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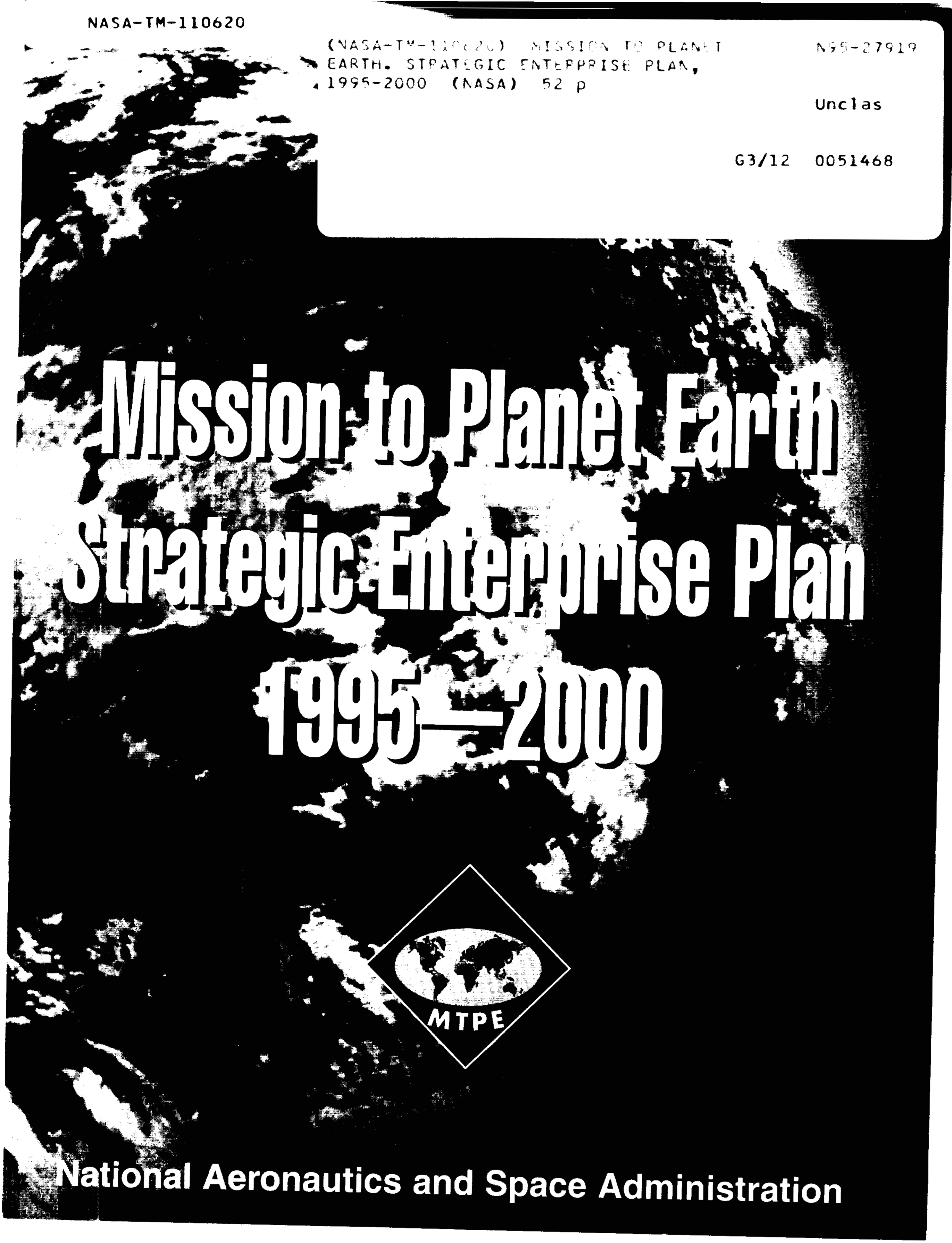

Mission to Planet Earth Strategic Enterprise Plan 1995—2000

MTPE

National Aeronautics and Space Administration

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MTPE

May 1995

To Our Team Members and Customers:

"Mission to Planet Earth" has its origin in "Leadership and America's Future in Space," a 1987 report to the NASA Administrator recommending the direction of the agency for the next decades. The "mission" carries an aura of purpose, planning, and team effort. For us, "mission" also connotes a strong ethical dimension to our work. We are providing the scientific understanding necessary for wise decisions in our stewardship of Planet Earth, both for our own and future generations. Natural environmental changes have always influenced human activities, and now human activities are also placing stresses on the global environment. Our civilization's power to change the environment carries with it the responsibility to wield that power with understanding, and with the future in view.

The Mission to Planet Earth (MTPE) Enterprise is a significant part of the national investment in fulfilling the responsibility to wield our power with understanding. In monetary terms, MTPE is about two-thirds of the inter-agency U.S. Global Change Research Program. The return to the American taxpayer for this investment must be continually reaffirmed, especially in stringent budgetary times like these. We expect to review the objectives and approaches of the program in these terms as we move forward. The connection of our work to national policy is critical and is supported by our participation on the Committee on Environment and Natural Resources of the President's National Science and Technology Council.

The ultimate product of Mission to Planet Earth is education; people are, after all, agents of global change and both benefactors and beneficiaries of MTPE research. Education and outreach activities have always been important products of NASA programs; in this Plan, we have elevated these activities to a Goal, on a par with spacecraft launches and scientific discovery. A wealth of information on the environment has already been collected by MTPE and is available on-line. I invite readers to view and use this information, via the Internet addresses contained in the Appendix to this Plan.

Mission to Planet Earth is a long-term endeavor that must be sustained in a complex scientific, technical, and political environment. To help us set our course, we enlist external expertise and recently have formed our Earth System Science and Applications Advisory Committee. We will regularly respond to the advice of this Committee in the formulation and evolution of this Plan. This Plan is a living document; it will be updated annually. As our team members and customers, we value your input.

Charles F. Kennel

Charles F. Kennel
Associate Administrator
Office of Mission to Planet Earth

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Section I
Introduction

Mission to Planet Earth (MTPE) provides long-term understanding of the Earth system needed to protect and improve our global environment, now and for future generations. Governments around the world seek environmental policies based upon the most reliable scientific understanding. The unique vantage point of space provides information about the Earth's land, atmosphere, ice, oceans, and biota that is obtainable in no other way. Today's program is laying the foundation for understanding and predicting of climatic processes. In concert with the global research community, the MTPE Enterprise is leading to the understanding needed to support the complex environmental policy decisions that lie ahead.

This MTPE Strategic Enterprise Plan states how NASA intends to meet its responsibility to the Nation for developing a long-term, integrated program of environmental observation in support of informed decision-making. This Plan implements the NASA Strategic Plan for the MTPE Enterprise; it is the first version of a rolling 5-year plan that will be updated annually. It is consistent with the interagency program developed by the Committee on Environment and Natural Resources of the National Science and Technology Council and implemented in large part through the U.S. Global Change Research Program.

Mission to Planet Earth is both an intellectual concept and a program. As an intellectual concept, MTPE seeks to develop an understanding of the changes in our global environment that is based on an integrated system approach. Thus MTPE is critically sensitive to the linkages between the traditional disciplines of Earth and atmospheric sciences. As a program, MTPE seeks to provide a research and observational architecture capable of providing policy makers and the public with the information and some of the analytic and predictive tools they will need as they consider whether and how to avoid, mitigate, or adapt to changes in the natural system.

Mission to Planet Earth was and is founded on a number of fundamental scientific issues; these are described in Section II *(Scientific Foundation).* The *Mission* (Section III) makes clear our destination and purposes. Next we state our *Principles of Operation*, the ethical and quality assurance standards for our performance. An analysis of our *Customer Base* follows, to ensure that we are delivering the right products and services. The *Internal and External Assessments* and the *Assumptions* sections inform us of the context in which we work. The *Goals, Objectives, and Strategies* in Section VIII lay out a plan of attack, providing specific objectives and strategies for the next 5 years. The *Linkages* section shows how our objectives and strategies tie us together with NASA's other Strategic Enterprises. A brief *Summary* reminds us that all this activity is directed toward a purpose.

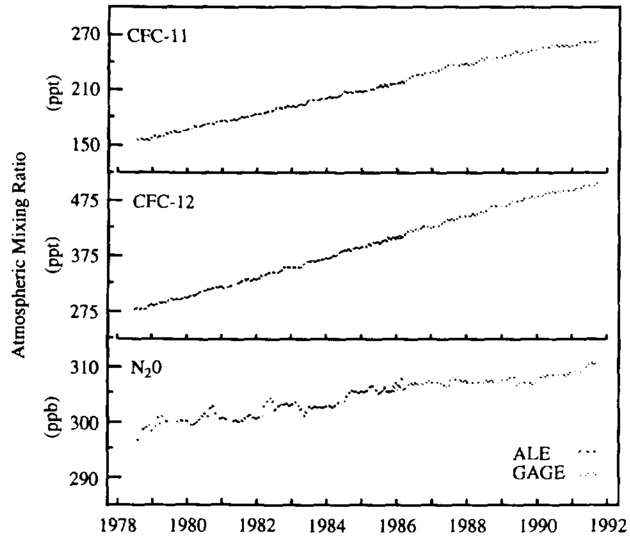
This MTPE Strategic Enterprise Plan, like the program itself, is designed to be both living and active. The program is committed to change and evolution over time as scientific understanding progresses and leads in new directions, as technology permits greater robustness and flexibility, and as our international and interagency partnerships mature. The program will also change as our customer needs dictate. MTPE is fundamentally a science program with significant application to policy makers, education, commercial enterprises, and the general public. MTPE will be responsive to those needs. The plan is a living document that will be reviewed annually following the update of the NASA Strategic Plan, in accordance with the NASA Strategic Management Handbook. It is an active document that forms the basis for program prioritization and budget planning. Ultimately, the strategies laid out in the *Goals* section will be subdivided into tasks to be allocated to specific individuals for accomplishment.

Section II
Scientific Foundation

The scientific issues of concern to MTPE are among the most complex and most relevant of any major scientific research program. The basic scientific goal of MTPE is to understand the Earth as a coupled system, including the effects and couplings of the solid earth, land surface, oceans, atmosphere, and biota. This may be the largest interdisciplinary effort ever undertaken. Results of MTPE science are critical to the development of sound global environmental policy, necessary for the long-term sustenance of life on Earth. MTPE science can also play a critical role in minimizing hazards to human life and property from natural events such as earthquakes, volcanic eruptions, severe storms, and floods.

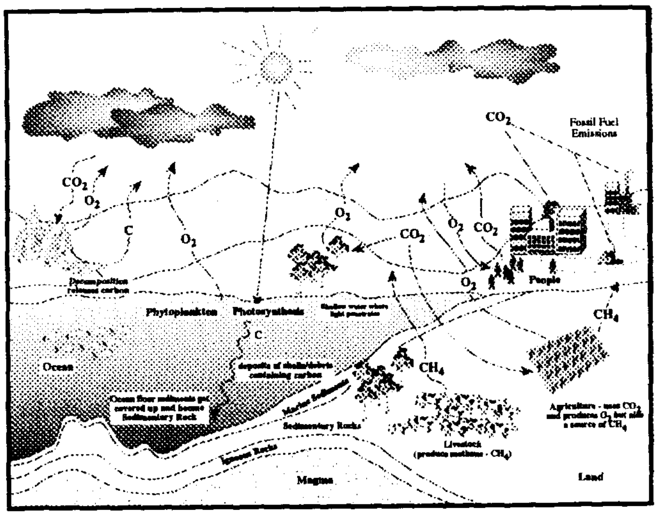
There are many examples that illustrate the importance of MTPE science to global environmental issues. A combination of ground- and space-based instruments has shown a persistent, long-term growth in the concentration of many radiatively and chemically active compounds in the atmosphere. These include carbon dioxide, which has important radiative effects, and others, such as methane, nitrous oxide, and the chlorofluorocarbons, which have both radiative and chemical effects. For many of these, the current concentrations are well outside their historic abundance as determined by ice core records that extend back in time through several ice ages. There is also strong evidence for an increase in global surface temperatures, although it is not large enough to be unambiguously attributed to trace gas accumulations.

Associated with these trace gas changes are changes in stratospheric ozone concentrations, which have been significantly reduced over most of the Earth's surface in the last 20 years. Over Antarctica in the spring, ozone amounts have been almost completely eliminated at some altitudes. This reduction, responsible for the "Antarctic Ozone Hole," has produced short-term increases in ultraviolet radiation at the Earth's surface. The biological implications of this change, as well as the impact of the Antarctic ozone loss on the global ozone budget, are not yet quantified.



Monthly average CFC-11, CFC-12, and N_2O (nitrous oxide) mixing ratios at Barbados.

Land use at the Earth's surface is changing as well. Deforestation and urbanization are changing the emission and sequestration of carbon into the atmosphere, notably in the form of carbon dioxide, while industrial and agricultural activities are affecting atmospheric composition. The oceans respond to changes in atmospheric composition and temperature on many time scales. Changes in atmospheric temperatures may be accompanied by changes in winds and precipitation, which could in turn lead to major changes in the hydrologic fresh water cycle, which could impact the availability of water for agricultural, industrial, and human use. Such changes could range from drought and possible resulting famine on the one hand to floods and runoff damage on the other.



The carbon cycle.

Naturally occurring processes can rapidly and dramatically alter the environment on spatial scales ranging from local to global. A single major flood can transport amounts of sediment or soil that might otherwise take tens of years, while a major volcanic eruption can inject aerosols into the stratosphere that may take several years to settle out and affect global atmospheric temperatures and chemical distributions. The long-term changes in the environment caused by human activity cannot be understood if the short-term changes from naturally occurring processes are not well understood.

In short, understanding climate change on a 10-year time scale requires study of the Earth as an integrated system. The conceptual foundation for this study was laid in the 1980's by the Earth Systems Science Committee of the NASA Advisory Council. This integrated Earth system modeling approach is illustrated in Figure 1.

It is this integrated system view of the Earth, plus the need to collect a consistent set of measurements over a 15-year or longer time scale to span an entire solar cycle and several El Niño events, which has given rise to the overall MTPE science and observational strategy. Currently, MTPE programs each collect data on one or a few of the processes depicted in Figure 1. Separate satellite systems observe land cover change, ocean circulation, and atmospheric trace gas concentration, for example. With some difficulty, these data sets can be linked for the study of coupled processes. Beginning in 1998, MTPE's Earth Observing System (EOS) will start collecting and organizing long-term data sets on the whole range of measurements needed for the study of global climate change, capturing most if not all of the Earth system processes in Figure 1. It is the ability to examine the coupling of atmosphere, ocean, land, and biological processes that will enable scientists to understand the natural and human-induced changes in the global environment.

Section III
Mission

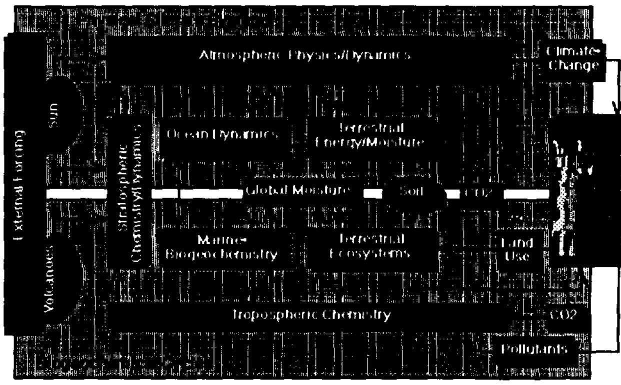
The overall mission of NASA's Mission to Planet Earth Enterprise is to develop understanding of the total Earth system and the effects of natural and human-induced changes on the global environment.

MTPE is NASA's contribution to a broader national and international effort to tackle this enormous task. Nationally, NASA collaborates with the National Oceanic and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), National Science Foundation (NSF), and other agencies on a wide variety of observation and research programs. Much of this national effort is coordinated through the U.S. Global Change Research Program (USGCRP). Internationally, NASA is collaborating with Japan, the European Space Agency (ESA), individual European nations, Russia, and Canada on several key spacecraft and instruments. MTPE participates with many other nations around the globe on programs in every area of environmental research, and is active in such international bodies as the Intergovernmental Panel on Climate Change (IPCC), the World Climate Research Program (WCRP), and the International Geosphere-Biosphere Program (IGBP).

The MTPE Enterprise is pioneering the study of global change. Today's program is laying the foundation for a long-term international observation system and for predicting changes in the land, atmosphere, ice, oceans, and biota.

Earth System Science has strong elements in the atmospheric, oceanic, hydrological, ecological, and solid Earth sciences, but integrates them in such a way that the full range of couplings in the Earth system can be addressed. Earth System Science is a young discipline, and MTPE investigators and programs make a significant contribution to its development as a field of scientific endeavor. Comprehensive measurements must be made covering the land, atmosphere, ice, bodies of water, and biota. Data are required for extended periods of time, due to the long-time constants associated with the changing Earth system. Data are also required to respond to specific policy issues and to address local and regional concerns. The MTPE Enterprise will ensure that the issues are addressed with scientifically relevant data and that critical assessments are provided on an objective basis.

Global Climate Modeling



Integrated Model of the Earth System for Decadal Climate Prediction

The MTPE Enterprise develops Earth-observing spacecraft and instruments, acquires, processes, and analyzes data, and disseminates these data, information, and scientific understanding throughout the world.

NASA brings to Earth System Science the ability to observe the Earth globally from space. The collection of global data characterizing the Earth system is a cornerstone of the MTPE Enterprise. Space-based observations are complemented with aircraft, balloon, and ground-based measurements. Data gathering and analysis must be accompanied by numerical modeling, which provides the framework for the interpretation of data and for making quantitative predictions of the global environment with regional resolution. Resultant data, information, and scientific understanding must be provided to all classes of users, including but not limited to the Earth science community. (The customers for MTPE are discussed in Section V.) Using these tools, NASA supports scientific assessment and predictions of our environmental future, thereby providing the basis for informed decision-making.

MTPE products contribute to public education and form the basis for training future generations of scientists and engineers.

Consistent with the mandate of the Space Act, providing for the widest practicable and appropriate dissemination of information concerning the environment is a fundamental responsibility of the Enterprise. MTPE has a responsibility to make the information that it collects and processes available in a form meaningful to ordinary citizens, so they may better understand their environment.

The training of future generations of Earth scientists fully representing the diversity of the United States is facilitated by the data and ideas developed by MTPE. Hopefully, they will be inspired by its vision.

The MTPE Enterprise develops and infuses technologies to enable new scientific investigations and contribute to American economic growth and competitiveness.

Methods used by MTPE to obtain, interpret, and distribute Earth system data and information must be cost-effective. MTPE uses currently available technology and works to develop and infuse new technologies particularly in environmental measurement and information systems. In many areas, the scientific requirements drive us to the cutting edge of technology.

MTPE investigators work to develop technologies and products that have multiple uses and can find markets that will help ensure continued economic competitiveness for the United States. This effort is closely coordinated with NASA's Space Technology Enterprise.

Section IV
Principles of Operation

Seven basic principles have been crucial in guiding the process that developed our strategy for implementing the MTPE Mission.

A Balanced Program: Using NASA's special capabilities, MTPE seeks to maintain a balanced program across the Earth science disciplines and among the various MTPE program elements. We strive to achieve balance in the following key areas:

- Investment in research and analysis compared with total program investment
- In situ observations with space-based observations
- Nonclimate research with climate research, consistent with Earth system science goals
- Science-drivers with satellite program-drivers in preserving program flexibility
- Long-term science questions with short-term policy demands
- Long-term data continuity with technology development and other mission initiatives
- Modeling with disciplinary research efforts

Both elements of each area are essential, and a proper balance is challenging to define and maintain given the relatively long development times and high costs of space missions. In most cases, this does not imply equivalent resource allocations, and the balance points move with time. Prioritization is essential, not only to order goals and objectives in times of tightening budgets and changing national needs, but to integrate the needs of policy makers and scientists.

External Review: We recognize that most of our customers and much of the required expertise are outside NASA. External advice must be solicited, and conflicting or competing advice reconciled. A wide range of reviews is conducted by the National Academy of Sciences, through among others the Space Studies Board. We will work closely with the Academy's or a new Board on Sustainable Development, which will govern its environment and natural resources work. We have established an Earth Systems Science and Applications Advisory Committee to work closely with MTPE managers to ensure that our program planning and direction are consistent with our mission and national priorities.

Peer Review as the Foundation for Program Selection: Program selection based upon competitive, peer reviewed proposals is the foundation on which the MTPE science program is built. Peer review is recognized among science policy makers and practitioners as fundamental to ensuring a world-class program. Scientific and technical peer review provides the best critical evaluation of ideas and fosters the best use of limited research resources. The same peer review process is applied to all MTPE research efforts, whether they come from within NASA or from the external community.

World-Class Science and Technology Content: Striving for program excellence—doing the right research and doing it objectively and well—is a guiding focus of MTPE. To do this, MTPE continues to strive for mission success and supports NASA's safety, reliability, and quality processes. Our standard for performance is nothing less than the best in the world.

Diversity: MTPE supports the development of a diverse work force and Earth science community. Diversity is a fundamental ethical dimension of global stewardship. Diversity brings to MTPE the strength of multiple viewpoints. Innovation within MTPE includes the personnel resources involved in the work force. The MTPE Enterprise must reflect the face of America.

National and International Policy Relevance: MTPE originated from a national need for a more reliable and predictable understanding of the changes occurring in our global environment; as a result, MTPE must be acutely attuned to the need for providing products that serve the national and international policy-making community. Strong links between MTPE and the national and international policy-making community are key.

Partnership with Other Domestic and International Organizations: Global environmental concerns require a global response. MTPE is an integral part of a cooperative interagency and international research endeavor, with all parties making essential contributions. The global nature of the issues involved, the critical need for credibility in data, and the increasingly constrained resource environment within which all parties operate mandate that MTPE foster partnerships and alliances across organizational and national boundaries. This only adds urgency to a synergistic approach in which the talent and resources of many countries are coordinated to address a shared problem. MTPE builds upon decades of international cooperation in the conduct of space and aeronautical research activities to strengthen the content of the program, leveraging its investment with over 60 significant agreements involving more than 20 other countries. International partnerships also foster consensus on the results and implications of the research for and the support to international scientific assessments.

Section V
Customer Base

MTPE's broad and highly diverse customer base includes science discipline researchers, policy makers at the Federal, State, and local levels, educators, private sector firms, and individual citizens. MTPE has customers not only nationwide, but worldwide, with data both produced and used by space agencies and researchers from many nations.

Our customer base can be usefully categorized into five types: Policy Makers, Environmental Decision Makers, Government and External Science Communities, Consumers of Information, and Consumers of Advanced Technologies. Each of these can be further subdivided into customer blocks. Definitions for each of these, as well as for the product types delivered, are provided in Appendix 2. A matrix displaying the major linkages between customer and MTPE product categories is provided in Figure 2.

Customer Matrix

	Product Levels Required							
	Integrated Assessments	**Risk Assessments**	**Forecasts**	**Understanding**	**Analyses**	**Data**	**Technology**	**Education and Training**
Policy Makers								
Administration	▨	░						░
Congress	▨	░	░					░
State and Local Government	▨	▨	▨	▨	▨	░	░	░
Environmental Decision Makers								
Regulatory Agencies		░	▨	▨	▨			
Industry			▨			▨	▨	▨
Agricultural/Industrial Managers	▨	░	▨	▨	▨	░		░
Natural Resource Managers	▨		▨			░		░
Govt. & External Science Comm.								
Earth Science Community	▨		▨	▨	▨	▨		
Non-Earth Science Community				▨	▨	▨	▨	▨
Consumers of Information								
General Public			░	▨	▨			▨
International Users	▨	░	▨	▨	▨	▨		░
Operational Users	░		▨	░		▨		
Education and Teachers				▨		░		▨
Value-Added Industry				▨		▨	▨	▨
Consumers of Advanced Tech.								
Commercial					░	░	▨	
Government Agencies					▨		▨	

▨ **Indicate the highest perceived demand by customers for particular product levels.**

░ **Indicate a lesser but still significant perceived demand.**

"Policy Makers" are high-level government participants in the Administration, Congress, and State and local offices. This set of customers will establish the policy questions to be answered and, through guidance and funding decisions, determine the direction to be taken for meeting the environmental challenges of the future. These are also the groups who establish the priority of federally sponsored environmental research in the Federal budget. Policy makers rely principally on integrated assessments to help determine the policy relevance of scientific research and the relative urgency of action on key issues.

"Environmental Decision Makers" are government, industry, and other participants whose decisions have significant environmental impact on outside groups. These include regulatory agencies, industrial plant managers, entities charged with responsibility for the stewardship of natural resources, and organizations responsible for enforcement and adjudication. These entities implement the policies set by the Administration and Congress. They require assessments, forecasts, understanding, analyses, technology, and education and training to weigh the consequences of decisions they are called on to make.

"Government and External Science Communities" are the most interactive users of MTPE products. Scientists from government laboratories, universities, and private sector organizations are active participants in MTPE. Some are assisting in the setting of requirements for spacecraft and data systems, and are designing instruments and algorithms. It is this group who will turn MTPE-collected data into understanding, enabling MTPE to serve its other customers.

"Consumers of Information" is the broadest category, encompassing all who use environmental information as an input to their processes of production or decision-making in other activities. This includes the general public, international users, operational users, academia, educators and students, libraries, the media, and value-added firms. These differ from "Environmental Decision Makers" principally in the scale of their activities; this category of customers does not typically make operational decisions on behalf of large groups of employees or colleagues, and this category is not directly responsible to national or international policy makers. The diversity of products required by this group is great, and so is the potential payoff for meeting their needs effectively.

"Consumers of Advanced Technology," by contrast, is a narrower category of customer and is different in kind from the others. These are commercial and governmental entities that find applications unique to their respective missions for the technologies produced by MTPE. In the case of commercial firms, more creative forms of communication are required to make each side aware of the other's needs and to effect the transfer of technology by equitable means. In the case of government entities, established mechanisms exist for them to contract with MTPE for technology development activities. In keeping with the Agency Strategic Plan, the MTPE Strategic Enterprise is not the sole NASA provider to this customer group; close interaction between MTPE and the Space Technology Enterprise is essential.

MTPE identifies policy maker and scientific community needs through the interaction of the U.S. Global Change Research Program and a variety of formal international committees and working groups and through the active involvement of advisory bodies, principally the National Academy of Sciences and the Earth System Science and Applications Advisory Committee. We are in the process of conducting a series of workshops with a broad range of other potential customers to identify their needs and to understand the scope of requirements. The efforts will culminate in the development of a user model that should be established by the end of 1995. In addition, the Earth Observing System Data and Information System (EOSDIS), our principle communication medium with the broadest range of actual data users, is currently distributing data from existing spacecraft and other data sources. Together, these activities will establish a baseline for customer needs that will guide the development of the EOS programs. Over time, MTPE will aggressively pursue understanding of the evolution of needs and will ensure that the system will adapt to satisfy them.

Section VI
Internal and External Assessments

Effective strategic planning requires an objective assessment of the current and future environment in which MTPE operates. MTPE's internal strengths must be evaluated to assess our readiness to carry out our mission. A clear picture of our external opportunities must guide decisions on the investment of our resources. These assessments complement the analysis of our customer base in the preceding section.

Strengths

The two most essential components of success already exist within MTPE. The first is a ***strong sense of mission***—the shared conviction that the work we do is important for the well being of this and future generations. Our mission has a strong ethical component. The second is the ***human and physical resources*** we have to carry out the MTPE program. The scientific, technical, and management expertise resident at NASA field installations, at Headquarters, and in the affiliated academic and industrial institutions is uniquely qualified to carry out this program.

Our programs are ***scientifically important as well as policy-relevant.*** We provide scientific understanding to inform national and international policy development. Our near- and long-term objectives are designed to gather data and carry out research on questions essential in decision makers' and the public's concern for action on issues relating to the Earth's environment.

MTPE continues to receive ***strong support from both the Executive and Legislative branches*** of the Federal government, a pattern that was established in the middle 1980's and has continued to this day. MTPE and the broader USGCRP have benefited from bipartisan support across three successive Administrations.

The MTPE mission is guided by the ***intellectual capital we invest in studying the Earth as an integrated system,*** posing and prioritizing the questions to be addressed, devising the means to do so, and assimilating the results to plan the next steps. MTPE has a strong, healthy interaction with the Earth system science community at large, and has formed a scientific advisory committee to ensure that scientific strategic level advice is provided. MTPE has proven its ability in the funding and management of scientific research.

The ***NASA Strategic Plan*** and the process by which the Agency establishes priorities within that Plan provide essential stability to support an endeavor of long-term spaceflight programs despite the potential for yearly budget-driven perturbations.

Opportunities

MTPE is well-positioned to assume national and international leadership. As the science community increasingly views the Earth as an integrated system, MTPE is focusing its efforts on interdisciplinary, problem-oriented analysis. In so doing, we stimulate research into key environmental questions and interactions, enabling us to provide policy-relevant information to decision makers in this as well as other countries. For example, we have earned worldwide respect for our objective leadership in ozone assessments.

Our investment in observation, archiving, and analysis capabilities secures for MTPE ***leadership in global observations*** of the Earth. We are providing to the world scientific and policy-making communities the most comprehensive data base ever developed on the Earth's ocean surface, atmosphere, and land cover. Pursuit of this avenue of research also establishes a solid foundation for a Global Observing System justified by scientific and operational needs, and for MTPE leadership as a principal system architect. We are also positioned to continue to promote an innovative mix of measurement systems, including Earth probe activities, aircraft programs, and remotely piloted vehicles and unmanned aerospace vehicles, as well as increased investment in mission-focused technology development.

One of the most exciting areas of potential leadership for MTPE is in the incorporation of our data and analysis products into education. Except for targeted activities such as the Graduate Student Fellowship program, our education efforts have been episodic—not organized toward achievement of a strategic objective. Given the enormous relevance of MTPE research to the sustainability and quality of life, ***the possibilities and benefits associated with an integrated education strategy are enormous.***

Similarly, the potential for ***broadened public support for, and community participation in, MTPE also holds out substantial benefits*** if we have a strategy to embrace it. NASA programs have always enjoyed substantial public support. However, the public generally does not view NASA as an environmental agency. We face a lack of understanding of the MTPE purpose and benefits to the general community (i.e., on the part of our customers).

An active outreach strategy will help us inform the public about our contributions to issues they care about. Our outreach strategy must take account of the fact that the intensity of awareness of even the most critical issues in society is not self-sustaining over long periods of time. The perceived urgency of global change research may gradually wax and wane over the next few years, especially as we are successful in explaining our progress on issues such as ozone depletion. We must be careful to place these results in their proper context. Along with the general public, the environmental policy-making community worldwide may fail to recognize, or react constructively to, scientific assessments of global change issues relative to economic/biospheric dangers. These are communication issues, and therefore can be addressed with tools we have in hand, or with tools we can devise.

Section VII Assumptions

A number of key assumptions have been incorporated into this MTPE Strategic Enterprise Plan. We believe these assumptions are valid for the 5-year planning horizon of this document, but we will reassess their validity each year in the course of the annual update. Changes in these fundamental assumptions could have significant effect on the objectives and strategies that follow.

Issues involving global change and the Earth's environment will remain important global and national issues into the foreseeable future.

Although the context of these issues and the particular topics of concern will evolve, the basic questions of how the Earth system is changing, what part human activities play in that change, and how we can continue to move toward sustainable development will remain high on the list of national and international concerns. Nationally, concern for the preservation of public health and safety and for the enhancement of our economic competitiveness will continue to be dominant issues for the foreseeable future.

There will continue to be a need for close interaction with international environmental managers, so that decisions can be considered with full awareness of all pertinent scientific data and that U.S. economic interests be equitably reflected. This can only occur with sustained, active participation in the research process. Because global change questions by their nature transcend national boundaries and require international investigation and action, domestic and foreign support for international cooperation in this area can be expected to be strong.

NASA will continue to have an important statutory role in Earth scientific research and to play a significant role in the policy framework for national efforts to understand global change.

The Federal Government will continue to look to the MTPE Enterprise to use the unique vantage point of space in addressing many environmental issues. Among Federal agencies, MTPE is unique in its ability to couple advanced new measurement concepts, broad-based collaborative scientific investigations of Earth science phenomena, and innovative methods of data dissemination and utilization.

The MTPE Enterprise will have to operate within a flat or possibly declining NASA budget.

Competition for national and international financial resources will increasingly compel NASA and MTPE to find new ways to achieve goals more effectively. It follows that even in a constrained budget, the MTPE Enterprise must make resources available to support the development and infusion of new technologies to enable an improved scientific rate of return on the national investment. Our job is not to answer all questions nor remove all uncertainties about the future of the environment. Rather, we are responsible for providing the best information base for environmental decisions that can be achieved within the resources provided.

Clear links between the MTPE program and its results to areas of high public concern are essential in maintaining public support for the long-term nature of the Enterprise's business.

MTPE's emphasis on the pursuit of scientific understanding, the applicability of this understanding to our daily lives, and the strong involvement of scientists in the Enterprise should ensure continued support from the external scientific community and concerned citizens. It is particularly important that MTPE foster a shared vision of science priorities within the scientific community and highlight areas of mutual interest with the industrial community. MTPE scientists and engineers are active participants in this process and lead the way through top-quality research and participation in scientific and technical forums; they must also be encouraged to share their knowledge in forums with broader public access.

Section VIII
Goals, Objectives, and Strategies

Of the six goals described below, four are listed in the MTPE Enterprise description in the NASA Strategic Plan. They describe the internal products we have committed to deliver to our external customers. Goals five and six are added here as goals that enable us to accomplish our mission.

Goal 1

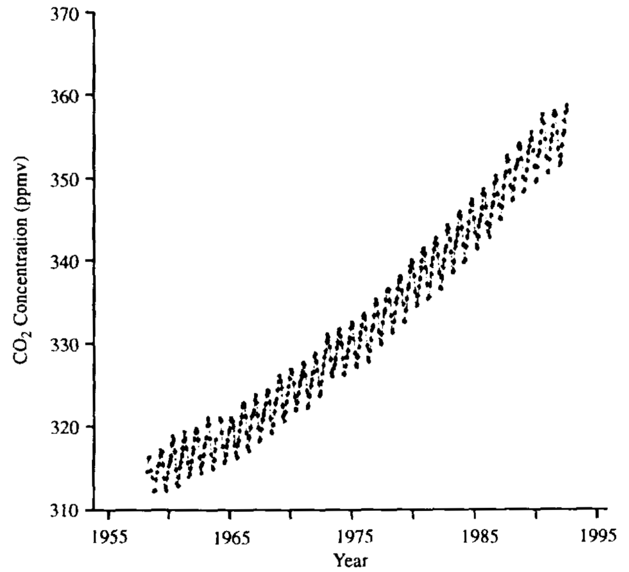
Increase scientific understanding of the Earth as an integrated environmental system and of its vulnerability to natural variations and human influences.

As we have stated, the fundamental objective of the MTPE Strategic Enterprise is to develop a comprehensive understanding of those processes that affect the global environment, including climate, atmospheric composition, distribution of vegetation, and distribution of water in the solid earth/ocean/atmosphere system, with sufficient fidelity to permit forecasting of trends. These quantities all affect the ability of the Earth to provide food, shelter, and resources for its increasing population. Our major focus is on global change, which addresses relatively long-term changes in the Earth system caused by natural and anthropogenic factors. An additional focus is on shorter term influences, especially those from naturally occurring hazards, such as volcanic eruptions, severe storms, earthquakes, and floods.

Objective 1.1: Determine evidence for the occurrence of global change.

Strategy: Examine historic data sets for climate, atmospheric composition, and land use.

These data sets must be "cleaned up" where needed to be of appropriate geophysical use; creation of Pathfinder data sets currently under way is an important part of this process. The recent past (post-Industrial Revolution) should be compared with the paleo-record so the relative variation on these two time scales can be understood. For example, a time series of sea ice cover based on satellite passive-microwave data going back to 1973 should be available by 1996 and continued into the future, while daily ice-motion fields going back to 1979 should be created by the use of observations of buoy motions and modeled ice velocities.



Monthly atmospheric CO_2 (carbon dioxide) concentrations at Mauna Loa.

Strategy: Develop new techniques for the detection of global change.

While the existing suite of data and geophysical quantities provides numerous tests for the assessment of past global change, it is important to consider what new detection techniques may be developed for this activity. This could include both experimental (e.g., instrument development) and theoretical/mathematical (e.g., applications of pattern recognition) techniques, as well as optimal design of networks.

Strategy: Maintain existing measurement networks and upgrade as appropriate to ensure adequacy of data.

The availability of appropriate data for these activities requires continuing support by MTPE. Existing measurement networks and space-based assets need to be maintained, and data analysis activities need to be part of the core research program. As technology improves, measurement networks should be augmented and updated. We must establish cooperation with other State and Federal agencies to leverage funds and ensure that all critical variables are measured. Where appropriate, we should consider data buy arrangements with nongovernment providers of data.

Objective 1.2: Understand causes and significance of global change.

Understanding the cause and significance of any global change needs to be understood in the context of models, which will typically be regional to global in scale.

Strategy: Develop component and coupled models for retrospective analysis.

Such models must have accurate representation of the fundamental geophysical processes involved, and must have sufficient representation of couplings across interfaces, such as land-atmosphere, land-ocean, and ocean-atmosphere. They should cover both physical and chemical variables; applications to the carbon cycle are particularly important in the pre-1998 time frame. Both free-running models and data assimilation models are needed. These models should help determine environmental consequences of past and projected global change, and thereby help us to understand how the Earth system will respond to current changes.

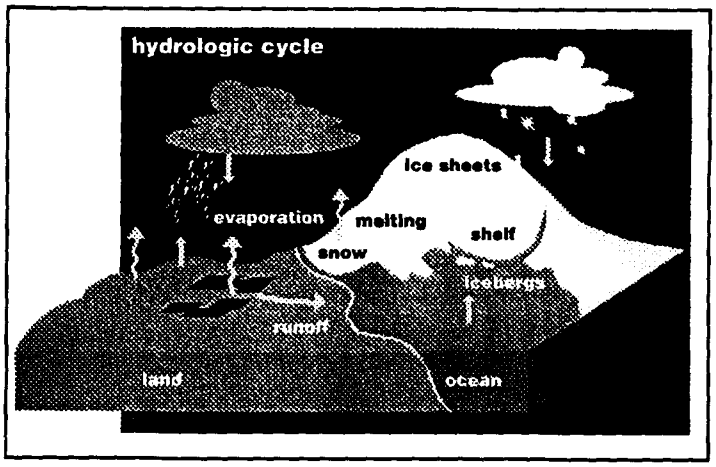
Strategy: By 1996, use data from the Boreal Ecosystem-Atmosphere Study (BOREAS) to improve parameterizations of the boreal forest biome in atmospheric general circulation models (GCM's).

A critical need for improving atmospheric GCM's is to have an accurate representation of processes occurring at the land-air interface, especially as they relate to the transfer of moisture between the surface and the atmosphere. To develop accurate parameterizations suitable for use in GCM's, knowledge of fundamental processes must be obtained. The recently completed BOREAS field study has provided substantial information on this issue, and should lead to the development of parameters that will be incorporated into GCM's by the end of FY 1996.

Strategy: By 1997, make available a 15-year assimilated data set for the physical state of the atmosphere, and by 2000 expand in scope the assimilation system to make use of a broader range of data types.

Atmospheric data assimilation is the process by which a GCM is used together with real atmospheric data (e.g., temperature, winds, etc.) to produce a consistent and accurate set of global data on the physical state of the atmosphere. By 1997, the Goddard Space Flight Center (GSFC) expects to have a 15-year assimilated data set for the troposphere. By 2000, the assimilation data set should be expanded in scope to use data from platforms launched during the 1990s, such as the Upper Atmosphere Research Satellite (UARS) (9/91), the Advanced Earth Observing System (ADEOS) (2/96), and the Tropical Rainfall Measuring Mission (TRMM) (1997). This should allow for the assimilation of quantities such as trace constituents and tropical precipitation.

Strategy: By 1997, assemble and organize in a uniform data base all of the Multi-Aircraft Campaigns (MAC's) and Spaceborne Imaging Radar-C (SIR-C) data for use in developing and validating hydrology and coupled land atmosphere models.



To understand global change, one must use both aircraft and satellite data in situ. A good understanding of these three areas and how they relate ultimately can serve to validate the satellite data. For the data to be useful to scientists who have not been personally involved with a specific aircraft campaign or spaceflight mission, the data must be organized into an accessible data base. This greatly increases the number of people who can work with the data and contribute their scientific expertise to the understanding of the problem at hand.

Objective 1.3: Determine predictability of changes, including their spatial and temporal dependence.

Prediction of future changes is critical because of the national interest in relating proposed policy to calculated global change. The issue of predictability needs to be understood, including fundamental limits to long-term predictability of global change variables.

Strategy: Develop models that can be used for both retrospective and prognostic purposes.

Predictive models need to be developed and tested by comparison with existing observations, including quantitative estimates of determining factors (retrospective data analysis). Once developed, models need to be run for prescribed scenarios. This will typically be done as part of internationally organized assessment activities.

A particular emphasis of modeling activities must be the study of couplings between processes, especially those where nonlinear processes can cause model results to vary sensitively with initial conditions or assumptions about atmospheric processes included in the models. This may be particularly important in areas such as chemistry-climate coupling, where formation of aerosols and polar stratospheric clouds are known to be exceedingly sensitive to temperature. Coupled model development and validation is a complex process and leads to an understanding of the fundamental limitations on predictability. For example, by 2000 the first generation of dynamic global vegetation models, which will be interactive with atmospheric general circulation models, should be available.

Strategy: By 1998, make available three-dimensional (3-D) atmospheric chemistry assessment models to simulate ozone distributions in the upper troposphere and in the stratosphere, and their dependence on natural and human-induced forcing, including the current subsonic and projected supersonic aircraft fleets.

Computational models that simulate the distribution of ozone in the atmosphere are needed if its past changes are to be understood and future evolution is to be projected. While most current assessment models have two physical dimensions and are focused on the stratosphere, 3-D models covering both the troposphere and stratosphere are needed. These models can simulate the response of the atmosphere to natural forces, such as the solar cycle, quasi-biennial oscillation, and volcanic eruptions, and to human-induced factors, such as increased trace gas loading (e.g., halocarbons, methane, nitrogen oxides, and carbon monoxide). A particular emphasis of these models should be to simulate atmospheric chemical response to the current subsonic aircraft and projected supersonic aircraft fleet. Development of these models is a joint project of MTPE and the Atmospheric Effects of Aviation Program of the Office of Aeronautics.

Objective 1.4: Develop improved systems for quantification of impacts of natural hazards and of possible mitigation strategies.

Short-term issues associated with natural hazards must also be an important MTPE focus. The global perspective pioneered by MTPE provides a way of obtaining information on hazards such as volcanic eruptions, floods, and earthquakes around the world. The data systems developed by MTPE in conjunction with its observing capability should allow MTPE scientists to play a critical role in quantifying the effects of hazards and, where appropriate, in supporting the definition of mitigation strategies. This is particularly true for less developed parts of the world where there is insufficient infrastructure to support local data gathering and forecasting.

Strategy: By 1996, develop a strategy for monitoring floods, estimating damage, and supporting mitigation strategies using currently available remote sensing data.

Natural disasters currently cost the United States, on average, $5 billion per week. Current or soon to be operational satellites, such as the Land Remote Sensing Satellite (Landsat), European Remote Sensing satellite (ERS), and RADARSAT, provide data useful for disaster reduction and strategies. MTPE will work with U.S. Government disaster management agencies to supply the data they require.

Goal 2

Observe and characterize the entire Earth system and make resultant data widely available.

This goal will be met by executing the overall MTPE program on time and on budget. This program includes implementing a flight segment, a complementary ground segment, and a corresponding science program.

Objective 2.1: Add multiyear data sets from the atmospheric chemistry and oceanographic disciplines to those from the meteorology and land imaging disciplines, and build on the lessons learned as a prelude to the overall, integrated program called EOS.

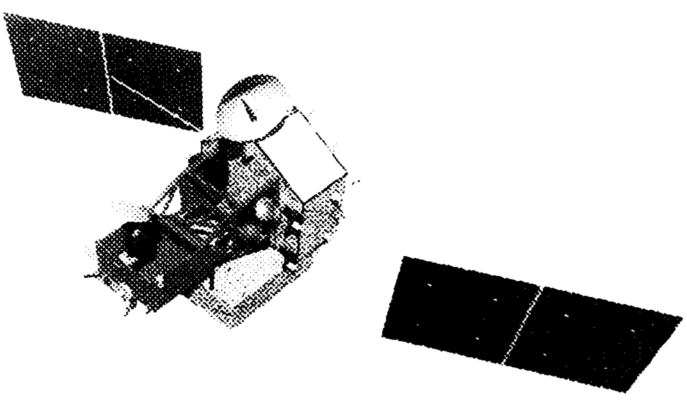
MTPE is developing several spacecraft to provide key measurements in these disciplines in advance of the EOS program. Data from these missions will help prepare for EOS, and will be managed in a prototype EOSDIS.

Strategy: Continue providing meteorology and land imaging data while adding data from atmospheric chemistry and oceanography.

In addition to continuing the operation of missions currently flying (e.g., UARS, the Earth Radiation Budget Satellite (ERBS), and TOPEX/Poseidon), the flight segment of the MTPE Program (Phase 1) includes the following new missions.

✣ In 1995, the Total Ozone Mapping Spectrometer (TOMS) instrument will be launched on a NASA Earth Probe satellite. Through a Memorandum of Understanding with the Federal Aviation Administration (FAA), TOMS data will be used by the FAA in a real-time test to explore its usefulness for hazard avoidance and increasing efficiency in jet aircraft routing. Additional flights of TOMS instruments will be on the Japanese ADEOS spacecraft and a Russian Meteor-3 spacecraft in 1996 and 2000, respectively.

✣ In 1995, a Sea-Viewing Wide-Field-of-View Sensor (SeaWiFS) instrument will be launched to measure ocean color for studies of ocean productivity. While this is a commercially built and launched instrument, MTPE has contracted through a "data buy" to obtain data for use in scientific studies. The exact timing of the launch will depend on the manifest for Pegasus XL launches.



Instruments onboard TRMM will measure precipitation and contribute to understanding and predicting global climate change.

✣ In 1996, an ADEOS mission by Japan will be launched with the objective of Earth, atmospheric, and oceanographic remote sensing. The ADEOS instrument complement includes eight instruments, of which NASA is supplying TOMS and the NASA Scatterometer (NSCAT). Its expected lifetime is 3 years. An ADEOS II is in the conceptual stage of design, with a mission objective of measuring ocean winds and circulation. NASA would provide the SeaWinds instrument (follow-on to NSCAT) for that 1999 mission.

✣ In 1997, a TRMM, provided jointly by NASA and Japan, will be launched with the primary objective of measuring precipitation in the tropics. NASA is supplying a Clouds and the Earth's Radiant Energy System (CERES) instrument and a Lightning Imaging Sensor (LIS).

✣ In 1998, a Landsat-7 mission will continue the surface observations begun with the earlier Landsat flights. The Landsat-7 mission will include an Enhanced Thematic Mapper plus (ETM+) instrument.

Strategy: Provide a prototype data system to demonstrate the concepts of, and to guide the development of, the data and information system necessary to accomplish the objectives of MTPE Phase 2.

The ground segment of EOS provides the data and information system infrastructure needed to provide the data to the user community. The EOSDIS is specifically being implemented to provide this infrastructure. The EOSDIS is being implemented in stages, with a working prototype (Version 0, comprising nine Distributed Active Archive Centers, or DAACs) presently demonstrating data set search, browse, and order capabilities on pathfinder data sets obtained from earlier missions.

Objective 2.2: Provide an 18-year base of data from which to address the fundamental physical, chemical, and biological phenomena that govern and integrate the Earth system.

With the launching of the first EOS spacecraft in 1998, NASA will commence Phase 2 of the MTPE program. Building on the lessons learned from Phase 1, Phase 2 is expressly designed to provide a long-term (18-year minimum) set of continuous data to provide a baseline for observing global change and separating natural and human-induced changes.

Strategy: Provide, via several series of spacecraft, the data needed to support the integrated studies of the EOS program.

In addition to continuing the operation of missions then flying (e.g., TRMM and ADEOS), the flight segment of Phase 2 of the MTPE program includes the following new series of spacecraft (the schedule for the launches of these spacecraft is provided in Appendix 4):

✣ An EOS AM series is named for its 10:30 a.m. local time southbound equatorial crossing. The EOS AM series spacecraft and the subsequent PM and CHEM series of spacecraft will be launched into 705-km, 98.2-degree, sun-synchronous orbits with a 16-day/233-orbit repeat cycle. The first spacecraft (EOS AM-1) of this series is to be launched in 1998. The thrust of the AM series is the characterization of the terrestrial surface, clouds, aerosols, and radiation balance. In addition, the Moderate-Resolution Imaging Spectroradiometer (MODIS) will contribute to measuring ocean productivity. Its morning crossing time was chosen to minimize cloud cover. Of the five instruments aboard the EOS AM-1, Japan is supplying one and Canada is supplying another. On the EOS AM series, MODIS data will be directly broadcast to users with suitable ground stations. A Landsat Advanced Technology Instrument (LATI) is being considered to fly on EOS AM-2.

✣ An EOS PM series is named for its 1:30 p.m. local time northbound equatorial crossing. Its scientific emphasis is on clouds, precipitation, radiation balance, terrestrial snow, sea ice, sea surface temperature, and ocean productivity. Its crossing time was chosen for its usefulness for meteorological forecasting. The first spacecraft (EOS PM-1) of this series is to be launched in 2000, with ESA supplying one of the five instruments being flown. All EOS PM data will be directly broadcast to users with suitable ground stations. The PM series may evolve into the next generation of NOAA/U.S. Air Force (USAF) weather satellites.

✣ An EOS CHEM series is named for its emphasis on atmospheric chemical species and their transformations. The first spacecraft (EOS CHEM-1) of this series is to be launched in 2002. Of the four instruments being flown, Japan is contributing one instrument and the United Kingdom is supporting two others. The CHEM northbound equatorial crossing time is 1:45 p.m. local time.

✣ A Radar Altimeter (ALT-R) series will be used to study ocean circulation and topography. This series will begin with the launch of ALT-R-1 in 1999 into a mid- or high-inclination orbit.

✣ A Laser Altimeter (ALT-L) series will be used to study ice-sheet mass balance and, secondarily, clouds and vegetation. These spacecraft will be in near-polar, non–sun-synchronous orbits and may not provide a contiguous data set.

✣ A Stratospheric Aerosol and Gas Experiment (SAGE) III will measure atmospheric aerosols, ozone, and other trace gases. Both mid-inclination and high-inclination flights are desired. The current plan is for launch on a polar sun-synchronous Russian Meteor-3 spacecraft in 1998 and the International Space Station in 2000 or 2001.

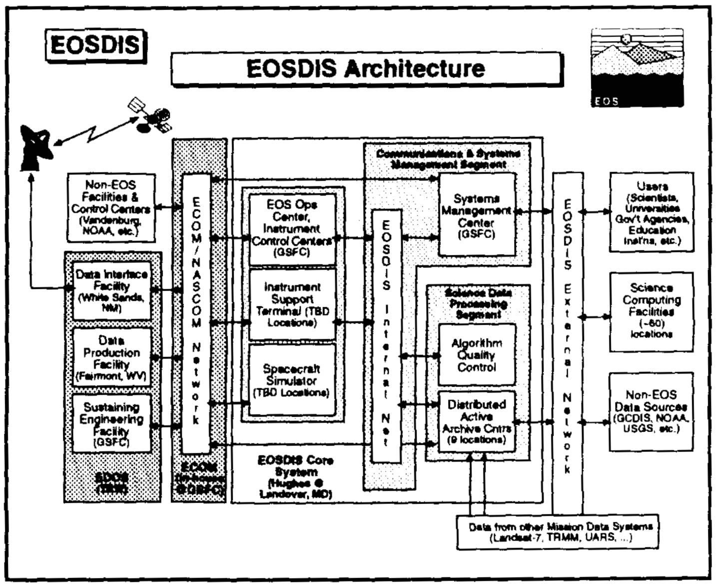
Strategy: Develop instruments, in addition to those being flown on NASA spacecraft, to be flown on flights of opportunity.

Several additional instruments have been designated for flights of opportunity. These instruments are being developed by NASA and will fly on yet undesignated spacecraft. With the exception of COLOR, these instruments are intended to provide 18-year data sets via a variety of spacecraft. These instruments are:

- ✣ A COLOR instrument to measure ocean productivity
- ✣ An Active Cavity Radiometer Irradiance Monitor (ACRIM) to measure solar energy
- ✣ A Clouds and the Earth's Radiant Energy System (CERES) instrument to fly on a mid-inclination orbit
- ✣ A Solar Stellar Irradiance Comparison Experiment (SOLSTICE) to measure solar ultraviolet flux

Strategy: Issue a new EOS Announcement of Opportunity for New Science Teams and Interdisciplinary Investigations in 1995.

The opportunity for participation by the external science community in the EOS program needs to be expanded. In addition, some of the current EOS interdisciplinary investigations need to be modified, given the years that have passed and the knowledge gained since their initiation in 1989.



Strategy: Provide the data and information handling infrastructure needed to fulfill the EOS mission objectives.

The ground segment of EOS supports the space segment and provides the data and information system infrastructure needed to provide the data to the user community. The EOSDIS, which provides this infrastructure, supports the following functions:

- ✣ Mission and instrument planning, scheduling, and control
- ✣ Resource management
- ✣ Communications
- ✣ Generation of both standard and special data products
- ✣ Archiving for data, products, and research results
- ✣ Data and information cataloging, searching, browsing, and ordering
- ✣ Effective distribution of all information holdings
- ✣ User support

MTPE is implementing EOSDIS using a distributed, open system architecture. This architecture allows for the distribution of EOSDIS elements to various locations to take the best advantage of different institutional capabilities and science expertise. Although the EOSDIS is physically distributed, it will appear as a single logical entity to the users. EOSDIS will consist of an EOSDIS Core System (ECS) to provide centralized mission and instrument command and control functions and distributed, but not common, product generation, archive, and information management functions. Capabilities also exist outside ECS, including site-unique extensions to ECS capabilities, computing facilities for EOS researchers, etc. Nine Distributed Active Archive Centers (DAAC's) covering various types of Earth science have been selected by NASA to carry out the responsibilities for processing, archiving, and distributing EOS data and related data and for providing a full range of user support. Acting in concert, DAAC's will support global change researchers whose needs cross traditional discipline boundaries while continuing to support the particular needs of their discipline community.

The EOSDIS is being implemented in stages.

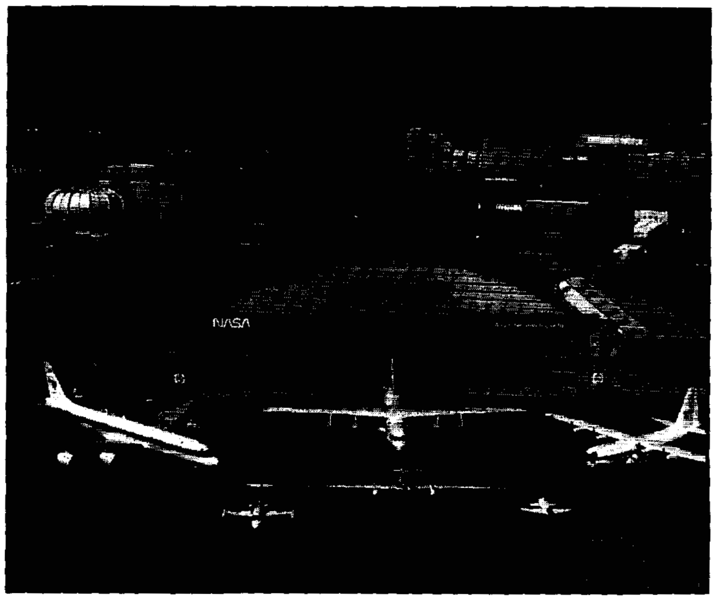
- Version 1, scheduled for release in early 1997, will provide support for the TRMM flight, prototype advertiser service, enhanced browse capability, and enhanced network delivery.

- Version 2, scheduled for release in the fall of 1997, will provide full support for the upcoming EOS AM-1 and Landsat-7 flights as well as data subsetting, an enhanced data serving capacity, and advertiser service.

Further versions will provide full support for EOS spacecraft being launched later and will provide evolutionary enhancements for the EOSDIS users.

Objective 2.3: Provide a complementary inventory of aircraft, balloon, and ground-based observations.

Space-based observations alone are insufficient to supply the data required to address most MTPE science questions. These must be supplemented by in situ and ground-based measurements to provide both calibration data and complementary data.



Strategy: Maintain and make available the current fleet of aircraft employed for MTPE research campaigns.

A highly capable fleet of aircraft is currently in operation and available for MTPE research. However, operations are always harder to fund than development programs, and considerable attention must be applied to preserve and enhance the health of these assets.

Strategy: Develop and deploy a set of remotely piloted vehicles for high-altitude airborne research.

MTPE should provide for the first demonstration flight of a remotely piloted vehicle capable of collecting data relevant to MTPE in 1996. Remotely piloted vehicles will be used for both MTPE-related research and the Environmental Research Aircraft Sensor Technology (ERAST) program run by the Aeronautics Enterprise.

Strategy: Conduct field campaigns to make essential observations to which space-based assets are not suited.

Intensive field campaigns are central to MTPE activities, and should average two per year over the period of this plan, with roughly half being discipline-specific and half being interdisciplinary (e.g., land-atmosphere, land-ocean, and ocean-atmosphere). Field campaigns should have both experimental and modeling components, and the needs of the modeling community should be incorporated into the design and conduct of campaigns.

Goal 3

Contribute to wise and timely national and international environmental policy.

Consistent with its mission and principles, MTPE continues to make significant contributions to environmental policy. The National Science and Technology Council's Committee on Environment and Natural Resources (CENR) and the subordinate U.S. Global Change Research Program (USGCRP) provide a process for coordinating U.S. environmental policy priorities. MTPE's heavy participation in these forums enables us to influence and be guided by these priorities. Similarly, our participation in international observing system organizations, such as the Global Climate Observing System (GCOS), and assessment organizations, such as the International Geosphere-Biosphere Program (IGBP) and the Inter-American Institute (IAI), enables international coordination on environmental observation priorities.

NASA MTPE's role in the policy-making process is to provide the scientific understanding necessary for effective environmental decision-making. We provide much of the data and analyses that allow policy and regulatory bodies to make informed decisions. MTPE identifies and pursues a set of scientifically important environmental research questions; the needs of the policy community help us establish the order and time scale in which we tackle these questions.

Objective 3.1: Ensure the availability of MTPE data and understanding for policy makers.

The National Performance Review recommended that NASA work to facilitate the availability of the data in which the Nation has invested so much effort to obtain. The ultimate measure of MTPE mission success is not operational spacecraft in orbit, but useful information provided to those with the responsibility to act on it.

Strategy: Provide EOSDIS-distributed data products that respond to policy-maker information and analysis requirements as defined in annual customer surveys by 1997.

MTPE is designing EOSDIS to be useful to a wide range of users who are not instrument Principal Investigators, or even specialists in the same or related discipline. The EOSDIS user model includes social scientists and policy makers, who will see data and data products in formats they help design. One of the nine DAAC's is dedicated to social and economic sciences data.

Strategy: Facilitate the increased understanding of global change issues among policy makers through the provision of sample user application scenarios by 1997.

While MTPE cannot guarantee some adequate level of understanding of environmental science by policy makers, we can make possible that understanding by providing reliable data. Further, we can create some sample scenarios of, for example, how data products built in EOSDIS from land cover, rainfall, and population observations can be used by city and regional planners in the Southwest in formulating long-range development strategies. These will give the user insight into the possibilities and help take that essential step of translating science results into policy.

Objective 3.2: Support assessments of critical environmental issues.

MTPE will take active part in the work of various national and international entities in generating environmental assessments in critical areas, lending to them both our data and our scientific expertise.

Strategy: Support all formal integrated assessments on the global environment beginning in 1995.

As a matter of definition, no global-scale environmental assessment can be generated effectively without the data that NASA provides. It should also be true that no such global-scale assessment work can credibly proceed without MTPE scientific involvement in analyses. MTPE scientists have a responsibility to participate in national and international global change assessments. This includes the analysis of data of past and present atmospheric change and the calculation of future changes using models with prescribed scenarios. Long-term changes in stratospheric ozone and a rigorous examination of those atmospheric processes responsible for them should be carried out for assessments organized by the World Meteorological Organization and United Nations Environment Programme. Changes in trace gas biogeochemistry and land use should be studied as part of the Intergovernmental Panel on Climate Change. The effects of aircraft, both the current subsonic fleet and the projected supersonic fleet on the global atmospheric environment should also be investigated.

Objective 3.3: Using models, provide predictive capabilities to anticipate future states of the environment.

The requirement for policy relevance can only be met if we can make useful statements about likely future states resulting from selected, important assumption sets. For this activity, integrated models are required. The challenge is to produce models that capture a sufficient level of detail available in individual arena models, and couple them in a manner that does not compound the errors from individual ones, or create new errors. The user must be able to run specified alternate assumption sets and meaningfully compare the resultant states predicted by the model.

Strategy: Apply at least one integrated model of the global atmosphere, oceans, and land surface incorporating space-derived data by 1998.

While atmospheric GCM's are at a relatively mature state (albeit far from finished), models that represent the atmosphere, the land surface, and oceans with appropriate feedbacks among them are much less developed. Such models will be particularly important for studying changing concentrations of atmospheric carbon dioxide, which are affected by production and consumption at the surface and also the equilibrium between atmospheric gas phase and dissolved oceanic concentrations. Space-derived data will play a critical role in developing the land system models by providing information on vegetation and land cover for the solid earth surface, and will support the atmospheric and oceanic models as well.

Goal 4

Foster the development of an informed and environmentally aware public.

NASA Headquarters and each of the field installations must work together, in coordination with NASA's Offices of Education, Public Affairs, and Legislative Affairs, to effectively convey the results of the various research programs in a focused manner for diverse audiences.

Formal education is one critical component of MTPE's education program. There is an immediate need to influence the emerging Earth scientists to think of the Earth as an integrated system. Data from the EOS program must be interpreted and analyzed from an interdisciplinary perspective. Therefore, a stable graduate-level student support activity must continue. However, other student support activities at lower grade levels must be weighed against their ultimate impact on the goal of fostering an educated citizenry. It is necessary to instead focus on "educating the educators" to implement the "multiplier" effect, whereby one teacher may reach other teachers and eventually hundreds of students.

In response to increasing demands for information in a time of limited resources, it is essential to leverage educational efforts with other government agencies and outside organizations that maintain Earth system science educational programs. Leveraging in various forms is necessary to build a sustainable education program within MTPE. The broader public outreach task must also use leveraging as part of its plan. Outside organizations are often more capable of translating, packaging, and disseminating data to the various information customers of MTPE.

Objective 4.1: Support curriculum development and resources to train the next generation of Earth scientists.

The continued success of the MTPE Enterprise requires sufficient new, talented scientists be trained to study the Earth from an interdisciplinary perspective as global change data are made available by EOS and other Earth-observing programs. Global change research relies on fresh ideas and new expertise. MTPE can support the development of the "next generation" of Earth system scientists in several ways.

Strategy: Increase Global Change Fellowships in line with the EOS budget through the year 2000.

The most direct approach is through student support through the Global Change Fellowship program, which sponsors graduate students conducting research in areas at the forefront of Earth and environmental science. MTPE should also continue to support the selection of students through NASA's Graduate Student Research Program. MTPE must work to coordinate efforts and resources with other USGCRP agencies.

Strategy: Encourage the increase in the number of colleges that offer an interdisciplinary approach to Earth system science studies by the year 2000.

At the undergraduate level, MTPE contributes to the development of emerging Earth system science curricula. The Earth System Science Education (ESSE) program is an example of how the development of interdisciplinary-oriented Earth system science courses has been facilitated by MTPE support and participation with cooperation from 22 universities across the country. The Joint Ventures (JOVE) program is a partnership between NASA and universities to develop research capabilities, promote science and engineering education, and encourage outreach activities at universities that traditionally have little or no involvement with NASA's programs.

Strategy: Engage MTPE scientists in the review of emerging K–12 science standards.

Earth science is unevenly represented in pre-college state curriculum standards at the present time. Therefore, participation in the review of national standards is critical to begin the flow of Earth science into the state and local classrooms. MTPE must coordinate with other agencies if a change in standards is to be realized.

Objective 4.2: Emphasize programs that enable educators to teach Earth system science.

MTPE must educate present and future educators if its efforts are to reach a national, diverse population of students. Programs and activities exist to enhance curriculum and train in-service teachers. However, many curriculum development products involve little or no training program, and they are available in limited quantities, because of limited resources and often ineffective leveraging. They are sometimes not supportive of the state and local curriculum standards that define exactly what a teacher must teach. The teacher training programs are usually based near a NASA field installation and are therefore not national in scope. Finally, there is an obvious weakness in the area of preservice training.

Strategy: By FY 1996, identify a set of core MTPE science issues and use them as a basis for augmenting, expanding, or deleting existing educational programs.

In line with the MTPE education strategy, MTPE must work across NASA field installations and with agen-

cies and outside organizations to relay its message of Earth system science to pre-service teachers and in-service teachers, then provide adequate tools to enhance their classroom instruction. First, MTPE content must be identified that directly correlates to what is being taught, as a state standard, in the schools. NASA field installation teams should meet annually to coordinate the development of new activities with the hope of replicating the development of the most successful programs and products nationally.

Strategy: Conduct at least one joint teacher workshop annually with other USGCRP agencies and/or outside organizations.

A guiding principle of the MTPE education strategy is to continue to educate and train educators as research evolves and capabilities change. The USGCRP agencies participate in the Committee on Environment and Natural Resources (CENR) Education and Communication Working Group and share the same principle. By leveraging each other's resources and unique scientific capabilities, the agencies can provide educators with opportunities for enrichment in the areas of global change and earth system science.

Strategy: In light of the weak area of pre-service teacher training, MTPE should support the development of at least one new tool or program annually to be used in introductory science courses for future teachers.

Students working toward a teaching certificate are required to take a core set of courses. MTPE education strategy formulators view this as an opportunity to educate educators of all different disciplines, thereby increasing awareness of those who, in turn, will soon be responsible for educating our young people. By working with university education departments, tools and materials conveying Earth system science can be introduced in pre-service courses.

Objective 4.3: Develop greater support by scientists for broad education efforts.

The researchers of MTPE are among its greatest resources to communicate their findings to the public. This resource has not been utilized as efficiently as it could be.

Strategy: Incorporate an educational outreach component into relevant research announcements by FY 1996.

To encourage the natural feedback process, research announcements directly supported with adequate resources should encourage this communication. Implementation methods must be considered by the NASA Science Council in FY 1995 and inserted into the announcement process by FY 1996.

Strategy: Beginning in FY 1995, develop new education products using integrated product teams consisting of scientists and educators.

As educational products are developed, scientists should team with educators in the future on integrated education product development teams. The science message must maintain integrity, yet be communicated in a useful way to educators at all levels.

Strategy: By FY 1996, establish rotational opportunities for teachers to visit USGCRP agency research facilities.

Joint sessions with USGCRP agencies should be established in FY 1996 to offer rotational opportunities for teachers to visit agency laboratories, etc. Continuing education credits for teachers and exposure to grades K–12 needs for scientists are two critical reasons to pursue this cooperative program.

Objective 4.4: Make information and assessments available to the general public.

MTPE must work closely with Public Affairs to develop a science communication strategy for the near term and long term. As new media are developed, MTPE must take advantage of the emerging technologies, while maintaining a parallel set of traditional mechanisms for reaching the portions of the population that are not equipped for the new means of receiving information.

Strategy: By FY 1996, support the development of a set of general global change communications products with other USGCRP agencies.

By joining forces, resources are most efficiently used to reach a broad customer base. One example is the production of a set of global change lithographs based on current data from all participating agencies.

Strategy: In FY 1995, develop an Internet "Home

Page" for MTPE information.

To encourage the use of technology to disseminate information, printed products and images should be made available on the Internet through different paths. A Headquarters MTPE "Home Page" must be developed and maintained to ensure linkages to various, reasonable locations on the Internet, in accordance with Agency policy.

Goal 5

Expand and improve the scientific return on investment by seeking and using advanced, cost-effective engineering and scientific techniques having potential for multiple uses.

In this post-Cold War and constrained budget era, pressure is increasing to demonstrate tangible economic benefits from the national research investment. Much of this will hinge on the development and infusion of new, cost-effective technologies and new ways of doing business. NASA is responding with a focused plan to develop and infuse new technologies and with new policies and initiatives to form partnerships with the private sector. Also, MTPE is a participant in government-wide efforts to disseminate environmental technologies.

Objective 5.1: Identify and assess the availability of new technologies and procedures for infusion into the ongoing program and for incorporation into follow-on developments.

EOS is intended to make observations over a period of 15 years or longer. This necessitates the design of strategies to insert new technologies into spacecraft, instruments, as well as ground-based information systems to constrain program costs and fulfill mission objectives.

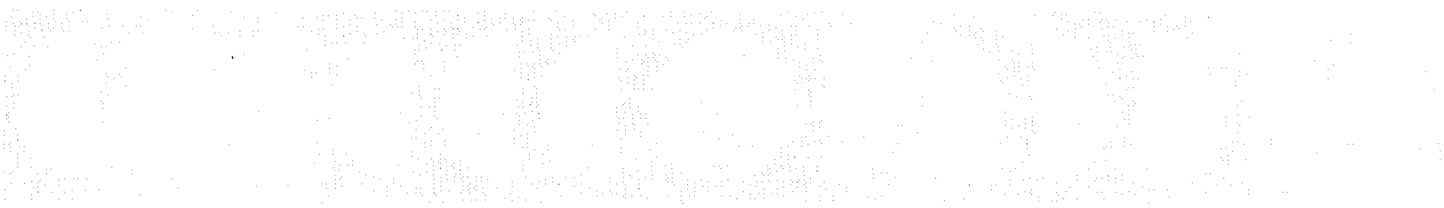
Strategy: Prepare and maintain a plan for advanced technology development.

MTPE will prepare an annual plan that reviews and updates scientific requirements and identifies technology areas that could create the opportunity to meet the scientific requirements. A technology taxonomy that covers the full range of instrument, spacecraft, and ground systems capabilities will be developed and maintained. The taxonomy will aid in the translation of scientific observing and measuring requirements into flight, operations, and data systems requirements. Technology selection and infusion criteria will be developed to aid in setting R&D priorities and to help convey the relationship and importance of key technologies to the scientific investigations. The relationship among NASA Enterprises will be manifest in the annual plan. An initial version of the Plan will be prepared in FY 1995.

Strategy: Conduct studies that identify and assess new approaches to improving performance, reducing costs, and/or reducing risks for carrying out the multidecade MTPE program.

In 1995, a group of senior university, physicists and related researchers, called the JASONs, will complete a MTPE-chartered study of technology options and make recommendations to the program on a "next generation" EOS concept. The concept is to provide a vision of EOS that fully exploits near-term and anticipated technological advances in the next 10 to 20 years. The study will make recommendations about research and advanced technology development paths that should be considered in the near future to establish and preserve the most cost-effective options for the future.

Also, in 1995, the National Research Council (NRC) is expected to complete its study of potential future



NASA involvement in the development and deployment of Synthetic Aperture Radar (SAR) technology. Recommendations will be incorporated into future versions of this strategic plan.

Additional planning will be commissioned as required to conduct advance planning of new space and airborne platforms and instruments and operational support systems. "New ways of doing business" will be identified and studied for program implementation.

Objective 5.2: Seek to apply cost-effective technology and techniques developed outside the MTPE program.

Relationships with non-MTPE and non-NASA sources of technology will be established to leverage MTPE investment in space and ground systems.

Strategy: Cooperate with other NASA organizations in the identification and selection of mutually beneficial advanced technologies, systems, and procedures.

In 1995, MTPE will complete a Memorandum of Understanding (MOU) with the Office of Space Access and Technology (OSAT) that establishes policies and procedures for coordinating programmatic activities, especially budget-related matters of mutual interest. Also, MTPE will actively participate in the ERAST Leadership Team, which was chartered in 1994 by the Office of Aeronautics to guide Remotely Piloted Vehicle (RPV) and associated instrument development for the High Speed Civil Transport stratospheric research program.

Strategy: Cooperate with other Federal agencies, non-Federal partners, and international organizations in the identification and selection of mutually beneficial advanced technologies, systems, and procedures.

MTPE will maintain awareness of relevant technology development and deployment efforts by other Federal and international agencies. As opportunities present themselves, MTPE will seek mutually beneficial partnerships during the definition stages of the effort as appropriate.

Specifically, MTPE will lead a multi-agency effort to investigate the feasibility of a global observing system, which might emerge early in the next century. Such an observing system could consist of space, air, and ground capabilities provided by several U.S. Government agencies, the U.S. commercial remote sensing industry, and international partners.

Objective 5.3: Develop advanced spacecraft and instrument capabilities, operations support systems, and data management systems.

Technology advances create scientific opportunities never before imagined. An aggressive technology development program is required to realize the "better/faster/cheaper" paradigm, which will help reconcile our hopes with financial reality.

Strategy: Aggressively pursue, with other NASA organizations, mutually beneficial advanced development ventures.

MTPE will actively contribute to the OSAT Small Satellite Technology Initiative, the Lewis and Clark demonstration program. This should include support of the science and applications teams. Involvement should assure the development of data policy and management procedures consistent with long-term MTPE policies and objectives.

MTPE will also provide technical and programmatic leadership and participate in the Next Generation

Spacecraft Development Program being jointly sponsored by OSAT, the Office of Space Science (OSS), and MTPE. MTPE will participate in programs such as New Millennium to assure a path to MTPE mission implementation.

Strategy: Provide for observing capabilities not currently available in MTPE, and begin a Small Earth Probes Initiative by 1999.

MTPE must carry out the following:

✣ Develop the capability to implement quick turnaround spaceborne missions to accomplish emerging scientific objectives in response to new national and international research priorities.

✣ Provide a periodic window of opportunity to accommodate new scientific priorities and infuse new technological and scientific participation into the MTPE program.

✣ Develop small missions with focused objectives as science and technology pathfinders to evaluate technologies and assess scientific need for long-term monitoring.

✣ Establish an implementation process that reduces mission cost by: (1) selecting missions based on best science value with scientific objectives prioritized against cost; (2) emphasizing mission life cycle cost at the proposal stage, requiring proposals to optimize science, instrument, spacecraft, launch, and mission operations and data analysis costs; and (3) providing new partners/sponsors (i.e., NSF, DOE, universities, etc.) to become significant contributors for small investments.

✣ Establish mission budget and schedule constraints that support a sustained program with periodic launches (at least one launch every 24 months).

Strategy: Provide for regular system technology improvements in EOSDIS through version 2 in 1997.

Computational and data storage technology is changing rapidly. MTPE must stay on top of these trends to reduce operations costs, which are the biggest portion of EOSDIS costs through FY 2000 and beyond.

Objective 5.4: Pursue technology transfer and commercialization opportunities.

MTPE works with the Space Technology Enterprise to allow MTPE-related technologies with potential commercial application to be made available to U.S. industry.

Strategy: Incorporate technology transfer and commercialization policies as part of each major acquisition process.

Implement the policies established in the July 1994 "Agenda for Change," NASA's Commercial Technology strategy developed in response to the National Performance Review and related Administration documents.

Goal 6

Ensure the availability of human and physical resources necessary to achieve the MTPE mission over the long term.

Understanding the global environment requires that NASA sustain a highly skilled work force at the NASA field installations and the Nation's universities. The MTPE program must strive to preserve its commitment to excellence while enhancing the representation of minority populations in MTPE programs. MTPE will develop, maintain, and enhance world-class facilities to support current and future programs. It will take a concerted effort to ensure a work environment equal to the challenge in the face of the work force reductions and budget pressures facing NASA. Overall Agency management of human resources among the Strategic Enterprises is a responsibility of the Human Resource Strategic Function, and overall Agency management of physical resources among the Strategic Enterprises is a responsibility of the Physical Resources Strategic Function. MTPE is responsible for ensuring that the requirements in each of these areas are clearly advocated and that funding is available to meet priorities. MTPE is responsible for ensuring that resources allocated to the MTPE program are deployed properly, consistent with the goals, objectives, and strategies contained in this Enterprise Plan.

The MTPE program is implemented principally at the Goddard Space Flight Center (GSFC), with significant contributions from the Ames Research Center, Langley Research Center, Marshall Flight Space Center, Stennis Space Center, and Jet Propulsion Laboratory. In addition to the critical importance of GSFC for the MTPE program, the MTPE Strategic Enterprise has overall responsibility for institutional management of GSFC. In this role, MTPE has an Agency-level responsibility to ensure that adequate human, physical, and technical resources are available at GSFC for the full range of programmatic requirements carried out at the Center. This responsibility requires close interaction with other Strategic Enterprises (principally the Scientific Research and the Space Technology Enterprises) and the Strategic Functions (Human and Physical Resources), to ensure that adequate funding and support are made available.

Hundreds of colleges and universities around the world participate in the program. MTPE will also ensure that the Nation's colleges and universities continue to play a fundamental and stimulating role in basic research, process analysis, and scientific modeling activities it conducts.

Objective 6.1: Continue to develop a highly skilled and motivated work force that reflects the diversity of people in America.

MTPE's work force is the key to its success thus far, and it faces greater challenges in the EOS era. Equally challenging will be the task at achieving personnel goals in an era of Agency-wide streamlining.

Strategy: Identify critical skills to be maintained during planned reductions to the Civil Service and contractor work force.

MTPE will match its goals and objectives with the skill base at Headquarters and field installations to preserve critical skills during streamlining activities.

Strategy: Within hiring constraints, conduct an aggressive program of outreach to underrepresented groups

This strategy contains the following four elements:

- Carry out formal visitations to at least five nontraditional universities per year

- Support selection processes for Historically Black Colleges and Universities (HBCU) and Other Minority Universities (OMU) grants

- Ensure that minority representation is an element considered in grant approval

- By the end of FY 1995, develop and begin to implement a plan for increasing minority participation in MTPE peer review by 25 percent per year

Objective 6.2: Maintain world-class MTPE research capabilities.

Ground-based research and development facilities are as critical to MTPE's success as its space-based assets. In the midst of pressure to reduce operations costs, MTPE must preserve the capabilities required to equip MTPE personnel to accomplish its research objectives.

Strategy: Maintain world-class capability in the following national research facilities essential to carrying out the MTPE program.

Field Installations	Facilities
Ames Research Center	Aircraft MTPE Operates - 3-ER-2s - DC-8 - C-130 Image Processing Laboratory
Goddard Space Flight Center	EOSDIS Building Earth Systems Science Building Detector Development Lab HPCC, the High Performance Computing Center Instrument Construction and Development Lab Wave Tank at Wallops
Jet Propulsion Laboratory	Environment Test Facility/Range Observational Instruments Laboratory Spacecraft Assembly Facility Multimission Imaging Processing Laboratory Microdevices Laboratory
Langley Research Center	Distributed Active Archive Center Electronic Design and Development Facility Spaceflight Development Laboratory Solid Laser Laboratory
Marshall Space Flight Center	Global Hydrology and Climate Center Distributed Active Archieve Center Lightning Imaging Sensor Calibration Facility Earth Science Applications Computing Facility

Objective 6.3: Ensure the continued capability of GSFC to support world-class research in all NASA science enterprises.

GSFC is the focus of activity for MTPE as well as a key player in space science and space communications. The long-term health of GSFC is essential to scientific excellence and mission success in these areas.

Strategy: Develop a 5-year Institutional Management Plan for GSFC.

This plan should be developed in conjunction with other Strategic Enterprises supporting research at GSFC. It should describe how participating Enterprises will jointly ensure adequate investment in the health of the Center. The plan will be kept current through annual updates keyed to the updates of the Strategic Enterprise Plan.

Objective 6.4: Foster new cooperative activities and partnerships among the NASA MTPE, university, and industry communities.

To achieve its mission, MTPE must continually enhance its ability to utilize expertise and capability from a broad range of scientific, technical, and educational institutions. The base from which MTPE draws must be as broad as possible, both to leverage the Nation's resources across institutional lines and to foster continued interest and intellectual investment in the Enterprise. MTPE must ensure that the Nation's colleges and universities play a fundamental and stimulating role in the basic research, process analysis, and scientific modeling activities conducted by MTPE. Industrial organizations must be encouraged to contribute new technical solutions to MTPE efforts.

Strategy: Each year, reach new agreements with societies, informal education institutions, and private companies to share data.

New agreements must continue to be developed with professional societies, educational interests, and private companies to share scientific data and disseminate information to their customers.

Strategy: Develop cooperative research and educational consortia involving NASA MTPE field installations with government, university, and industry partners.

These partnering arrangements should build on the active participation in MTPE by the NASA field installations and provide leveraging of resources and capabilities between the installations and a variety of external organizations.

Section IX - Linkages to Other Strategic Enterprises

The goals, objectives, and strategies of MTPE could not be accomplished without support from the other NASA Strategic Enterprises and the Strategic Functions. The Human Exploration and Development of Space (HEDS) Enterprise provides the services of the Space Shuttle for MTPE's Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) and Atmospheric Laboratory for Applications and Science (ATLAS) missions. HEDS will also provide accommodations on the Space Station for SAGE III, which is one of the instruments in the EOS program. There is also an interaction between MTPE and HEDS science and technology goals and objectives with respect to global medicine and disaster response. MTPE acquires transportation to orbit services from HEDS and the Space Technology Enterprise. In addition, Space Technology assists MTPE with the transfer of technologies to the private sector.

MTPE is partnering with the Aeronautics Enterprise in the study of the impact of aircraft emissions on the atmosphere. MTPE and the Office of Aeronautics, through its Atmospheric Effects of Aviation Program (AEAP), jointly support the instrument development, field measurements, and modeling efforts needed to address this issue in the context of other atmospheric issues. AEAP studies aviation-specific issues, such as aircraft engine emissions and aircraft wake-near field interactions. Aeronautics also supports the development of new aircraft and instruments through its ERAST program.

MTPE and the Scientific Research Enterprise meet in the mesosphere. Both MTPE and Scientific Research provide data on solar radiation and particle inputs into the atmosphere, as well as the chemical and dynamical state of the mesosphere and lower thermosphere. Scientific Research and MTPE will together explore how the regions of the atmosphere above and below the stratopause are affected by (and affect) each other, by examining the role of chemical, radiative, and dynamical coupling processes.

Finally, the Space Technology Enterprise develops new Earth-orbiting spacecraft and remote sensing instrument technologies that MTPE will incorporate in EOS. The Lewis and Clark spacecraft are of particular importance in this arena.

As with all other NASA Strategic Enterprises, MTPE relies on NASA's Strategic Functions to provide some essential tools. The Communications Function supplies tracking, up/down link, and flight dynamics services. The Human and Physical Resources Functions ensure that MTPE's essential personnel and facility needs are satisfied. The Office of Safety and Mission Assurance ensures that safety, reliability, and quality needs are being met.

Section X
Summary

The MTPE Enterprise is a critical investment in the future of our Nation and our world. Both the importance of MTPE's task and the scarcity of Federal resources demand that the Enterprise sets the wisest possible course and pursue it diligently. The MTPE Strategic Enterprise Plan goals are established to guide in implementing the Enterprise's vision and mission according to principles of operation in the best interests of MTPE customers. This Plan will be made widely available among MTPE team members and customers, and it will be kept current with their input.

In this Plan, MTPE has endeavored to make its strategies as specific and measurable as practicable so that it might gauge its own performance. These strategies will be subdivided into tasks and assigned to teams or individuals for implementation. This will complete the flow from the mission all the way through to individual performance plans, orchestrating all MTPE team members in a concerted assault on the challenges ahead.

Appendix 1
Acronym List

ACRIM	Active Cavity Radiometer Irradiance Monitor
ADEOS	Advanced Earth Observing System
AEPA	Atmospheric Effects of Aviation Program
ALT-L	Laser Altimeter
ALT-R	Radar Altimeter
ATLAS	Atmospheric Laboratory for Applications and Science
BOREAS	Boreal Ecosystem-Atmosphere Study
CENR	Committee on Environment and Natural Resources
CERES	Cloud and Earth's Radiant Energy System
CHEM	Chemistry
COFUR	Cost of Fulfilling User Requests
DAAC	Distributed Active Archive Center
DOE	Department of Energy
DOL	Department of Interior
ECS	EOSDIS Core System
EOS	Earth Observing System
EOS AM	EOS Morning Crossing (Descending) Mission
EOS PM	EOS Afternoon Crossing (Ascending) Mission
EOSDIS	Earth Observing System Data and Information System
EPA	Environmental Protection Agency
ERAST	Environmental Research Aircraft Sensor Technology
ERBS	Earth Radiation Budget Satellite
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ESSE	Earth System Science Education
ETM+	Enhanced Thematic Mapper Plus
FAA	Federal Aviation Administration
GCM	General Circulation Model
GCOS	Global Climate Observing System
GSFC	Goddard Space Flight Center
HBCU	Historically Black Colleges and Universities
HEDS	Human Exploration and Development of Space
IAI	Inter-American Institute
IGBP	International Geosphere-Biosphere Program
IPCC	Intergovernmental Panel on Climate Change
JOVE	Joint Ventures
Landsat	Land Remote-Sensing Satellite
LATI	Landsat Advanced Technology Instrument
LIS	Lightning Imaging Sensor
LPM	Landsat Program Management

MAC	Multi-Aircraft Campaign
MODIS	Moderate-Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MTPE	Mission to Planet Earth
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSCAT	NASA Scatterometer
NSF	National Science Foundation
OMB	Office of Management and Budget
OMU	Other Minority Universities
OSAT	Office of Space Access and Technology
OSS	Office of Space Science
OSTP	Office of Science and Technology Policy
RADARSAT	Canadian Space Agency Radar Satellite
RPV	Remotely Piloted Vehicle
SAGE	Stratospheric Aerosol and Gas Experiment
SAR	Synthetic Aperture Radar
SeaWiFS	Sea-Viewing Wide-Field-of-View Sensor
SIR-C/X-SAR	Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Ocean Topography Experiment
TRMM	Tropical Rainfall Measuring Mission
UARS	Upper Atmosphere Research Satellite
USAF	United States Air Force
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
WCRP	World Climate Research Program

Appendix 2 Definitions

Matrix User Group Definitions

Policy Makers: This user group includes all individuals, organizations, and governments that establish policy, pass legislation, or negotiate treaties dealing with environmental issues. This includes members of the legislative and executive branches of Federal, State, Local, and foreign governments. This includes those private and charitable organizations that actively lobby for policies, legislation, or treaties dealing with environmental issues. Examples include: The Executive Office of the President (Office of Management and Budget (OMB) and Office of Space and Technology Policy (OSTP)); congressional authorization committees; congressional appropriation committees; and congressional issue committees such as the House Committee on Science Space and Technology.

Environmental Decision Makers: Those groups with the authority to implement the policy made by the policy makers group. This group includes:

✣ *Regulatory Agencies:* Federal, State, or local agencies that translate policies into regulations and standards to be followed by both the public and private sector—e.g., Environmental Protection Agency (EPA), Department of Interior (DOI), etc. This user group includes all individuals and organizations that write and enforce environmental regulations. This includes Federal, State, and local agencies. This does not include the legislative bodies in the Federal, State, and local governments. This includes the use of environmental data in the legal system.

✣ *Industry:* Commercial entities THAT impact the environment as a consequence of the conduct of their business.

✣ *Agricultural and Industrial Managers:* Entities whose decisions impact land use and its attendant environmental impacts, such as the conversion of forest or arid acreage to farm land or the development of open lands into residential or commercial properties.

✣ *Natural Resource Managers:* This user group includes all individuals and organizations that decide the use, consumption, or management of any natural resource. This includes all organizations that own or control land, water, air, or mineral resources, such as Federal and State agencies, mining and timber companies, fishing fleets, farmers, etc. This includes those Federal, State, and local agencies or organizations that make zoning and land use decisions and those private and charitable organizations that clean up, control, or maintain resources for use by the general public.

Government and External Science Communities: The scientific community—university and other scientists who require environmental information as an input to the conduct of their research, or in the education and training of college and postgraduate students.

✣ *The Earth Science Community:* Environmental researchers/scientists using existing data, field experiment data, satellite data, or in situ data to produce new environmental knowledge. The permanent data sources could include ground research stations, ocean buoys, regularly scheduled observations, satellites, etc. This includes those researchers who develop and maintain operational algorithms for the continuous or routine processing of raw data into higher level products.

✣ *Non-Earth Science Community:* Researchers in other fields who use existing environmental data in their field of study—e.g., economists and environmental assessment teams. This latter group includes all individuals and teams that perform focused studies on environmental issues in support of the policy-making process. Instead of pure research, these individuals and teams focus on solutions to specific environmental issues. The teams produce environmental, economic, and cost impact statements, reports, and assessments.

Consumers of Information: Entities that use environmental information as an input to their processes of production or decision-making.

✣ *The General Public:* Individuals, families, and neighborhood or community groups that use environmental information along with a variety of other types of information in making the whole host of decisions that affect their everyday lives.

✣ *International Users:* Foreign country users of MTPE data. These include policy makers and researchers.

✣ *Operational Users:* Entities that use environmental information along with a variety of other types of information in making near-term decisions affecting their operations and the services they provide to their customers—e.g., FAA and NOAA.

✣ *The Education/Teaching Community (K–12):* This user group covers elementary schools (kindergarten through eighth grade), high schools, 2 year colleges, and community colleges. This user group includes both educators and students who use existing environmental information for educational purposes.

✣ *Value Added Industry:* Firms that use environmental information to produce higher level environmental information products. This user group includes all individuals and organizations that use free, public data to generate environmental products for sale to the general public. The products include location services, derived data, enhanced access, assessments, etc.

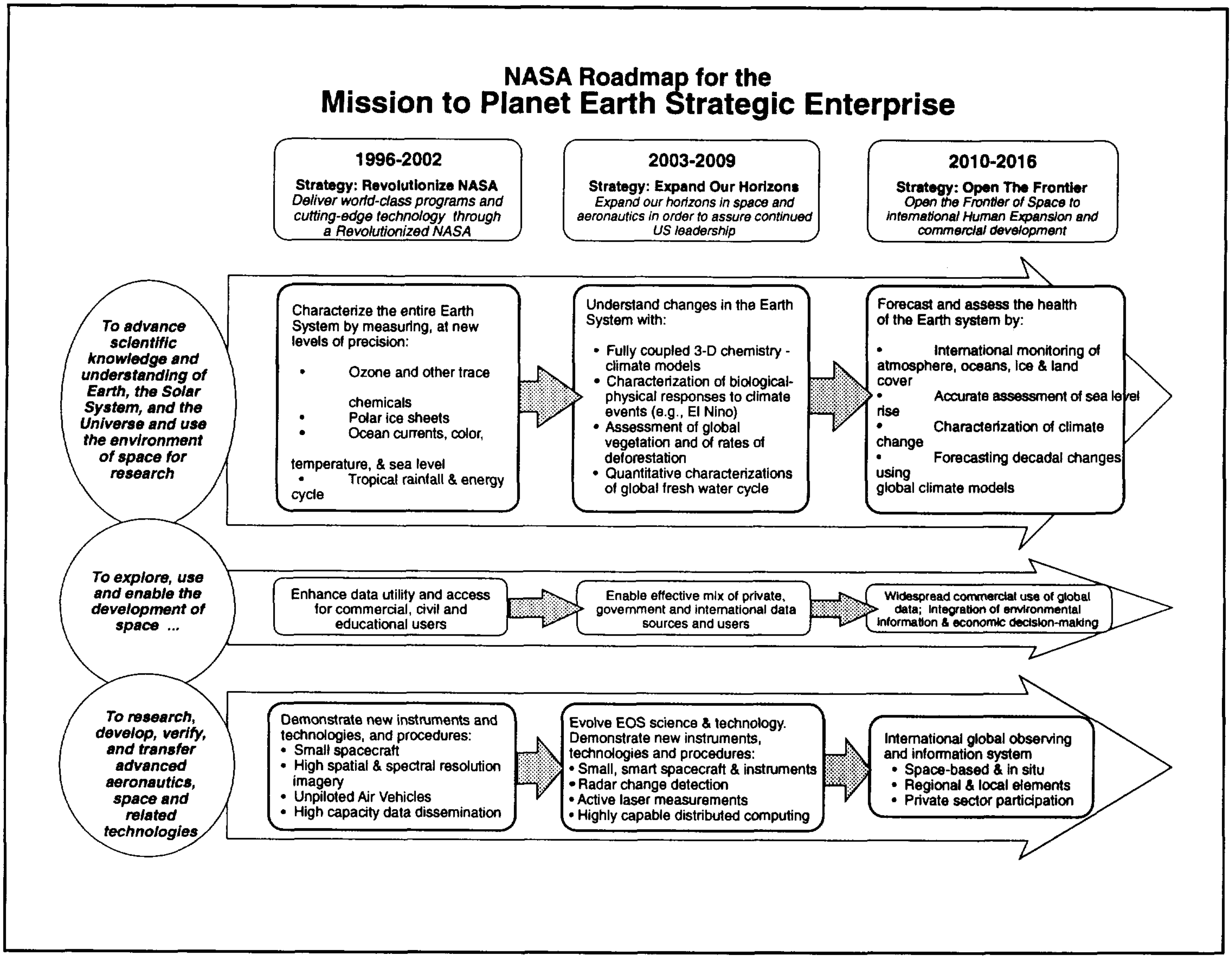
✣ *Libraries:* This user group includes all libraries that distribute environmental information and data. This includes both the libraries and their patrons. Libraries include Federal, State, local, educational, and technical libraries and their associated professional organizations. The patrons include all of the other user groups and the general public.

Consumers of Advanced Technology: Entities that use technologies produced in the course of MTPE activities, whether for Earth System Science-related work or not.

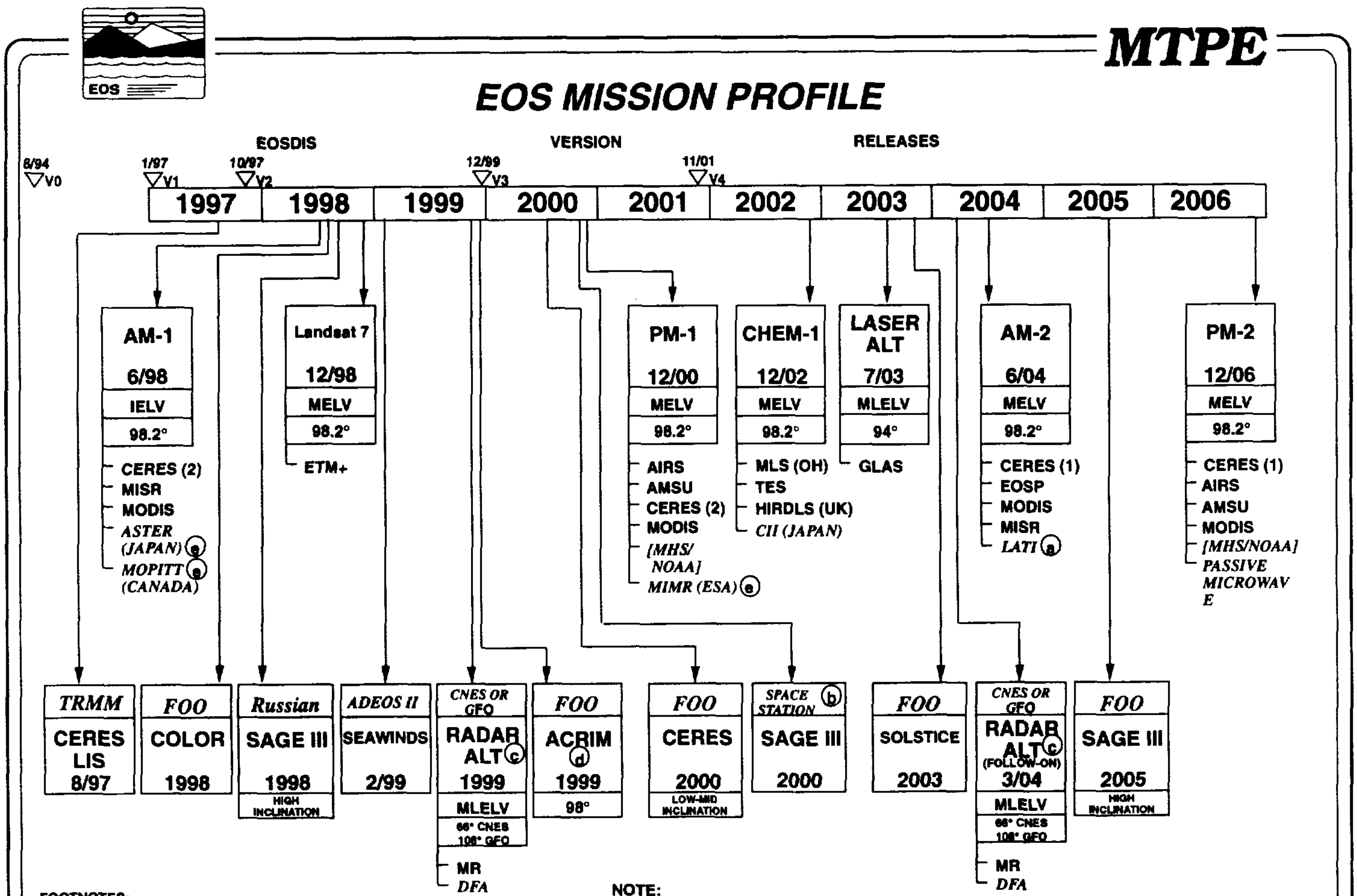
✣ *Commercial:* Firms that find applications for MTPE developed technology that can be employed in existing or new areas of business—e.g., oil companies that use atmospheric trace gas detection equipment to spot pipeline leaks.

✣ *Government Agencies:* Agencies that enter into agreements with NASA-MTPE for the purpose of obtaining technologies with applications to those agencies' missions.

Appendix 3
Science Timeline, 1995–2030



Appendix 4
Mission Schedule



FOOTNOTES:

(a) NOT CURRENTLY BUDGETED
(b) SAGE III INSTRUMENT REPLACED EVERY 5 YEARS
(c) ACCOMMODATIONS UNDER REVIEW
(d) SERIES OF FLIGHTS
(e) ALGORITHM ACTIVITIES FUNDED BY EOS

NOTE:

- SPACECRAFT REFLIGHTS CONTINUE BEYOND 2006 TO SUPPORT GENERATION OF THE 15-YEAR SCIENCE DATA SET
- *ITALICS DENOTE ELEMENTS NOT FUNDED BY THE EOS PROGRAM*
- SECOND MOPITT FLIGHT OPPORTUNITY - TBD

Appendix 5
Internet Addresses

DAAC's: Distributed Active Archive Centers

ASF DAAC:
http://goofy.gi.alaska.edu:12355

EDC DAAC:
http://sun1.cr.usgs.gov/landdaac/landdaac.html

Goddard DAAC:
http://daac.gsfc.nasa.gov

JPL DAAC:
http://seazar.jpl.nasa.gov

Langley DAAC:
http://eosdis.larc.nasa.gov

Marshall DAAC:
http://wwwdaac.msfc.nasa.gov

NSIDC DAAC:
http://eosims.colorado.edu:1733

ORNL DAAC:
http://www-eosdis.ornl.gov

SEDAC DAAC:
http://www.ciesin.org

Earth Data & Imagery

AVHRR Land Pathfinder:
http://xtreme.gsfc.nasa.gov

JPL TOPEX/POSEIDON Images:
http://podaac-www.jpl.nasa.gov/topex

AVISO TOPEX/Poseidon data:
http://192.134.216.41

Oceans SST Pathfinder (NOAA/NASA):
http://sst-www.jpl.nasa.gov

NASA/JPL Imaging Radar Homepage:
http://southport.jpl.nasa.gov

SIR-C/XsSAR images:
http://www.jpl.nasa.gov/sircxsar.html

The World-Wide Web Library: Oceanography:
http://www.mth.uea.ac.uk/ocean/oceanography.html

Appendix 6
Statutes

The **National Aeronautics and Space Act** of 1958 (as amended) contains the following features relevant to MTPE:

✣ Title I lists the objectives of U.S. aeronautics and space activities. First among these is: "(1) The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space."

✣ Title II defines the functions of NASA, which include:

"(2) arrange for participation by the scientific community in planning scientific measurements and observations to be made through the use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations;

(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

✣ Title IV serves to "authorize and direct the Administration to develop and carry out a comprehensive program of research, technology, and monitoring of the phenomena of the upper atmosphere so as to provide for an understanding of and to maintain the chemical and physical integrity of the Earth's upper atmosphere..."

The **Global Change Research Act of 1990** named NASA as a member of the Committee on Earth and Environmental Sciences [succeeded by the Committee on Environment and Natural Resources] and mandated the establishment of a National Global Change Research Plan and a U.S. Global Change Research Program.

The **Land Remote Sensing Policy Act of 1992** brought the Landsat program back under the management of the Federal Government and established a Landsat Program Management (LPM) entity consisting of NASA and DoD [DoD subsequently withdrew and was replaced by Executive action with DOC/NOAA and DOI/U.S. Geological Survey (USGS)]. LPM is responsible for negotiating data policy for Landsats 4 and 5 with the Landsat 6 contractor, and acquiring, operating, and disseminating data at Cost of Fulfilling User Requests (COFUR) from a Landsat 7 spacecraft. Within LPM, NASA is responsible for acquiring the spacecraft and ground systems. In addition, NASA is charged with pursuing a technology demonstration program in preparation for achieving data continuity beyond the lifetime of Landsat 7.

Appendix 7
Key Studies and Reports

Earth System Science: A Program for Global Change, Earth Systems Sciences Committee of the NASA Advisory Council (Bretherton Report)
- *Earth System Science Overview,* May 1986

The Crisis in Space and Earth Sciences, November 1986 by the Space and Earth Science Advisory Committee of the NASA Advisory Council

Earth System Science: A Program for Global Change, Earth Systems Sciences Committee of the NASA Advisory Council (Bretherton Report)
- *Earth System Science: A Closer View*, January 1988

Our Changing Planet: The U.S. Global Change Research Program, 1989 and annually thereafter, formerly by the Committee on Earth and Environmental Sciences of the Federal Coordinating Committee on Science, Engineering and Technology, and currently by the Committee on Environment and Natural Resources of the National Science and Technology Council

Scientific Assessment of Climate Change, 1990, World Meteorological Organization and United Nations Environment Programme

1993 EOS Reference Handbook, NASA Headquarters (edited by Asrar and Dokken)

Global Change Research and NASA's Earth Observing System, 1993, Office of Technology Assessment, U.S. Congress

EOS Science Strategy, 1994, Ghassem Asrar, EOS Program Scientist, NASA Headquarters

Appendix 8 - List of Goals, Objectives, and Strategies

Goal 1

Increase scientific understanding of the Earth as an integrated environmental system and of its vulnerability to natural variations and human influences.

Objective 1.1: Determine evidence for the occurrence of global change.

Strategy: Examine historic data sets for climate, atmospheric composition, and land use.

Strategy: Develop new techniques for the detection of global change.

Strategy: Maintain existing measurement networks and upgrade as appropriate to ensure adequacy of data.

Objective 1.2: Understand causes and significance of global change.

Strategy: Develop component and coupled models for retrospective analysis.

Strategy: By 1996, use data from the Boreal Ecosystem-Atmosphere Study (BOREAS) to improve parameterizations of the boreal forest biome in atmospheric general circulation models (GCM's).

Strategy: By 1997, make available a 15-year assimilated data set for the physical state of the atmosphere, and by 2000 expand in scope the assimilation system to make use of a broader range of data types.

Strategy: By 1997, assemble and organize in a uniform data base all of the Multi-Aircraft Campaigns (MAC's) and Spaceborne Imaging Radar-C (SIR-C) data for use in developing and validating hydrology and coupled land atmosphere models.

Objective 1.3: Determine predictability of changes, including their spatial and temporal dependence.

Strategy: Develop models that can be used for both retrospective and prognostic purposes.

Strategy: By 1998, make available three-dimensional (3-D) atmospheric chemistry assessment models to simulate ozone distributions in the upper troposphere and in the stratosphere, and their dependence on natural and human-induced forcing, including the current subsonic and projected supersonic aircraft fleets.

Objective 1.4: Develop improved systems for quantification of impacts of natural hazards and of possible mitigation strategies.

Strategy: By 1996, develop a strategy for monitoring floods, estimating damage, and supporting mitigation strategies using currently available remote sensing data.

Goal 2

Observe and characterize the entire Earth system and make resultant data widely available.

Objective 2.1: Add multiyear data sets from the atmospheric chemistry and oceanographic disciplines to those from the meteorology and land imaging disciplines, and build on the lessons learned as a prelude to the overall, integrated program called EOS.

Strategy: Continue providing meteorology and land imaging data while adding data from atmospheric chemistry and oceanography.

Strategy: Provide a prototype data system to demonstrate the concepts of, and to guide the development of, the data and information system necessary to accomplish the objectives of MTPE Phase 2.

Objective 2.2: Provide an 18-year base of data from which to address the fundamental physical, chemical, and biological phenomena that govern and integrate the Earth system.

Strategy: Provide, via several series of spacecraft, the data needed to support the integrated studies of the EOS program.

Strategy: Develop instruments, in addition to those being flown on NASA spacecraft, to be flown on flights of opportunity.

Strategy: Issue a new EOS Announcement of Opportunity for New Science Teams and Interdisciplinary Investigations in 1995.

Strategy: Provide the data and information handling infrastructure needed to fulfill the EOS mission objectives.

Objective 2.3: Provide a complementary inventory of aircraft, balloon, and ground-based observations.

Strategy: Maintain and make available the current fleet of aircraft employed for MTPE research campaigns.

Strategy: Develop and deploy a set of remotely piloted vehicles for high-altitude airborne research.

Strategy: Conduct field campaigns to make essential observations to which space-based assets are not suited.

Goal 3

Contribute to wise and timely national and international environmental policy.

Objective 3.1: Ensure the availability of MTPE data and understanding for policy makers.

Strategy: Provide EOSDIS-distributed data products that respond to policy-maker information and analysis requirements as defined in annual customer surveys by 1997.

Strategy: Facilitate the increased understanding of global change issues among policymakers through the provision of sample user application scenarios by 1997.

Objective 3.2: Support assessments of critical environmental issues.

Strategy: Support all formal integrated assessments on the global environment beginning in 1995.

Objective 3.3: Using models, provide predictive capabilities to anticipate future states of the environment.

Strategy: Apply at least one integrated model of the global atmosphere, oceans, and land surface incorporating space-derived data by 1998.

Goal 4

Foster the development of an informed and environmentally aware public.

Objective 4.1: Support curriculum development and resources to train the next generation of Earth scientists.

Strategy: Increase Global Change Fellowships in line with the EOS budget through the year 2000.

Strategy: Encourage the increase in the number of colleges that offer an interdisciplinary approach to Earth system science studies by the year 2000.

Strategy: Engage MTPE scientists in the review of emerging K–12 science standards.

Objective 4.2: Emphasize programs that enable educators to teach Earth system science.

Strategy: By FY 1996, identify a set of core MTPE science issues and use them as a basis for augmenting, expanding, or deleting existing educational programs.

Strategy: Conduct at least one joint teacher workshop annually with other USGCRP agencies and/or outside organizations.

Strategy: In light of the weak area of pre-service teacher training, MTPE should support the development of at least one new tool or program annually to be used in introductory science courses for future teachers.

Objective 4.3: Develop greater support by scientists for broad education efforts.

Strategy: Incorporate an educational outreach component into relevant research announcements by FY 1996.

Strategy: Beginning in FY 1995, develop new education products using integrated product teams consisting of scientists and educators.

Strategy: By FY 1996, establish rotational opportunities for teachers to visit USGCRP agency research facilities.

Objective 4.4: Make information and assessments available to the general public.

Strategy: By FY 1996, support the development of a set of general global change communications products with other USGCRP agencies.

Strategy: In FY 1995, develop an Internet "Home Page" for MTPE information.

Goal 5

Expand and improve the scientific return on investment by seeking and using advanced, cost-effective engineering and scientific techniques having potential for multiple uses.

Objective 5.1: Identify and assess the availability of new technologies and procedures for infusion into the ongoing program and for incorporation into follow-on developments.

Strategy: Prepare and maintain a plan for advanced technology development.

Strategy: Conduct studies that identify and assess new approaches to improving performance, reducing costs, and/or reducing risks for carrying out the multidecade MTPE program.

Objective 5.2: Seek to apply cost-effective technology and techniques developed outside the MTPE program.

Strategy: Cooperate with other NASA organizations in the identification and selection of mutually beneficial advanced technologies, systems, and procedures.

Strategy: Cooperate with other Federal Agencies, non-Federal partners, and international organizations *in the identification and selection of mutually beneficial advanced technologies, systems, and procedures.*

Objective 5.3: Develop advanced spacecraft and instrument capabilities, operations support systems, and data management systems.

Strategy: Aggressively pursue, with other NASA organizations, mutually beneficial advanced development ventures.

Strategy: Provide for observing capabilities not currently available in MTPE, and begin a Small Earth Probes Initiative by 1999.

Strategy: Provide for regular system technology improvements in EOSDIS through version 2 in 1997.

Objective 5.4: Pursue technology transfer and commercialization opportunities.

Strategy: Incorporate technology transfer and commercialization policies as part of each major acquisition process.

Goal 6

Ensure availability of human and physical resources necessary to achieve the MTPE mission over the long term.

Objective 6.1: Continue to develop a highly skilled and motivated work force that reflects the diversity of people in America.

Strategy: Identify critical skills to be maintained during planned reductions to the Civil Service and contractor work force.

Strategy: Within hiring constraints, conduct an aggressive program of outreach to underrepresented groups.

Objective 6.2: Maintain world-class MTPE research capabilities.

Strategy: Maintain world-class capability in the following national research facilities essential to carrying out the MTPE program.

Objective 6.3: Ensure the continued capability of GSFC to support world-class research in all NASA science enterprises.

Strategy: Develop a five-year Institutional Management Plan for GSFC.

Objective 6.4: Foster new cooperative activities and partnerships among the NASA MTPE, university, and industry communities.

Strategy: Each year, reach new agreements with societies, informal education institutions, and private companies to share data.

Strategy: Develop cooperative research and educational consortia involving NASA MTPE field installations with government, university, and industry partners.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