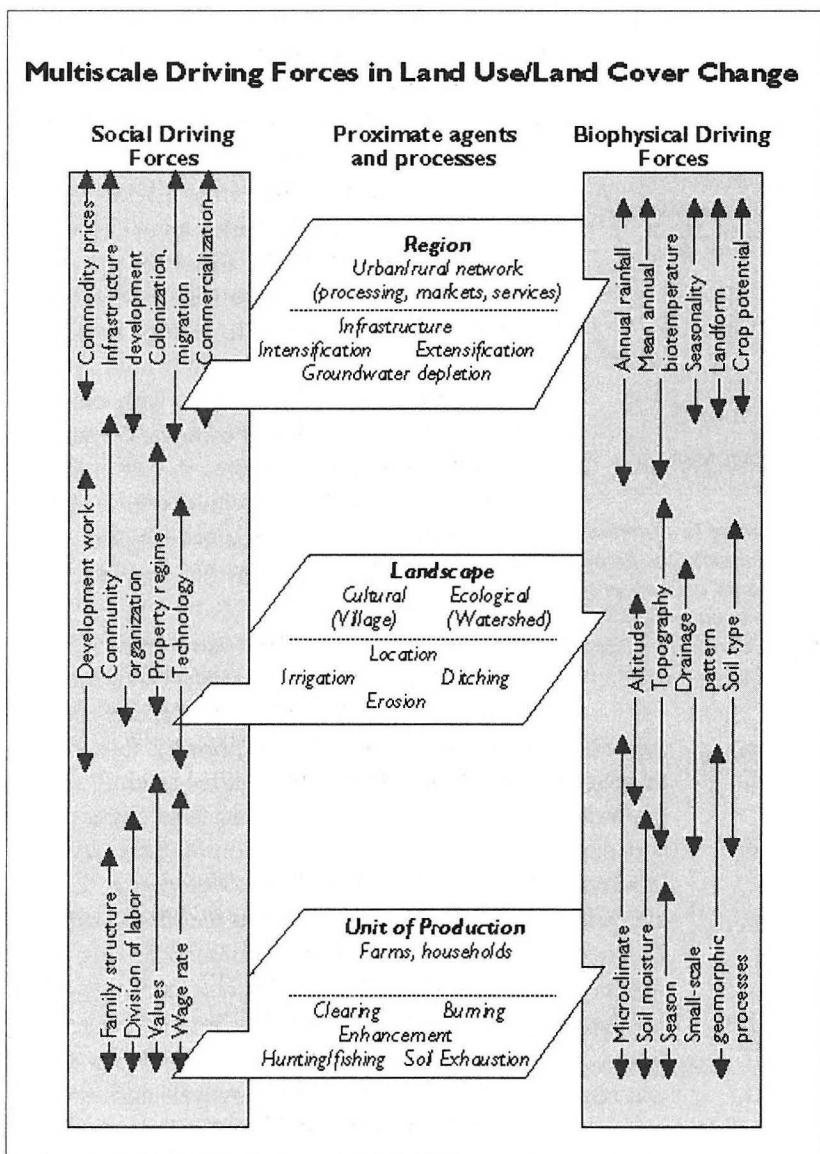


Figure 2. While Figure 1 shows the basic scheme for land use and cover change at the level of the land manager, the complex and dynamic processes of LUCC operate through strata of forces at different scales — from the unit of production, through the landscape, and large regions. Both social and biophysical factors influence, and are influenced by, LUCC at various scales.

emphasizing research on global ecosystem metabolism. However, a net uptake of approximately 1.5×10^{15} gC yr⁻¹ spread over large undisturbed forested ecosystems would be difficult to measure or detect in the field at the hectare scale. Thus, models which predict such sinks must infer the magnitude of the sink as a residual calculation from estimates of fluxes associated with land cover change.

Again turning to the Amazon as an example, the rate of deforestation appears to have increased from the early 1970s to the late 1980s, reaching a peak and then declining quite dramatically through the early 1990s. At the same time, but probably lagged by several years, the rate of abandonment to secondary growth has likely increased as well, but just out of phase. Such asynchronicities in two related, but non-linear and phased pulses of land cover change have interesting consequences for atmospheric carbon dioxide and global carbon budgets. Is it possible that while the rate of deforestation is declining, the rate of reforestation is increasing, causing the net flux of carbon to be unusually low, at least temporarily? Over the long term, what socio-economic factors are controlling the relative balance between deforestation and abandonment? How will they persist into the next century? Are these socio-economic factors influenced by interannual and long-term climate changes?

Biological Diversity

Typically, species/area curves are used to estimate the relative loss in species due to habitat loss. A simple approach would be to use rates of deforestation to estimate the change in forest habitat area. New research, however, is elucidating a fascinating new role for land use and cover change. This work points to three factors: (a) spatial geometry of ecosystem disturbance through habitat fragmentation and its relationship to land use practices, (b) the time-varying "matrix" of areas in agriculture or selective logging and secondary succession over time, and (c) historical changes in land use within "natural" ecosystems.

It is not enough to know only aggregate rates of forest loss since it is the spatial geometry of deforestation that is critically important to understanding forest fragmentation. Deforestation affects biological diversity in three ways: the destruction of habitat, isolation of fragments of formerly contiguous habitat, and edge effects within a boundary zone between forest and deforested areas.

When one considers the spatial geometry of land cover change and calculates this total effect, the impact is much larger than if one used deforestation rates alone. In my own research with C. J. Tucker we found the total affected habitat to be twice as large as the deforested area.

It is not possible to predict the spatial geometry, and hence the total effect on habitat, from aggregate information on deforested areas alone. Also, within a landscape of various land uses, the dynamics of disturbance and succession create a changing matrix of vegetation types and habitats which are more complex than simply forest *vs.* non-forest. The spatial relationship between primary forest, deforested land, and secondary forest imposed by different land uses creates a specific spatial topology which cannot be determined by aggregate figures alone. Detailed measurements need to be made, considering, for example, regions where disturbance patterns are small and dispersed *vs.* large and clustered. Information on land use can provide insights into the cause and characteristics of forest fragmentation. The size and shape of clearings are often related to the land use system being employed, whether they are large commercial farms or small-holder sites. The spatial orientation is influenced by transportation corridors, population nodes, historical foci of settlement, and local environmental conditions such as slope, soils, and rivers. Moreover, as mentioned above in the discussion of the carbon cycle, land use strategies are coupled closely to the dynamics of secondary growth. Some fundamental LUC questions begin to emerge from this view: within a given landscape how do land use, tenure, and management influence the spatial topology of primary and secondary land covers and biological diversity?

Peter Vitousek and colleagues have estimated that as much as 40% of global net primary productivity (NPP) has already been utilized by human activities. A large component of this appropriation of NPP occurs when human land uses directly disturb natural ecosystems, such as clearing forests for agriculture or logging. The work of anthropologists, ethnobotanists, and ecologists suggests the biological diversity of large areas of so-called "natural" ecosystems can also be directly affected by human use. In what he refers to as the Empty Forest, Kent Redford and others have shown an important influence of the customary use of natural ecosystems, where humans exploit the flora and fauna of intact

forests to a significant degree, particularly those in close proximity to disturbed areas.

If our concept of global change rests solely on the issue of climate change, we would likely ignore intact forests, since their influence on carbon dioxide, sensible and latent heat flux, and the atmosphere are relatively unchanged compared to logged areas and croplands. But as Redford states, "We must not let a forest full of trees fool us into believing all is well." This leads to interesting land use and human dimensions questions to be asked if we want to look beyond climate change: How do changing patterns of consumption and human population density affect biological diversity, even in intact ecosystems? How does the spatial orientation of land use affect intact ecosystems?

Infectious Disease

There are very good data relating the incidence of certain human diseases to changes in land cover. Malaria rates (per thousand individuals) increased fivefold in the Amazon between 1975 and 1990 as deforestation rates increased dramatically over the same period. Regions of most rapid deforestation had the highest infection rates. The epidemiology of disease is complex, multivariate, and not linearly related to disturbance rates, but the link between changes in cover/habitat and disease is becoming an important area of research. The case of Oropouche disease reported by Robert Shope and his colleagues in the Amazon in the 1960s is indicative. The construction of the Belem-to-Brasilia highway resulted in an outbreak of a flu-like epidemic, which was later attributed to a virus from a biting midge. The midge population grew explosively when settlers cleared the land, and certain crop harvesting practices associated with the land use in the region provided an ideal breeding ground.

The work of Paul Epstein at the Harvard School of Public Health shows the relationship with deforestation in Honduras, where cases of malaria rose from 20,000 to 90,000 from 1987 to 1993. But he also notes that in addition to ecological effects from road building and deforestation, it is the *interaction* between land cover change and climate that is important.

Along with an emphasis on these kinds of established diseases, there is increasing speculation on the relationship between land cover change and the origin of new disease. There is considerable work to be done in this

area, but like no other example the case of infectious disease illustrates the direct link between global change, LUCC, and human health.

LUCC as an IGBP Program Element

The global effects of land use and cover change is an emerging and important area of research. Over the past four years an international community of scientists has been making the case for its inclusion into the IGBP framework, first under the auspices of an *ad hoc* working group (IGBP Report #24/HDP Report #5), then under the auspices of a formal core project planning committee (IGBP Report #35/HDP Report #7). There have been a number of special conferences and symposia which have also helped focus the discussion, including the 1991 Global Institute in Snowmass, Colorado, (published by Cambridge University Press, 1994), the 1992 Ecological Society of America Symposium on Global Impact of Land Cover Change (published as a special issue of *BioScience*, May 1994), and the LUCC Open Science Meeting in Amsterdam, The Netherlands in 1996.

The development of a Core Project on LUCC comes at an important moment in the evolution of the IGBP. Other Core Projects, such as GCTE, BAHC, LOICZ, and IGAC urgently need to incorporate LUCC dynamics in their research. The global synthesis and integrated models provided by GAIM will now need to include the transient states caused by LUCC. The 1 km AVHRR/Global Land Cover dataset being developed by IGBP-DIS will soon be ready for widespread distribution. At this stage of IGBP development it is becoming increasingly evident that the research community which the LUCC Core Project joins will be pressured in two important ways: (i) to produce timely scientific results and policy-relevant information — in my own view through focused research campaigns or projects, such as the Large Scale Amazon Basin Experiment (LBA) or the IGBP Transects, and (ii) to strengthen the inter-program-element nature of our research, linking across rather than within the Core Projects and Framework Activities.

LUCC should be a critical nexus for this kind of IGBP research. At the same time, LUCC should provide a bridge between the human dimensions and the geophysical/biophysical dimensions of global change. Moreover, LUCC can provide direct links to policy, as it relates to climate, biodiversity, agriculture, and human health. ■

NASA Selects 50 New Graduate Student Fellows in Response to the Earth System Science Graduate Student Fellowship Announcement

— **Ghassem Asrar** (gasrar@mtpe.hq.nasa.gov), EOS Program Scientist, Office of Mission to Planet Earth, NASA Headquarters

The selection of this year's recipients of NASA Earth System Science Graduate Student Fellowships is complete. A total of 311 applications were received by the Office of Mission to Planet Earth at NASA Headquarters in response to the announcement released in December, 1995. In all, over 90 universities and educational institutions from 44 states were represented by the applicants. They represent 28 countries. However, they are all currently accepted/enrolled as full-time M.S. and Ph.D. graduate students at 90 universities in the United States.

The applications were evaluated through a two-step peer review process: first through mail/panel review, and then by a panel of evaluators composed of members of professional scientific societies, academic institutions, and the Educational Affairs Office and the Office of Mission to Planet Earth at NASA Headquarters.

A total of 50 new candidates from 25 states representing 34 academic institutions and 3 countries were identified to receive the fellowships this year. The new fellowships, added to the pool of students whose support continues from last year, brings a total of 141 students now funded by this program. This educational program is intended to support graduate students involved in Earth system science research as part of NASA's contribution to the U.S. Global Change Research Program.

The purpose of the Fellowship program is to train a pool of highly qualified scientists to help analyze and interpret the wealth of data generated by the Mission to Planet Earth programs. NASA understands that the future of Earth science rests with today's students who will be tomorrow's scientists. The financial wherewithal to

pursue an advanced education obviously plays a vital role in securing the necessary talent to further Earth system science objectives.

Fellowships are given for an initial 1-year term and may be renewed annually for up to 3 years, based on satisfactory progress as reflected in academic performance and evaluations made by faculty advisors. The amount awarded is \$20,000 per annum, which may be used to defray living expenses, tuition, fees, and other educational expenses. An

additional \$2,000 may be requested by the faculty advisor to support the student's research. Students receiving these stipends must not receive another Federal fellowship.

The name, affiliations, and titles, of selected recipients for this year are given in the table. An announcement for the 1996-97 Fellowships will be released in December 1996, and the deadline for submission of new applications to NASA is March 15, 1997. Please contact Dr. Ghassem Asrar, Mail Code YS, NASA Headquarters, Washington, D.C. 20546 for further information.

NASA understands that the future of Earth science rests with today's students who will be tomorrow's scientists. The financial wherewithal to pursue an advanced education obviously plays a vital role in securing the necessary talent to further Earth system science objectives.

Name	Organization	Title
Aalto, Rolf E	U. of Washington	Quantitative Mesoscale Geomorphology of the Amazon Basin
Asner, Gregory P	U. of Colorado, Boulder	Satellite Remote Sensing Ecosystem Structural and Functional Change in Spatially Heterogeneous Regions: Integrating Spectral Mixture Analysis, BRDF Inversions, and a Biogeochemical Model
Baisden, William T	U. of California, Berkeley	The Relationship Between Soil Age, Land Use and C Cycling in the Great Valley of California
Booth, Mary	Utah State University	Land Cover Change in the Great Basin: Plant Influences on Nitrogen Dynamics
Catovsky, Sebastian	Harvard University	Effects of Elevated CO ₂ and Nitrogen Deposition on Species Physiology and Community Composition in a Mixed Conifer-Hardwood Forest: Implications for Ecosystem Function
Chen, Yalei	Colorado State University	Studies of Homogeneous Freezing Nucleation at the Upper Tropospheric Conditions
Cherry, Hilary	U. of California, Berkeley	The Development of Potassium Tantalate Niobate Thin Films for Satellite-based Pyroelectric Detectors
Cybulski, Walter J	West Virginia University	Assessing the Consequences of Ozone Depletion on Ecosystem Function: Effects of Ultraviolet-B Radiation on Plant Litter Quality and Decomposition
Drummond, Charles	Colorado State University	Retrieval of Cirrus Cloud Microphysical and Radiative Properties from Multispectral MODIS and MAS Measurements
Dukes, Jeffrey S	Stanford University	Anthropogenic Changes in Grasslands: Consequences of Increasing Atmospheric Carbon Dioxide and Species Invasions for Decomposition, Productivity and Biodiversity
Finlay, Jacques C	U. of California, Berkeley	Hydrologic Controls on Nutrient Cycling and Trophic Dynamics in California River Ecosystems
Fischer, Tobias P	Arizona State University	Variability of Volatile Flux from Volcanoes
Geiger, Franz M	Georgetown University	Surface Chemistry of Polar Stratospheric Cloud Particles
Graham, Stephen	University of Texas, Austin	A Continental River Routing Algorithm for Global Water Cycle Closure in Coupled Earth System Models
Hall, Alexander	Princeton University	An Assessment of the Role of Water Vapor Feedback in Natural Climate Variability Using the GFDL Coupled Ocean-Atmosphere Model
Hall, Sharon J	U. of California, Berkeley	Effects of Nitrogen Additions on Gaseous Nitrogen Loss and Soil Nutrient Dynamics Across a Gradient of Nutrient Limitation
Hargrove, John	U. of Miami	Mid-Ocean Mesoscale Variability as Deduced from TOPEX Altimetry and High-Resolution Numerical Modeling

Name	Organization	Title
Henderson, Keith A	Ohio State University	An Ice Core Paleoclimate Study of Windy Dome, Franz Josef Land(Russia): Development of a Sea Ice Proxy from Satellite and In Situ Data and Reconstruction of a Sea Ice History for the Barents Sea
Higgins, Sean M	Columbia University	Interannual SST Variability of the Tropical Western Pacific "Warm Pool" from Coral Sr/Ca Proxy Records for the Last 1000 Years
Jaiteh, Malanding	Michigan Technological University	The Dynamics of Human-Driven Land Cover Change in Southern Africa
Jin, Menglin	U. of Arizona	A Study of 1993 USA Flood Mechanism on Regional and Global Scale Using Climate Models and Remote-Sensing
Johnson, Thomas J	U. of Texas, Austin	The Variability of Oceanic Angular Momentum and the Planetary Angular Momentum Budget: A Geodetic Approach to Global Climate Change Research
Jordan, Carolyn	U. of New Hampshire	Chemistry and Deposition of Atmospheric Nitrogen in the Coastal Marine Environment
Klonecki, Andrzej	Princeton University	Analysis of the Factors Determining the Distribution of Ozone in the Troposphere
Kucera, Paul A	University of Iowa	Validation of Rainfall Estimates from Space-Borne Radars
Ladd, Carol A	U. of Washington	Structure, Dynamics, and Variability of Thermocline Circulation and Mode Water Formation in the Eastern Subtropical North Pacific
Legarsky, Justin J	U. of Kansas	Radar Interferometry For Improved Cross-Track Resolution Measurements of the Thickness of the Greenland Ice Sheet
Mao, Ailin	U. of Miami	Monitoring Absolute Sea Level Change and Coastal Subsidence with GPS
McKinney, Karena A	U. of California, Irvine	A Laboratory Investigation to Determine the Role of HOONO in the Reactive Nitrogen Balance of the Atmosphere
Meier, Walter N	U. of Colorado, Boulder	Improving the Predictability of Polar Climate through the Assimilation of Remotely-Sensed Data
Moisan, Tiffany A	U. of California, San Diego	Ocean Color Models of Primary Production for Phaeocystis Blooms in Polar Regions
Panegrossi, Giulia	U. of Wisconsin, Madison	Assimilation of Spaceborne Passive Microwave Measurements into Mesoscale-Cloud Model for Improving Precipitation Retrieval
Perakis, Steven S	Cornell University	The Internal Nitrogen Cycle of Temperate Forests: Patterns and Mechanisms in the Absence of Human Disturbance

Name	Organization	Title
Peterson, Garry D	U. of Florida	Fire, Insect Outbreaks, and Climate Change in Boreal Forests: Resilience of Cross-Scale Dynamics
Phelps, Allan R	U. of Alaska, Anchorage	Shallow Lake Processes and Methane Flux to the Atmosphere During Ice Break-Up of High Latitude Lakes
Ramaprasad, Jaya	Purdue University	Effect of Anthropogenic Aerosol on Cloud Optical Properties: A Case Study of the Eastern United States
Rieck, Donna	Kansas State University	Using Spatio-Temporal Heterogeneity for Landcover Characterization: Multi-Sensor Analysis of a Tallgrass Prairie Gradient
Saco, Patricia M	U. of Illinois	Characterizing Climatic Signatures in Hydro-Geomorphologic Response
Sahami, Kamran	U. of Colorado, Boulder	A Proposal for El Niño Prediction Using Heuristic Algorithms
Sayal, Mehmet	Northwestern University	Scalable and Adaptive File Management in Networks of Workstations
Sorensen, Cynthia L	Ohio State University	Biomass Burning in Tropical Rain Forests: An Analysis of Land Settlement and Land Use Practice to Assess Burning Patterns in the Brazilian Amazon
Sulzman, Elizabeth	Colorado State University	Partitioning of Ecosystem Respiration and Vectors of Water Loss: An Analysis Using d13C and d18O with Implications for NDVI-Driven Ecosystem Models
Sutton, Paul C	U. of California, Santa Barbara	Estimation of Human Population Parameters with Nighttime Satellite Imagery (DMSP) and GIS
Tiampo, Kristy F	U. of Colorado, Boulder	Proposal for the Study and Modeling of the Magmatic Intrusion Source Mechanism at Long Valley Caldera, California
Toracinta, Ernest	Texas A & M University	Lightning and its Relationship to 85 GHz Ice Scattering Signatures in the Global Tropics
Varlyguin, Dmitry	Clark University	West Siberian Peatland Dynamics in Relation to the Global Carbon Balance
White, Michael	U. of Montana	Developing a Global Phenology Monitor: A Method for Detecting Biospheric Responses to Climate Change
Worden, Alexandra Z	U. of Georgia	Measurement of In Situ Growth Rates of Two Important Oceanic Primary Producers Using Flow Cytometry and RNA-targeted Probes
Yin, Baoyu	U. of Maryland, College Park	Role of Mountains in the Generation of Seasonal Climate Anomalies
Yurcik, William J	U. of Pittsburgh	Providing Earth Systems Science Applications Access to EOS Data Over Wide Area High Speed Networks

Selection Results for the NASA Research Announcement

Opportunities to Participate in NASA Mission to Planet Earth and Earth Observing System Science and Education Programs

— **Ghassem Asrar** (gasrar@mtpe.hq.nasa.gov), EOS Program Scientist, Office of Mission to Planet Earth, NASA Headquarters

Background

The Office of Mission to Planet Earth at the National Aeronautics and Space Administration (NASA) Headquarters issued a research announcement (NRA-95-MTPE-03) soliciting research and education proposals in September of 1995. Five types of proposals were requested by this announcement. The deadline for submission of proposals was December 1995.

The objective of this Announcement was to solicit and select investigations that will complement existing NASA Research and Analysis and the EOS investigations by: 1) selecting a science team for Landsat, which is now part of the MTPE/EOS program; 2) filling gaps in the expertise of existing science teams for NASA Research Facility Instruments/Missions; 3) providing opportunity for new investigations to address scientific issues not covered well by existing EOS Interdisciplinary Science Investigations; 4) establishing a New Investigators Program to support recent Ph.D. graduates pursuing research in support of MTPE objectives; and 5) establishing science education and communication grant supplements to foster effective communication of scientific results. The overall goal that the selected proposals share with other investigations funded by NASA is to improve our understanding of the Earth as a coupled and integrated system, how it responds to natural and human-induced perturbations, and how this response manifests itself as global changes.

NASA received 309 proposals in response to this announcement. Each proposal was evaluated by scientific peers including representatives from government, academia, industry, and the international Earth-observation community. NASA then selected, from the ones

viewed as acceptable by peer evaluators, those proposals needed to accomplish its mission objectives.

The selection breakdown includes 14 Landsat Science Team Members/Leader, 2 Atmospheric Infrared Sounder (AIRS), 5 Moderate Resolution Imaging Spectrometer (MODIS), 2 Multifrequency Passive Microwave Radiometer (MPMR), and 2 Tropical Rainfall Measuring Mission (TRMM) Science Team Member investigations; 31 Earth System Science Interdisciplinary investigations (30 U.S. and 1 foreign); and 21 New Investigator Program investigations. The various teams selected comprise 198 individuals from 60 institutions, universities or laboratories in 19 states (includes the District of Columbia) and 5 other countries.

Landsat Science Team

Landsat is now part of the NASA MTPE/EOS Program, and this announcement solicited proposals for team members and a team leader to conduct basic research, develop new and innovative methods of extracting information content of Landsat observations for global change studies, and guide the development of the follow-on to the Enhanced Thematic Mapper Plus (ETM+) instrument. All selected investigators will be official members of the Landsat Science Team. Landsat-7 is currently scheduled for launch in 1998. The selected science team will evaluate the quality of data acquired by land-surface imaging missions sponsored by other U. S. Government agencies and private industry for assessing future alternatives in addressing the Landsat observations continuity requirement. NASA received a total of 41 proposals and the selected Team Leader and Members are listed in Table 1:

Table 1.

Landsat		
Robert Bindschadler	Goddard Space Flight Center	Enhanced Antarctic Research with Landsat: Ice-sheet Dynamics, History, and Cartography
Robert F. Cahalan	Goddard Space Flight Center	Clear Sky and Cloud: Characterization and Correction for Landsat
Kendall L. Carder	U. of South Florida	Bottom-Assessment and Water-Constituent Algorithms for the ETM in the Coastal Zone
Luke P. Flynn	U. of Hawaii, Manoa	Analysis of Volcanic Eruptions and Fires Using Landsat-7
Alexander Goetz	U. of Colorado, Boulder	Land and Land-Use Change in the Climate Sensitive High Plains: An Automated Approach with Landsat
Samuel N. Goward (<i>Team Leader</i>)	U. of Maryland, College Park	Terrestrial Monitoring at High Spatial Resolution: The Role of Landsat-type Sensors in Mission to Planet Earth
Susan Moran	U.S. Dept. of Agriculture	Landsat TM and ETM+ Data for Resource Monitoring and Management
Frank D. Palluconi	Jet Propulsion Laboratory	Landsat-7: Calibration and Atmospheric Correction for Thermal Band 6
John Price	U.S. Dept. of Agriculture	Surface Classification for MODIS, Radiometric Calibration and Project Support
John R. Schott	Rochester Institute of Technology	Absolute Calibration, Atmospheric Correction and Application of Landsat ETM + Thermal Infrared Data
David L. Skole	U. of New Hampshire	Acquisition and Analysis of Large Quantities of Landsat-7 Data for Measuring Tropical Land Cover Change
Kurtis J. Thome	U. of Arizona	Absolute Radiometric Calibration and Atmospheric Correction of Landsat-7 Thematic Mapper
James E. Vogelman	U.S. Geological Survey	Characterization of Landsat-7 Geometry and Radiometry for Land Cover Analysis
Curtis E. Woodcock	Boston University	Monitoring Changes in Temperate Coniferous Forest Ecosystems

Existing Facility Instruments and Missions

A subset of the instruments to be deployed as part of the EOS program are managed as Research Facility Instruments. Members of science teams for the Research Facility Instruments in EOS were selected individually in response to NASA AO No. OSSA-1-88 in 1989. Additional or replacement science team members were

solicited for very specific tasks to complement existing investigations, and replace retired or deceased members through this announcement. Research Facility Instruments include the Atmospheric Infrared Sounder (AIRS), Moderate-Resolution Imaging Spectroradiometer (MODIS), and Multifrequency Passive Microwave Radiometer (MPMR). In addition, NASA also intends to add two new members to the existing Tropical Rainfall Measuring

Mission (TRMM) Science Team. The selected instrument investigations will guide and support the technical development of these instruments and their future versions as well as develop scientific methods/algorithms for analysis of the resulting data and retrieving the information content. NASA received a total of 55 proposals and the selected Team Members are listed in Table 2.

Earth System Science Interdisciplinary Investigations

These were proposals for interdisciplinary research requiring analysis, interpretation, and significant use of data from current and planned NASA Earth science missions. They proposed to carry out a scientific investigation leading to improved understanding of the Earth

Table 2.

Moderate-Resolution Imaging Spectroradiometer (MODIS)		
Janet W. Campbell	U. of New Hampshire	Development of Algorithms and Strategies for Monitoring Chlorophyll and Primary Productivity in Coastal Ocean, Estuarine and Inland Water Ecosystems
Bo-Cai Gao	Naval Research Laboratory	Correction of Thin Cirrus Effects and Characterization of Cirrus Radiative Properties from EOS/MODIS Data
Ranga B. Myneni	U. of Maryland, College Park	Radiative Transfer Based Synergistic MODIS/MISR Algorithm for the Estimation of Global LAI and FPAR
John R. Townshend	U. of Maryland, College Park	Enhanced Land Cover and Land Cover Change Products from MODIS
Eric F. Vermote	U. of Maryland, College Park	A Global Land Surface Reflectance Product for Use in MODIS Land Algorithms
Multifrequency Passive Microwave Radiometer (MPMR)		
Alfred T. Chang	Goddard Space Flight Center	Retrieval of Snow Information Using Multifrequency Passive Microwave Radiometer (MPMR)
Eni G. Njoku	Jet Propulsion Laboratory	Estimation of Land Surface Parameters from EOS Multifrequency Passive Microwave Radiometer (MPMR) Data
Atmospheric Infrared Sounder (AIRS)		
Mitchell D. Goldberg	National Environmental Satellite, Data, and Information Service	AIRS/AMSU/MHS Operational Retrieval Algorithm Development
Eugenia Kalnay	National Weather Service	Evaluation and Optimal Use of AIRS for Global and Mesoscale Operational Numerical Weather Prediction
Tropical Rainfall Measuring Mission (TRMM)		
Raphael L. Bras	Massachusetts Institute of Technology	Amazon Deforestation and Regional Climate
Carol A. Clayson	Purdue University	The Impact of Precipitation on the Tropical Ocean Mixed Layer

as a coupled and integrated system. Interdisciplinary research implies addressing scientific questions that pertain to more than one of the traditional Earth science disciplines. The selected investigations will complement the existing interdisciplinary investigations in using space-based, multispectral remotely sensed and *in situ* observations to study Earth system processes. The studies will address key areas of uncertainty in the global climate system and/or diagnostic analysis of long-term remotely sensed data sets in conjunction with coupled Earth system models. The scientific knowledge gained from these efforts will be used to assess the consequences of variabilities and changes in the Earth's climate on the regional and global agricultural, industrial, and social infrastructure. NASA received 120 proposals and the selected investigations are listed in Table 3.

Table 3.

Earth System Science Investigations		
Robert Bindschadler	Goddard Space Flight Center	Interdisciplinary Determination of Snow Accumulation Patterns on the Greenland Ice Sheet: Combined Atmospheric Modeling and Field and Remote Sensing Studies
Robert Brakenridge	Dartmouth College	River Flooding and Global Climatic Change: A Multi-Sensor Approach
Guy P. Brasseur	National Center for Atmospheric Research	Climate and Chemical Cycles: The Role of Sulfate and Ozone in Climate Change
William L. Chameides	Georgia Institute of Technology	The Yangtze Delta of China as an Evolving Metro-Agro-Plex (MAP)
Kelly V. Chance	Smithsonian Center for Astrophysics	Satellite-Based Stratospheric and Tropospheric Measurements: Determination of Global Ozone and Other Trace Species
Jean Dickey	Jet Propulsion Laboratory	Retrieval, Assimilation and Modeling of Atmospheric Water Vapor from Ground and Space GPS Networks: Investigation of the Global and Regional Hydrological Cycles
Ralph Dubayah	U. of Maryland, College Park	Combining Remote Sensing and Hydrological Modeling for Applied Water and Energy Balance Studies
Anthony W. England	U. of Michigan	Estimating Water Stored in Soil and Vegetation Using LSP Model Soil Wetness and Satellite Radiobrightness
Jonathan A. Foley	U. of Wisconsin, Madison	Integrating Biogeochemical, Ecological, and Hydrological Processes in a Dynamic Biosphere
Steven J. Ghan	Battelle Pacific Northwest Laboratory	Develop and Apply a Global Aerosol Model to Estimate Radiative Forcing of Climate Change

New Investigator Program

As part of this announcement, the Mission to Planet Earth (MTPE) program established the "New Investigator Program" (NIP) in which scientists and engineers at an early stage of their professional career can receive financial support to establish and develop their research efforts. Although this program is designed primarily for investigators at academic institutions, scientists and engineers with permanent status at other institutions are eligible to propose. NIP proposals were restricted to recent Ph.D. recipients (graduating on or after January 1 of the year that falls no more than five years before the issue date of this announcement) who propose to contribute to furthering NASA MTPE scientific goals and objectives. These investigations had to be based on

Earth System Science Investigations (continued)

Sirpa Hakkinen	Goddard Space Flight Center	Fresh Water Cycle in the Global Ocean: A Numerical Model Study
Brent N. Holben	Goddard Space Flight Center	Characterizing Aerosol Forcing Over the Atlantic Basin
Marc Imhoff	Goddard Space Flight Center	Assessing the Impact of Expanding Urban Land Use on Agricultural Productivity Using Remote Sensing Data and Physically-Based Soil Productivity Models.
Thomas J. Jackson	U.S. Dept. of Agriculture	Soil Moisture Mapping at Satellite Temporal and Spatial Scales
Daniel J. Jacob	Harvard University	An Investigation of the Coupling Between Tropospheric Ozone, Sulfate Aerosols, and Climate Using a General Circulation Model
Prasad Kasibhatia	MCNC-North Carolina	A Study of Carbon Monoxide Using Trace Constituent Data Assimilation: A New Approach in Global Tropospheric Chemistry Analysis
Malcolm K. Ko	Atmospheric & Environmental Research Inc.	Climate Change and Atmospheric Chemistry, Ozone, Aerosol and Clouds
Charles E. Kolb	Aerodyne Research Inc.	Urban Metabolism and Trace Gas Respiration
Randal D. Koster	Goddard Space Flight Center	The Land Surface Component of the Climate System: (i) Improved Representation of Subgrid Processes and (ii) Analyses of Land Surface Effects on Climate Variability
Robert McGraw	Brookhaven National Lab.	Representation of Aerosol Microphysics in Regional to Global Scale Models
Linda O. Mearns	National Center for Atmospheric Research	Analysis of the Effect of Changing Climate Variability on Crop Production in the Southeast: An Integration of Stochastic Modeling, Crop Modeling and Remote Sensing Techniques
Massimo Menenti	Winand Staring Center/The Netherlands	Observation and Modelling of Heat and Water Fluxes Over Heterogeneous Land Surfaces at Mesoscale
Norman L. Miller	Lawrence Livermore National Lab.	Global Climate Impact on Regional Hydro-Climate and its Effect on Southeastern Asian Agro-Ecosystems
Kenneth E. Pickering	U. of Maryland, College Park	Tropospheric Convection and Stratosphere-Troposphere Exchange: Effects on Photochemistry, Aerosols, and Climate
Dale A. Quattrochi	Marshall Space Flight Center	A Remote-Sensing Based Study of Past and Future Land Use Change Impacts on Climate and Air Quality of the Atlanta, Georgia Metropolitan Region
Cynthia Rosenzweig	Goddard Institute for Space Studies	Impacts of Interannual Climate Variability on Agro-Ecosystems and Fisheries
Ronald B. Smith	Yale University	Climate Change and Human Response in the Semi-Arid Near East
Graeme L. Stephens	Colorado State University	Water Vapor in the Climate System
Ina Tegen	Columbia University	Modeling of Distribution and Interannual to Interdecadal Variations of Aerosols
Owen B. Toon	Ames Research Ctr.	The Role of Natural and Anthropogenic Aerosol in Earth's Radiation Budget and Climate: Microphysical Simulations with the NCAR Community Climate Model
Konstantin Vinnikov	U. of Maryland, College Park	Global Soil Moisture Data Set from Satellite and Gravimetric Observations for Climatic Studies and Evaluation of the Hydrological aspects of Climate Models

analysis, interpretation, and significant use of data from space-based observations. They had to propose to carry out a scientific investigation with data from the existing/planned NASA missions leading to the improved under-

standing of some aspect of the Earth system and global change. NASA received a total of 67 proposals and the selected investigations are listed in Table 4. ■

Table 4.

New Investigator Program		
Kevin R. Arrigo	Goddard Space Flight Center	Remote Sensing of Phytoplankton Production in the Southern Ocean
Ana P. Barros	Pennsylvania state University	Space-Time Scaling of Water Transfers Between the Land Surface and the Lower Atmosphere
Sundar A. Christopher	South Dakota School of Mines & Technology	Satellite Investigations of Aerosol Radiative Forcing
Curt H. Davis	U. of Missouri, Kansas City	Long Term Elevation Change of the Greenland Ice Sheet from Satellite Radar Altimetry
Elfatih Eltahir	Massachusetts Institute of Technology	Use of Satellite Remote Sensing to Study the Role of Rainforest in Tropical Climate
Franklin Evans	U. of Colorado	Satellite Remote Sensing of Tropical Ice Clouds and Precipitation for GCM Verification
Mark A. Fahnestock	U. of Maryland, College Park	New Methods for Measuring Ice Motion: The Field Component Required for SAR Interferometry
James S. Famiglietti	U. of Texas, Austin	Multiscale Soil Moisture Variability from Combined Remote Sensing, Modeling and Observations
Amy L. Field	Columbia University	Global Ocean-Atmosphere Interactions Forced by Tidal Mixing of SST
Robert C. Frohn	U. of California, Santa Barbara	Using Landsat Data to Develop an Image Based Logistic Regression Model for Predicting Deforestation in the Amazon
Rong Fu	U. of Arizona	The Role of Atmosphere-Land-Ocean Coupling in Determining Clouds, Precipitation and Water Vapor
Joseph Hellerstein	U. of California, Berkeley	Implementation and Deployment of a Generalized Search Tree for Managing Multiple Data Types
Praveen Kumar	U. of Illinois, Urbana	Characterizing Multiscale Interaction of Hydrologic Processes Using Multisensor Satellite Data
Manuel T. Lerda	State University of New York, Stony Brook	Development and Validation of a Tropical Isoprene Emission Model
Aaron Moody	U. of North Carolina	Improved Area Estimates for Land Cover and Land-Cover Change from Low Spatial Resolution Remote Sensing
Bo Qiu	U. of Hawaii, Manoa	Understanding Seasonal-to-Interannual Fluctuations of the North Pacific Subtropical Gyre through Modeling and Satellite Observation
Guido Salvucci	Boston University	Thermal and Hydrologic Signatures of Soil Controls on Evaporation: A Combined Energy and Water Balance Approach with Implications for Remote Sensing of Evaporation
Heidi M. Sosik	Woods Hole Oceanographic Institution	Biological Interpretation of Ocean Color: Observations and Models for Waters of the Mid-Atlantic Shelf
Alan R. Townsend	Harvard University	An Integrated Use of Experimental Modeling and Remote Sensing Techniques to Investigate Carbon Isotope and Phosphorus Dynamics in the Humid Tropics
John F. Weishampel	U. of Central Florida	Detecting and Modeling Spatial Canopy Properties of Forested Landscapes
Dong L. Wu	Jet Propulsion Laboratory	Analysis of Small-scale Atmospheric Gravity Waves Using UARS MLS Radiance Measurements

Weather-Changing Ocean Waves Charted from Space

— **Douglas Isbell**, Headquarters, Washington, DC. (Phone: 202/358-1753)

— **Mary Hardin**, Jet Propulsion Laboratory, Pasadena, CA. (Phone: 818/354-5011)

RELEASE: 96-71

New results from the ocean-observing TOPEX/Poseidon satellite are challenging a fundamental oceanographic theory about the speed of large-scale ocean waves — a finding that could ultimately revise science textbooks and improve global weather forecasting.

The large-scale ocean waves, with wavelengths of hundreds of miles from one wave crest to the next, are called Rossby waves. These waves carry a “memory” of weather changes that have happened at distant locations over the ocean, according to Dr. Dudley Chelton, a TOPEX/Poseidon science team member at the College of Oceanic and Atmospheric Sciences at Oregon State University, Corvallis. Using data gathered by the satellite, scientists tracked the waves as they moved through the open ocean and determined that, at mid-latitudes, the Rossby waves are moving two to three times faster than previously thought.

Rossby waves are a natural result of the Earth’s rotation and a key feature of large-scale ocean circulation. In animations of altimeter data from the TOPEX/Poseidon satellite, the waves appear as alternating positive and negative sea level features traveling throughout much of the world’s oceans.

“Every first-year student in physical oceanography learns about Rossby waves. However, observing them away from the Equator has been extraordinarily difficult, because they cause changes in sea level of 4-8 inches, spread over hundreds of miles, and move westward so slowly that a wave may take more than ten years to cross the Pacific at the latitude of Los Angeles, and more than 30 years at the latitude of Portland, Oregon,” said

Dr. Victor Zlotnicki, an oceanographer at NASA’s Jet Propulsion Laboratory, Pasadena, CA.

“Thanks to TOPEX/Poseidon, for the first time we can see these waves very clearly, and this research shows that they become more intense to the west of the great mountain chains on the ocean floor, and, more fundamentally, that they travel much faster than the accepted theory predicts,” said Zlotnicki.

Since Rossby waves can alter currents and their corresponding sea surface temperatures, the waves influence the way the oceans release heat to the atmosphere and thus are able to affect weather patterns.

For example, in 1994, oceanographers at the Naval Research Laboratory mapped a Rossby wave that they concluded was a remnant of the 1982-83 El Niño event. They found evidence that the Kuroshio current, located off the coast of Japan, was pushed northward, raising the temperature of the northwest Pacific. Some scientists blamed this shift for contributing to the flooding across the midwestern United States in 1993.

“If our traditional notions about the wave speeds are incorrect,” Chelton said, “then the waves get from one side of the mid-latitude ocean to the other twice as fast, which means that the ocean evidently adjusts more rapidly than we previously thought.”

This more-precise information about how fast the waves are traveling may help forecasters improve their ability to predict the effects of El Niño events on weather patterns years in advance.

TOPEX/Poseidon, a joint program of NASA and the

Centre Nationale d'Etudes Spatiales, the French space agency, uses a radar altimeter to precisely measure sea-surface height. Scientists use the TOPEX/Poseidon data to produce global maps of ocean topography, which then can be used to identify Rossby waves.

TOPEX/Poseidon is part of NASA's Mission to Planet Earth, a coordinated, long-term research program to study the Earth as a global system. TOPEX/Poseidon's sea-surface height data are essential to a better understanding of the role oceans play in regulating global

climate, one of the least understood areas of climate research.

The Jet Propulsion Laboratory manages the U.S. portion of the TOPEX/Poseidon mission for NASA.

An image to accompany this release is available to news media representatives by calling the Imaging Branch on 202/358-1900. Photo numbers are:

B&W — 96-H-217, Color — 96-HC-217. ■

Robotic Aircraft for Earth Science Shipped for First Flight Test

— (excerpted from NASA Press Release number 96-85)

A prototype robotic aircraft called Theseus, with potentially unique abilities to support NASA's Mission to Planet Earth enterprise, has been shipped to California to be prepared for its first test flight.

Theseus is built for NASA under an innovative, \$4.9 million fixed-price contract by Aurora Flight Sciences Corp., Fairmont, WV, and its partners at two West Virginia universities. The twin-engine, uncrewed vehicle has a 143 foot wingspan, and is constructed largely from composite materials. Powered by two 80 horsepower, turbocharged piston engines that drive twin 9-foot diameter propellers, Theseus is designed to fly autonomously at high altitudes, with take off and landing under the active control of a ground-based pilot viewing a video screen.

High-speed taxi testing of Theseus at NASA's Dryden Flight Research Center, Edwards, CA, is scheduled to begin in mid-May, with first flight by late June, according to Kevin Niewoehner, NASA Theseus project manager.

NASA's Office of Mission to Planet Earth is currently developing a long-term strategy for the use of robotic research aircraft. If the demonstration flight of Theseus is successful, it would become a candidate for participation in this effort.

Work on Theseus began formally in June 1994, less than two years ago. "Theseus represents a highly productive partnership between the government, the private sector, and the academic community, focused on rapid prototyping, tightly controlled budgets and cost-sharing," Niewoehner said.

With the potential ability to carry 700 pounds of science instruments to altitudes above 60,000 feet for durations of greater than 24 hours, Theseus is intended to support research in areas such as stratospheric ozone depletion and the atmospheric effects of future high-speed civil transport aircraft engines. Instruments carried aboard Theseus also would be able to validate satellite-based global environmental change measurements made by NASA's planned Earth Observing System.

In addition to these scientific missions, Theseus derived vehicles are expected to have applications in commercial remote sensing and as telecommunications relay platforms, according to John Langford, President of Aurora Flight Sciences. "We can envision a small fleet of vehicles based on Theseus, with flexible payloads and flight times," Langford said.

Aurora Flight Sciences' partners in the development of Theseus include West Virginia University, Morgantown, WV, and Fairmont State College, Fairmont, WV.

NASA press releases and other information are available automatically by sending an Internet electronic mail message to domo@hq.nasa.gov. In the body of the message (not the subject line) users should type the words "**subscribe press-release**" (no quotes). The system will reply with a confirmation via E-mail of each subscription. A second automatic message will include additional information on the service. NASA releases also are available via CompuServe using the command GONASA. ■

Low-Cost Aircraft Navigation System to Aid Global Climate Change Studies

— **Douglas Isbell**, Headquarters, Washington, DC. (Phone: 202/358-1753)

— **Keith Koehler**, Wallops Flight Facility, Wallops Island, VA (Phone: 804/824-1579)

RELEASE: 96-99

A low-cost aircraft navigational system developed by NASA is making it possible for scientists to make precise maps of ice sheets that should yield valuable data on the potential effects of global climate change.

The system, which uses a personal computer to provide navigational data to the cockpit, allows aircraft pilots to fly flight paths to an accuracy of one foot. This allows the scientists on board the aircraft to map the icy terrain below to an accuracy of 4 inches.

NASA and university researchers today began their sixth mission since 1991 to map the ice sheets of Greenland. These missions are providing researchers with a baseline set of measurements to help them better understand glacial changes that may be due to global climate change.

The new navigation system that is aiding these researchers took less than six months to develop, according to Wayne Wright, system developer at the NASA Goddard Space Flight Center's Wallops Flight Facility, Wallops Island, VA. The system currently uses an IBM-compatible 486 personal computer, but it can be installed in an aircraft using a lap-top computer. "The total cost of the system is less than \$3,000," Wright said.

A receiver in the aircraft tuned to the Global Positioning System of orbiting satellites acquires precise position information and then compares these readings to a predetermined flight path. The navigation system then generates steering signals that are sent to the autopilot to direct the aircraft toward its optimal path.

In addition, the system presents an aircraft position display to the pilot. This display allows the pilot to determine if the aircraft is right or left of the flight path centerline to within one foot. The system also can show the pilot position data on a larger scale, or the "big picture," such as the entire flight path.

"The system can be used on other aircraft-based Earth science missions to map varied terrain such as volcanoes and coastlines," Wright said.

NASA pilot Rich Rogers compares using the navigational system to interacting with an aircraft piloting video game. "Flying science 'lines' requires great precision, and is both challenging and fun at the same time," Rogers said. "Close coordination between the pilots, the aircraft flight crew, and science team is needed to successfully operate the navigation system and accomplish the Greenland mission," he added.

NASA ice mapping project scientist Bill Krabill calls the system "absolutely critical to be able to re-fly flight lines with a tolerance of 150 feet," which is the scientific requirement. "It is the only means by which this project can be properly accomplished."

"In fact, the navigational system allows the aircraft to be flown within approximately 20 feet of previously measured points on the ice sheets," Wright said. This enables the researchers to both gather accurate measurements at a single data point and to record any regional changes from previous flights.

The current mission will include mapping previous data points over Greenland and new data points over Iceland and Spitsbergen. Points on the northern coast of Greenland are of particular interest because other satellite data indicate there is a possible decrease in the ice sheet's elevation, Krabill said.

It has been estimated that a 10-inch decrease in the average height of the central Greenland ice sheet would result in a 0.04 inch increase in sea level of the world's oceans.

During the mission, which runs from mid-May to mid-June, a P-3B aircraft from Wallops will carry four instru-

ments for mapping the ice sheets. The instruments include a laser ranging system from Wallops called the Airborne Topographic Mapper I (ATM I), a profiling laser system from Goddard, and an ice-penetrating radar from the University of Kansas in Lawrence. The fourth instrument, still under development, is a smaller version of ATM I. The 400-pound ATM II is approximately half the size of the ATM I.

Researchers located on the ice in Greenland will conduct ground truth studies beneath the flight path of the aircraft to verify the airborne data. The field team includes researchers from Ohio State University in Columbus, the University of Arizona in Tucson, and the University of Nebraska in Lincoln.

The ice mapping program is conducted by Wallops for NASA's Office of Mission to Planet Earth, Washington, DC. ■

Approach to Flexibility in EOSDIS Data Format Standards

— **H. K. Ramapriyan** (Rama.Ramapriyan@gsfc.nasa.gov) or (rama@ulabsgi.gsfc.nasa.gov), ESDIS Project, Code 505, NASA GSFC

It is the intent of NASA's Earth Science Data and Information (ESDIS) Project to establish, maintain, and evolve data standards to support interoperability across Earth science disciplines, to improve and promote easy access to science data, and to empower users and developers of Earth science software and tools. The ESDIS Project believes that Earth Observation System Data and Information System (EOSDIS) support for a minimal set of data format standards supports this intent. The recent rapid growth of the World Wide Web, a system that empowers users and provides an environment that promotes dynamic evolution by adherence to a few basic data standards, validates this purpose.

The ESDIS Project, after years of review and extensive prototyping, established HDF and conventions for geolocated data known as HDF EOS as its baseline data format standard. The ESDIS Project continues to support HDF EOS as its baseline standard data format for new products and for community-directed heritage data upgrades. As EOSDIS's baseline standard, HDF EOS will be fully supported by the ESDIS Project with multi-platform read-and-write libraries and tools, updates to

correct deficiencies, and continued development to make it the best solution for the majority of EOSDIS data. The specification for HDF EOS is accessible from the World Wide Web at <http://eos.nasa.gov/esdis/InfoArch>.

Heritage Data Upgrades

Upgrades of heritage data into the HDF format are based on the EOSDIS Version 0 data migration plans being developed at the direction of the EOSDIS Distributed Active Archive Centers (DAACs) in consultation with their user communities. Where the DAACs and their user communities desire HDF upgrades, they will be performed on a priority basis determined by the user communities. Where the DAACs and their user communities do not desire such upgrades, native formats will be retained for the old data sets after migration.

New Data Products

The ESDIS Project levies no data format requirements on data systems that are not part of NASA's Mission to

Planet Earth Program. Data brought into the EOSDIS system for archive are preferred to be HDF EOS (as EOSDIS can provide a higher level of distribution and access service for those products). EOSDIS, however, has always had, and will continue to have the ability to support “native” format data with inventory search and data delivery at the file level, and will accept data in those formats. However, the ESDIS Project will not generally fund an upgrade in services for “native” or other non-HDF EOS format data sets.

The ESDIS Project has established EOSDIS Core System (ECS) requirements to support conversion of a limited number of formats for ingest and distribution. These are identified and handled on a case-by-case basis.

Supporting Evolution

EOSDIS is designed to support evolutionary change and can evolve from HDF EOS for production and archive when and if better methodologies can feasibly support the technical requirements. To ensure that evolution can take place, a change process is now in place and is detailed in the following paragraphs.

Change Process - Identifying Alternatives

In consultation with, and representing the user community, the DAACs may determine what alternative formats should be supported, based on DAAC systems engineering analysis of the need. ESDIS expects the DAACs themselves to initiate this effort. Data Producers who wish to propose alternative formats will work with their host DAAC to accomplish the required system engineering analysis.

Where the science community strongly desires consideration of an alternative format, but is not represented by a DAAC, those users should contact the ESDIS Project and request that the ESDIS Project initiate DAAC or Project analysis of an alternative. Adoption of a user-initiated alternative will follow the same process as a DAAC-initiated alternative.

Change Process - White Paper

To substantiate the need for an alternative format the DAAC or Data Producer will develop and submit to the ESDIS Project a white paper defining and selecting an alternative format and demonstrating an important

technical need or resource savings within the Earth science community. The white paper should be coordinated with other DAACs and Data Producers to determine like need. Collaboration among DAACs and Data Producers is recommended.

The white paper should provide a life-cycle cost estimate for the support of the alternative format pinpointing what ECS components will be required to integrate the alternative format and showing estimated costs or cost savings associated with needed ECS tailoring, development, and maintenance. The white paper should also show a timeline of events that can be worked into current mission deadlines. The ESDIS Project will support cost and schedule analysis where needed. The white paper should show limitations of already supported formats which preclude their use. The white paper should also address collection, ingest, access, and usage of metadata required by EOSDIS to meet the requirements of the proposed alternative format.

Change Process - Consultation

The alternative format must have technical and scientific justification. To validate scientific justification, the Project will consult with relevant Project Scientists and Instrument teams.

Change Process - Resources

The ESDIS Project will accept any DAAC-determined alternate format as long as it can be supported by a combination of: application of DAAC-unique funds taken as an aggregate across all DAACs; the ECS Contractor currently levied requirements for conversion; and savings based on using the alternative format.

Change Process - Prioritization

The ESDIS Project will support alternative formats to the extent they are needed by the science community and are higher priority than other EOSDIS services or functions.

If the overall collection of formats desired by the DAACs (representing the user community) and Data Producers is not supportable, or impacts the goal of interoperability, then the ESDIS Project will prioritize them based on DAAC, User Community, and Data Producer feedback. The final prioritization will be published to allow impacted parties to provide feedback and comment. ■

Space Radar Reveals Ancient Segment of China's Great Wall

— **Douglas Isbell**, Headquarters, Washington, DC. (Phone: 202/358-1753)

— **Mary Hardin**, Jet Propulsion Laboratory, Pasadena, CA. (Phone: 818/354-5011)

RELEASE: 96-77

Scientists in China are using space radar images to locate and study two generations of the Great Wall of China that have been eroded and buried in place by centuries of blowing sand.

"In the images, we can recognize two different dynasties that built the Great Wall. One was built in the Ming Dynasty and is about 600 years old. The other was built during the Sui Dynasty and is more than 1,000 years old," said Dr. Guo Huadong, a SIR-C/X-SAR science team member from the Institute of Remote Sensing Applications at the Chinese Academy of Sciences in Beijing.

The radar images were taken by the Spaceborne Imaging Radar C/X-band Synthetic Aperture Radar (SIR-C/X-SAR) that flew on the Space Shuttle Endeavour in April and October of 1994.

The Great Wall is one of several archeological sites around the world being studied through the use of the space radar images. Other sites include Angkor, Cambodia, the Lost City of Ubar in Oman, and the Silk Road along the desert of northwestern China.

"Archeology wasn't one of our original science objectives, but the imaging radar data has been found to be very useful for this type of research. It's an exciting spin-off," said Dr. Diane Evans, the SIR-C project scientist at NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA. Evans was discussing the radar's role in archeological research at a symposium at the University of Florida, Gainesville. The week-long conference was organized by the World Monuments Fund, the Royal Angkor Foundation, and the university, with support from the J.M. Kaplan Fund and the Samuel H. Kress Foundation.

The Great Wall of China dates back to the 3rd century B.C., when it was built to protect the country from northern invaders. The wall, which spans more than

1,860 miles, has been periodically rebuilt and modified throughout history by each reigning dynasty.

The scientists are studying a segment of the wall about 430 miles west of Beijing in a remote region of the north-central China desert. The most recent version of the wall was built by the Ming Dynasty during the 14th century, and it is clearly visible both on the ground and in the radar data. An older version, built during the Sui Dynasty, runs parallel to the present wall.

"Part of the wall is visible on the surface, but part of it is buried by the strong winds that blow sand dunes across this part of the desert," Guo said. "In this region the wall was made out of loose soil and mud, not bricks or rocks. Usually you cannot find these segments even if you go there, so the radar data are helping to show us the whole wall."

"Using radar to look at archeological structures has been very powerful because the radar is sensitive to vertical structures, such as walls. Even if they are highly eroded, like these segments of the Great Wall, the radar is able to capture a reflection off it and the wall shows up quite clearly in the radar image," said Dr. Jeffrey J. Plaut, the SIR-C experiment scientist at JPL. "This is a part of the world where we can also take advantage of the radar's ability to penetrate through layers of dry sand to image buried structures. The multiple channels of the SIR-C/X-SAR system increase our ability to detect different kinds of structures that a single-channel radar system would not see."

The Spaceborne Imaging Radar project is managed by JPL for NASA's Office of Mission to Planet Earth, Washington, DC. SIR-C/X-SAR is a joint mission of the United States, German, and Italian space agencies.

Radar images of the Great Wall at various resolutions are available over the Internet on the JPL SIR-C/X-SAR home page at the following URL: <http://www.jpl.nasa.gov/sircxsar/> ■

NOAA Ready to Distribute Data from Japanese Environmental Satellite

— (excerpted from Press Release number 96-34)

The Commerce Department's National Oceanic and Atmospheric Administration is ready to acquire and distribute vital information about the oceans from the first of a new series of environmental satellites to be launched by Japan in August, the agency announced.

The data will be distributed electronically to users in the United States, Japan, and other countries around the world for use in weather forecasting and environmental monitoring.

The Advanced Earth Observing Satellite (ADEOS), to be launched by the National Space Development Agency of Japan, will observe and monitor the global environment. NOAA, which has enhanced its processing and communications systems to support the data, will use and share data products from several of the instruments.

"NOAA will be a near-real-time user of data from the NASA Scatterometer (NSCAT) and NASDA's Ocean Color and Temperature Scanner," said Helen Wood, NOAA's Director of Satellite Data Processing and Distribution. "Access to these data will provide U.S. and other users with enhanced environmental monitoring capabilities through NOAA's ocean remote-sensing program."

The scatterometer will measure wind speed and direction over the ocean. These data are important in short-term weather warnings and forecasts and will play a key role in our ability to understand and predict complex global weather patterns and climate systems.

Ocean color data will play a vital role in protecting coastal ecosystems and building sustainable fisheries. The data are useful in monitoring pollution and river discharge, detecting and monitoring noxious algal blooms, and locating optimum fishing grounds.

"NOAA looks forward to the upcoming launch of ADEOS and the important new data stream," said D. James Baker, Under Secretary of Commerce for Oceans and Atmosphere. NOAA is a partner in the implementation and operation of the ADEOS program. The National Space Development Agency of Japan and NASA signed an agreement on ADEOS in October 1994.

In addition to NSCAT, NASA is also flying a Total Ozone Mapping Spectrometer (TOMS) aboard ADEOS. TOMS will measure ozone concentration in the atmosphere. NOAA is evaluating TOMS data for possible use in volcanic ash tracking in support of aviation safety.

The satellite will also carry other instruments provided by Japanese and French agencies.

Further information on environmental satellites can be found on the World Wide Web at:
http://www.nnic.noaa.gov/SOCC/SOCC_Home.html ■



Mission to Planet Earth Technology Aids in Fire Fighting

— Information excerpted from NASA press release 95-116.

A NASA research aircraft played a critical role in fighting a major fire that threatened life and property in the Scottsdale and Fountain Hills areas of Arizona last summer. The plane, a C-130B based at Ames Research Center (ARC) was in the area collecting geological data for Mission to Planet Earth. The plane was equipped with a host of data-gathering devices and photographic equipment, including thermal scanners able to penetrate thick smoke and clouds.

Observers on the plane saw the fire while on approach to Phoenix on July 8. Mission manager Chris Jennison obtained clearance from ARC to document the fire and assist local emergency management personnel. Three high-altitude flights with the ability to cover a wide area were immediately flown and data were recorded on videotape. These tapes were delivered to Scottsdale officials upon arrival at Sky Harbor airport for use by the incident commander, Jeff Whitney. Subsequently, additional help with flights before dawn on July 9 were requested. Because the on-board instruments had the capability to penetrate both smoke and darkness, and peer into hidden canyons, local mapping experts and other observers aboard the C-130B were able to record changes and significant events within the fire perimeter and transfer that information to command maps for rapid distribution to fire-fighting personnel. The aircraft provided visual evidence of the existence and location of dangerous remaining hotspots on its black-and-white video monitors.

“NASA played a direct role in controlling the 23,000 acre fire that threatened the communities of Scottsdale and Fountain Hills this weekend,” Wilson Orr of the Scottsdale City Manager’s Office said in a letter to NASA Administrator Dan Goldin dated July 12. “The C-130 based at Ames Research Center was made available with its unique instrumentation capabilities, which include infrared sensors capable of fire detection. This use of

Mission to Planet Earth resources to help us manage local emergencies for the preservation of life and property is a significant return on taxpayer investment. We appreciate the practical value of this program.”

“With pre-dawn flights, we were able to accurately identify the fire perimeter showing overnight changes in fire intensity and spread,” Orr said. “This was invaluable information in deploying limited resources to protect threatened life and property. The C-130 crew also identified a two-mile change in the fire front which let the fire team deploy this morning with greater accuracy and safety.” ■

What's New? What's New? What's New? What's New?

Education Page/The EOS Educator's Visual Materials Package

Recently, we added a link to the Lorain County Joint Vocational School for ordering the EOS Educator's Visual Materials Package: http://sps0.gsfc.nasa.gov/eos_edu.pack/toc.html.

National Science Teacher's Association WWW homepage

URL: <http://www.nsta.org/misg/>

http://sps0.gsfc.nasa.gov/sps0_homepage.html

Science Calendar

- August 12-14 MISR Science Team Meeting, JPL, Pasadena, CA. Contact Stuart McMuldloch (stuart@jpl.nasa.gov) or (818) 354-3420.
- August 27 SAGE III Science Team Meeting, NOAA, Boulder, CO. Contact William P. Chu (w.p.chu@larc.nasa.gov) at LaRC, .
- September 17-19 International Land-Surface Temperature Workshop, University of California at Santa Barbara, CA. Contact Zhengming Wan (wan@icess.ucsb.edu) or Fax: (805) 893-2578.
- September 18-20 CERES Science Team Meeting, NASA/LaRC. Contact Theresa Hedgepeth (t.c.hedgepeth@larc.nasa.gov) or (804) 825-0001.
- October 29-31 AIRS Science Team Meeting, University of Maryland, Baltimore Campus. Contact George Aumann (hha@airs1.jpl.nasa.gov) or (818) 354-6865.
- December 2-6 12th ASTER Science Team Meeting — Pacifico Yokohama Conference Center, Yokohama, Japan. Contact H. Tsu (tsu@ersdac.or.jp) at (+011+81-3-3533-9380), or Anne Kahle (anne@aster.jpl.nasa.gov) at (818) 354-7265.

Global Change Calendar

- August 4-9 SPIE Annual Meeting, Denver, CO. Contact Diane Robinson, Tel. (363) 676-3290 Ext. 357, e-mail: diane@spie.org.
- August 20-22 William T. Pecora Memorial Remote Sensing Symposium, "Human Interaction with the Environment - Perspectives from Space," Sioux Falls, SD. Contact Gary Johnson (pecora13@edcserver1.cr.usgs.gov), Technical Program Chair.
- September 14-18 National States Geographic Information Council, 6th Annual Meeting, Doubletree Hotel, Tucson, Arizona. Contact Ammie Collins, Tel. (603) 643-1600, Fax (603) 643-1444, e-mail: NSGIC@AOL.COM.
- September 23-27 European Symposium on Satellite Remote Sensing III, Taormina, Italy and Conference on Sensors, Systems and Next Generation Satellites. Call for Papers. Contact Steve Neeck, Tel. (301) 286-3017, e-mail: steve.p.neeck.1@gsfc.nasa.gov
- November 4-7 ECO-INFORMA '96 — Global Networks for Environmental Information: Bridging the Gap Between Knowledge and Application, Lake Buena Vista, FL. Contact Robert Rogers, Tel. (313) 994-1200, ext. 3234, Fax (313) 994-5123. In Europe, contact Otto Hutzinger, (+49) 921-552-245 or 155.
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- March 17-19 Fourth International Conference on Remote Sensing for Marine and Coastal Environments, Orlando, Florida. For more information contact ERIM/Marine Conference, P.O. Box 134001, Ann Arbor, MI 48113-4001. Tel. (313) 994-1200, ext. 3234. Fax: (313) 994-5123. e-mail: wallman@erim.org. WWW URL: <http://www.erim.org/CONF/conf.html>
- August 4-8 1997 International Geoscience and Remote Sensing Symposium, Singapore. Call For Papers — Abstract submission deadline is January 13, 1997. For more information contact IEEE/GRSS, 2610 Lakeway Drive, Seabrook, TX 77586, U.S.A., e-mail: tstein@phoenix.net, Tel. (713) 291-9222; Fax: (713) 291-9224.

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