NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WEATHER PROGRAMS

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office has continued to improve NASA's weather support capabilities for both manned and unmanned space launch vehicles. It is expected that these improvements will strengthen and enhance the information provided to the ground-based decision-makers and astronaut observers to insure that NASA achieves the best operational posture for Space Shuttle launches and landings. The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at Cape Canaveral Air Station of Kennedy Space Center (KSC) and Johnson Space Center to support the Space Shuttle program. The focus is on detecting and forecasting the mesoscale weather events which strongly impact Shuttle ground processing, launches, and landing operations. NASA's also performs aviation research to improve safety, develop weather information technologies, and increase aviation system capacity. Advanced operations technologies can increase the number of operations per runway in all weather conditions. The research applies to both commercial and general aviation.

OPERATIONS

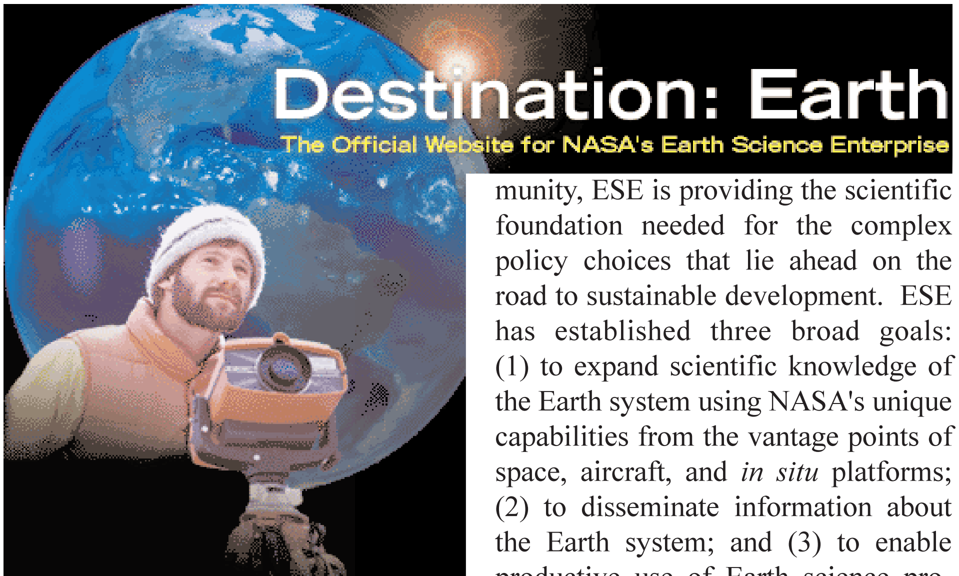
The goal of the National Aeronautics and Space Administration (NASA) operations program is to provide the specialized meteorological data needed by forecasters at Cape Canaveral Air Station and the Spaceflight Meteorology Group at Johnson Space Center (JSC) to support the Space Shuttle and Expendable Launch Vehicle programs. The focus is on detecting and forecasting the mesoscale weather events that strongly impact ground processing, launch, and landing operations.

This goal requires exploitation of the latest technology. The Applied Meteorology Unit (AMU), collocated with the Air Force's Range Weather Operations, provides a facility to evaluate and, if warranted, transition new meteorological technology into operations. For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of Kennedy Spaceflight Center's (KSC) frequent mesoscale summer thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program-Space Shuttle, Department of Defense (DOD), and commercial. Special attention has been given to evaluating mesoscale numerical models. The AMU functions under a joint NASA, Air Force, and National Weather Service (NWS) Memorandum of Understanding. AMU tasks during FY 2000 include: (1) develop statistical short-range forecast tools and tools to forecast thunderstorm anvil development, movement, and dissipation; (2) provide technical advice to the Eastern Range (ER) on the procurement, development, testing, and integration of weather infrastructure items; (3) improve use and exploitation of the 5cm WSR-74C radar with SIGMET processor; (4) detect and analyze chaff signatures for source region(s); (5) analyze performance of the models that predict path of toxic and debris clouds after an unplanned explosion of a satellite launch rocket; (6) evaluate the ER Dispersion Assessment System (ERDAS), especially its meteorological component; (7) install the Local Data Integration System, developed by the AMU, at NWS and at JSC's Spaceflight Meteorology Group; and (8) provide technical advice to the Planet Mars Ascent Vehicle program (which will return samples from the Martian surface to earth), and on electric field measurements and lightning detection for incorporation into future Mars exploration programs.

The development of a new toxic model system ERDAS was completed in March 1999. NASA was the contracting agency for ERDAS development; funding was sent to NASA KSC by the Air Force. Operational implementation is complete. However, the AMU continues to work on Range Standardization and Automation (RSA). RSA is a major Air Force program to evaluate and document the day-to-day capabilities and limitations of ERDAS. Deliveries of weather sensors, models, and control and display systems began in FY 2000 and will conclude in FY 2001. Transfer of the KSC 50 MHz Doppler Radar Wind Profiler to the ER and modernization of its electronic components is proposed. There are considerable issues related to the pending changes to the Eastern and Western Ranges' meteorological infrastructures. The Air Force and NASA weather communities have expended considerable resources to solving potential major deficiencies. NASA KSC, JSC, and Marshall Space flight Center (MSFC) depend heavily on this infrastructure for their weather support.

SUPPORTING RESEARCH

The supporting research activities are sponsored by the NASA's Earth



Science Enterprise (ESE). The purpose of the ESE is to observe the global Earth environment, to understand the mechanisms that underlie natural and human-induced environmental changes, and to identify consequences that could impact human societies. In short, the purpose of the Enterprise is to provide scientific answers to the fundamental question:

How is the Earth changing and what are the consequences for human civilization?

A fundamental discovery made during the 20th Century is the existence of a multiplicity of linkages between diverse natural phenomena and interactions between the individual components of the Earth system. As a result, a new "Earth system science" concept was developed, with the aim of investigating the complex behavior of the total Earth environment in which the global atmosphere, the oceans, the solid Earth and ice-covered regions of the Earth, and the biosphere all function as a single interactive system. Earth system science is an area of research with immense benefits to the Nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, ESE is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. ESE has established three broad goals: (1) to expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft, and *in situ* platforms; (2) to disseminate information about the Earth system; and (3) to enable productive use of Earth science program science and technology in the public and private sectors. NASA has long been pursuing a vision of an interdisciplinary Earth system science. Traditional scientific disciplines have already progressed a long way in the study of the atmosphere, biosphere, land, and oceans as quasi-independent components of a stationary Earth system, while treating the interfaces between components as prescribed boundary conditions. Building on these scientific achievements, the strategy of Earth system science is to promote a "coordinated [research] effort between adjacent scientific disciplines and observation programs focused on common interrelated problems that affect the Earth as a whole" (*Toward an International Biosphere-Geosphere Program*; National Research Council (NRC), 1983). The ultimate goal of the NASA ESE is to achieve this synthesis and understand the interactive physical, chemical, and biological processes that govern the total Earth system. With this knowledge, NASA and its partners will develop prediction capabilities to quantify the effects of natural and human-induced changes on the global environment. Operational agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS), who are partners in this effort, can use these capabilities to improve weather and climate forecasting, natural resource management, and other services on which the Nation relies.

STRATEGY FOR ACHIEVING GOALS

The first Earth Science Research Plan, published in 1996, laid out a strategy for study in five Earth system science areas of: (1) maturing scientific understanding and significant societal importance; (2) land-cover and land use changes; (3) short-term climate events, natural hazards research, and applications; (4) long-term climate change research; and (5) atmospheric ozone research. The plan also outlined some 20 related areas of research, which round out the Earth science contribution to Earth system science. NRC recognized the complexity of global Earth environment issues, the multiplicity of interactions between component processes and the cross-disciplinary connections they evoke (*Research Pathways for the Next Decade-Overview*; NRC, 1998). In the face of such complexity, the NRC outlined a diversity of unsolved scientific questions that call for further study, but also emphasized the need for a focused, scientific strategy, concentrating efforts and resources on critical scientific problems that are most relevant to national policy issues. Responding to the latter recommendation, the ESE is developing a targeted research program, focused on an updated set of specific science questions that can be addressed effectively with NASA's capabilities, and formulating comprehensive research strategies that can lead to definitive scientific answers, as well as effective applications of those scientific results.

The key research topics studied by NASA's ESE fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies in essence to all research areas of NASA's Earth science program, although it is particularly relevant to the problem of climate change--a major Earth science-related issue facing the countries of the world. The ESE has articulated a set of science questions which its observational programs and research, modeling, and analysis activities are directed at answering.

§ *How does the Earth change naturally?*

§ *What are the primary forcings of the Earth system by human activities?*

§ *How does the Earth system respond to natural and human-induced changes?*

§ *What are the consequences of changes in the Earth system for human civilization?*

§ *How can we predict the changes in the Earth system that will take place in the future?*

NASA expects that expanded scientific knowledge of Earth processes and the utilization of advanced space-based and airborne observing techniques or facilities developed by NASA will result in practical applications beneficial to all citizens. Examples of these applications may include the prediction of impacts of environmental changes on fisheries, agriculture, and water resources; quantitative weather and hydrologic forecasts over an extended range of one-to-two weeks; and prediction of seasonal or longer-range climate variations, global air quality forecasts, and natural hazards risk assessments. NASA ESE has a role in demonstrating the potential applications.

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. NASA's Earth science research program comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive, and distribute global data sets; and research and analysis projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state, and local government use this knowledge to produce products and services essential to achieving sustainable development. Enabling us to get at the answers to the science questions, our top priority continues to be our existing near-term commitments with the launch of our first series of EOS and selected Earth probe missions that are nearing completion. In addition, NASA is committed to deliver a functioning data and information system to support the processing, archival, and distribution of data products for these missions. These satellites will propel the Enterprise into a new era of data collection, research, and analysis for which both the national and international Earth science community has been preparing over the last decade.

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the Terra, Aqua (formerly PM), Chemistry, Landsat-7, Jason-1, ICEsat, ACRIMSAT and follow-on missions) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change. The first EOS satellite launches began in 1999. Preceding the EOS were a number of individual satellite and Shuttle-based missions that are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instruments, launched in 1978, 1991, and 1996, measure ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated United States Earth Probe (Figure 3-NASA-1). France and the United States collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. QuikScat, which was launched after a one-year development, is providing measurements originally provided by the NASA Scatterometer (NSCAT), which mapped ocean winds for one year prior to an on-orbit failure of the Japanese ADEOS-I. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation. Also in 1997, ESE began purchasing ocean color data from a commercial vendor based on our joint investment in the SeaWifs instrument.

Figure 3-NASA-1. Artist drawing of ADEOS spacecraft in Earth orbit. (Source: NASA web site)

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy LIDAR (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. The first is the Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations -Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) mission. The second is the CloudSat mission. Both are scheduled for launch in 2003. The scientific objectives of the

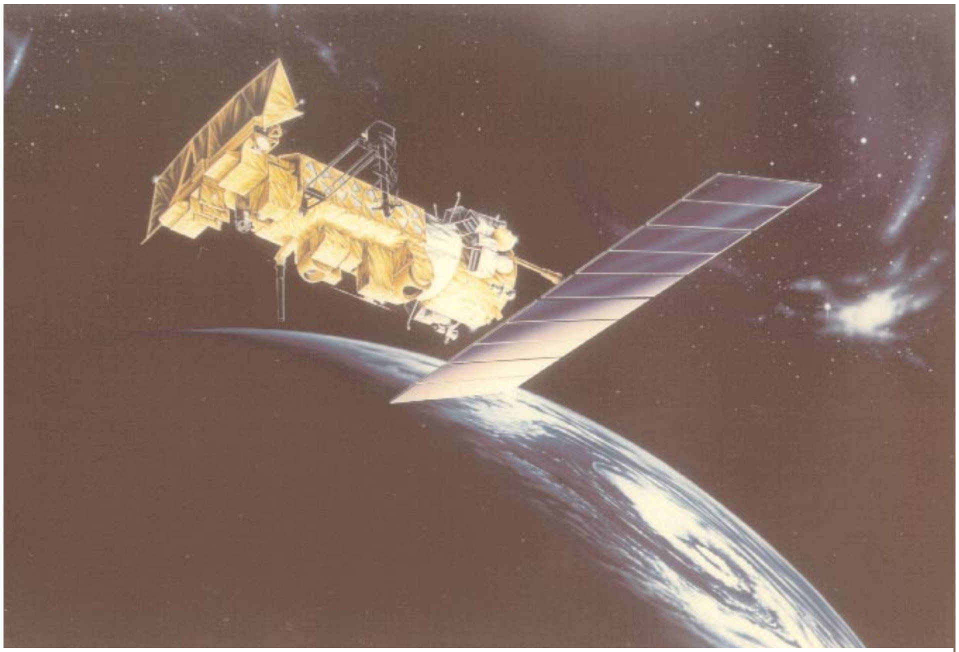


Figure 3-NASA-2. NPOES spacecraft in Earth orbit.

TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS Flight Model-5 has been completed and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, NASA has completed its re-planning and will be ready to fly FM-5, as QuikToms, on a United States vehicle and spacecraft in August 2000.

In developing its measurement/mission strategy, the ESE desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each successive future mission in the ESE flight program will be based on specific solicitation alternatives (e. g. Announcement of Opportunity, Request for Proposal, etc.) and competitive selection of instrument payloads and implementation options. In each solicitation, NASA will ask commercial industry to come forward and offer science-quality data that meet NASA requirements. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based, space-based measurement concept set is indispensable to guide these pre-mission technology developments, particularly, the Enterprise's Instrument Incubator Program. Our goal is to reach a mission development cycle of 2-3 years from the time of selection.

NASA ESE is developing a science implementation plan, which will drive the selection of Earth observation satellite missions in the 2003-2010 time frame. An early, high priority in this time frame is the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program (NPP). NPP will provide continuity with the Terra and Aqua missions as well as serve as a demonstration of instruments for the converged weather satellite program (Figure 3-NASA-2). NASA and the Integrated Program Office (IPO) jointly fund the NPP mission. The IPO consists of representative from the three agencies participating in NPOESS - NASA, NOAA, and the Air Force.

Data from Earth science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well-beyond the Earth science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists, and the general academic community, educators, state, and local government--anyone who wants the information.

Following the recommendation of the NRC, NASA is exploring the creation of a federation of Earth science information partners in academia, industry, and government to broaden the participation in the creation and distribution of EOSDIS information products. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products. This effort is part of a broader analysis of how ESE's approach to data and information systems services should evolve in the future.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every state within the United States are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with United States researchers, are also part of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to two scientists who first recognized that cholorflorocarbons provided a threat to upper atmospheric ozone (Figure 3-NASA-3). The research and analysis program is also the basis for generation of application pilot programs that enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

From FY 2000 on, there is increased emphasis on a viable Applications, Commercial, and Education (ACE) program that bridges our focused research and analysis and mission science investments with the Applications and Commercial Remote Sensing Program towards demonstration of new remote sensing data products for industry and regional and local decision-makers. The need is to focus on the dissemination of information to non-traditional Earth science customers, such as states, counties, and regional managers and decision-makers. This budget identifies initial funding requirements for the Digital Earth Initiative designed to develop usable, remote sensing-based information products for state and local users around the Nation and beyond. A base program is funded to put the essential tools in place and pilot several key demonstration projects. Eventually, NASA anticipates that our demonstration of this concept will allow products to reach a much broader user base--practically every state in the Union.

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. NASA's Earth science research program constitutes its contribution to the United States Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change. The USGCRP coordinates research among ten United States government agencies.

NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs. NASA has extensive collaboration with the NOAA on climate-related issues. The ESE is the responsible managing agent in NASA for the development of NOAA's operational environmental satellites. NOAA, NASA, and DOD jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the USGS on a range of land surface, solid Earth, and hydrology research projects. NASA and USGS collaborate in the Landsat-7 program and NASA, DOD, and USGS are working together on a third flight of the Shuttle Radar Laboratory modified to yield a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere

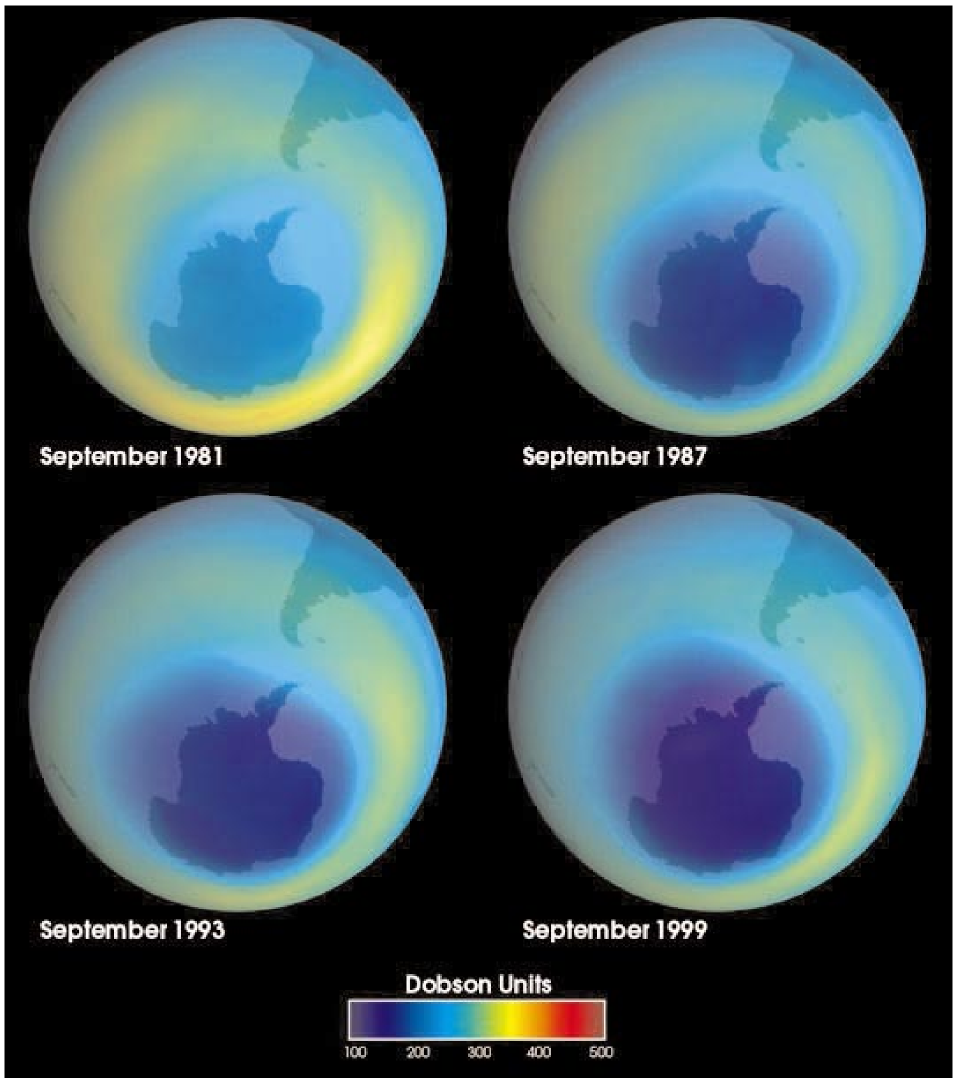


Figure 3-NASA-3. Observations of the Antarctic Ozone hole by NASA's Total Ozone Mapping Spectrometer (TOMS) Earth Probe show the progressive depletion of ozone. Values below 150 Dobson units indicate extremely low levels.

Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years, over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine, and others.

In addition to ensuring a robust science program, this budget contains a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes the New Millennium Program (NMP), Instrument Incubator and High Performance Computing and Communications (HPCC), an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft, and information system technologies.

Figure 3-NASA-4. Terra mission logo (Source: GSFC Web site)

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together, they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education, and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance, and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia. Technology efforts will be made in the following areas:

- •Advanced instrument and measurement technologies for new and/or lower cost scientific investigations;
- •Cutting-edge technologies, processes, techniques, and engineering capabilities that reduce development, operations costs, and mission risk and that support rapid implementation of productive, economical, and timely missions;
- •Advanced end-to-end mission information system technologies: technologies affecting the data flow from origination at the instrument detector through data archiving for collecting and disseminating information about the Earth system, and enabling the productive use of Enterprise science and technology in the public and private sectors.

Terra (formerly AM) was recently launched on December 18, 1999 (Figure 3-NASA-4). Terra will provide key measurements that will significantly contribute to our understanding of the total Earth system. The instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 was also launched in 1999. Landsat-7's single instrument, the Enhanced Thematic Mapper Plus (ETM+), is making high spatial resolution measurements of land surface and surrounding coastal regions. This mission is successfully providing data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, and other civil and commercial purposes.

With the EOS missions, such as QuikScat, Terra, Landsat-7, and ACRIMSAT that were launched in 1999, NASA is beginning to turn flight data into information. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users, such as regional Earth science applications centers and Earth science information partners. Efforts are also under way to fuse science data, socio-economic data, and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The first of two cooperative missions with the Russian Space Agency (RSA), the Meteor-3M (1) Stratospheric Gas and Aerosol Experiment (SAGE III) mission, had been planned for launch in 1999. At this time, it is uncertain that the Russians will meet their commitment to be ready to launch SAGE III in FY 2000. The instrument is completed and in storage at LaRC in the meantime but will not be shipped due to safety-related issues until the spacecraft is ready to accommodate its integration. This mission will collect global profiles of key gaseous species from the troposphere to the mesosphere. The science team will investigate spatial and temporal variability and investigate the effects of aerosols and clouds on the Earth's environment. The Russian METEOR-3M (2) spacecraft had planned to carry the last planned TOMS into orbit in 2000, providing continuity in the essential measurement of the total column of ozone in the stratosphere. This past year, NASA learned that Russia would not be able to meet its goals for producing a spacecraft and launch vehicle for the TOMS instrument. Since then, NASA and the RSA mutually agreed to terminate cooperative activities on the project. NASA is currently implementing QuikToms using an United States provided launch vehicle and spacecraft.

The QuikScat spacecraft was launched in April 1999. QuikScat, carrying instruments to collect sea surface wind data, is filling the gap in such critical data between ADEOS-I, which failed in June 1997 after seven months on-orbit, and ADEOS-II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikScat. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but the ESE still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikScat. It now appears that ADEOS-II will be launched no earlier than late 2001 with the delay due in part to a failure of a Japanese launch vehicle.

The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) was launched on December 20, 1999 providing for the continuation of the long-term, quantitative understanding of the solar forcing of Earth's climate.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

AVIATION WEATHER RESEARCH

NASA is performing research that will substantially improve the display of weather information in the cockpit, will provide dramatic improvements in synthetic vision (electronic vision aids to see at night in poor visibility), turbulence detection, and icing protection. The research applies to commercial aviation as well as general aviation. Some of the research makes extensive use of data from the Global Positioning System (GPS) satellite network.

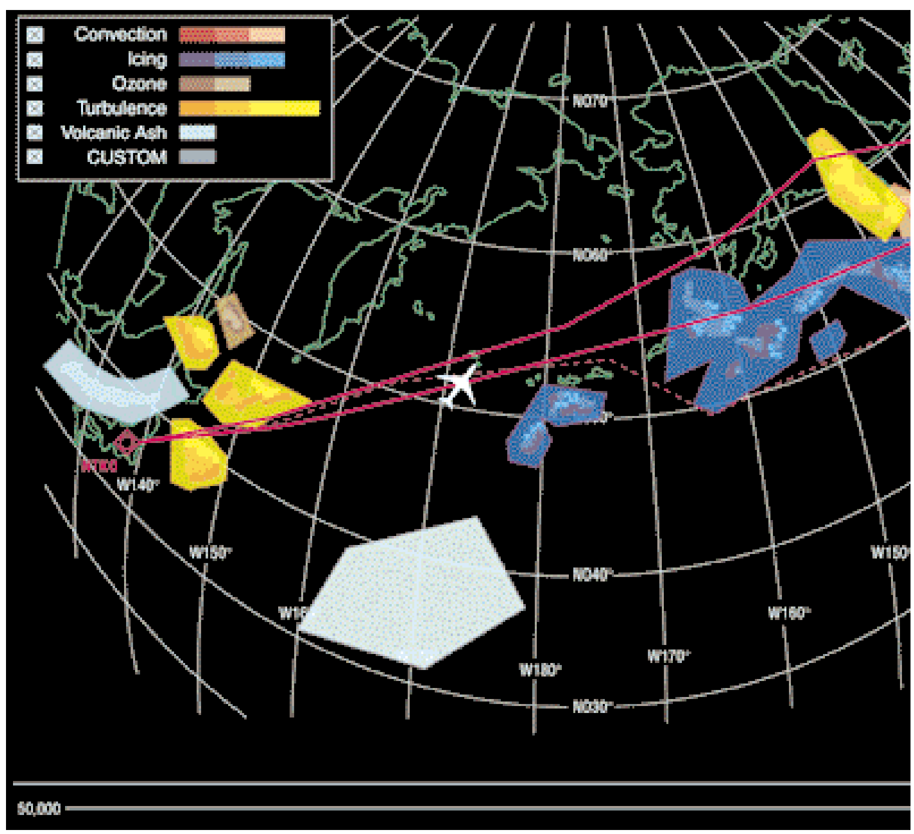


Figure 3-NASA-5. Aviation Weather Information Cockpit display.

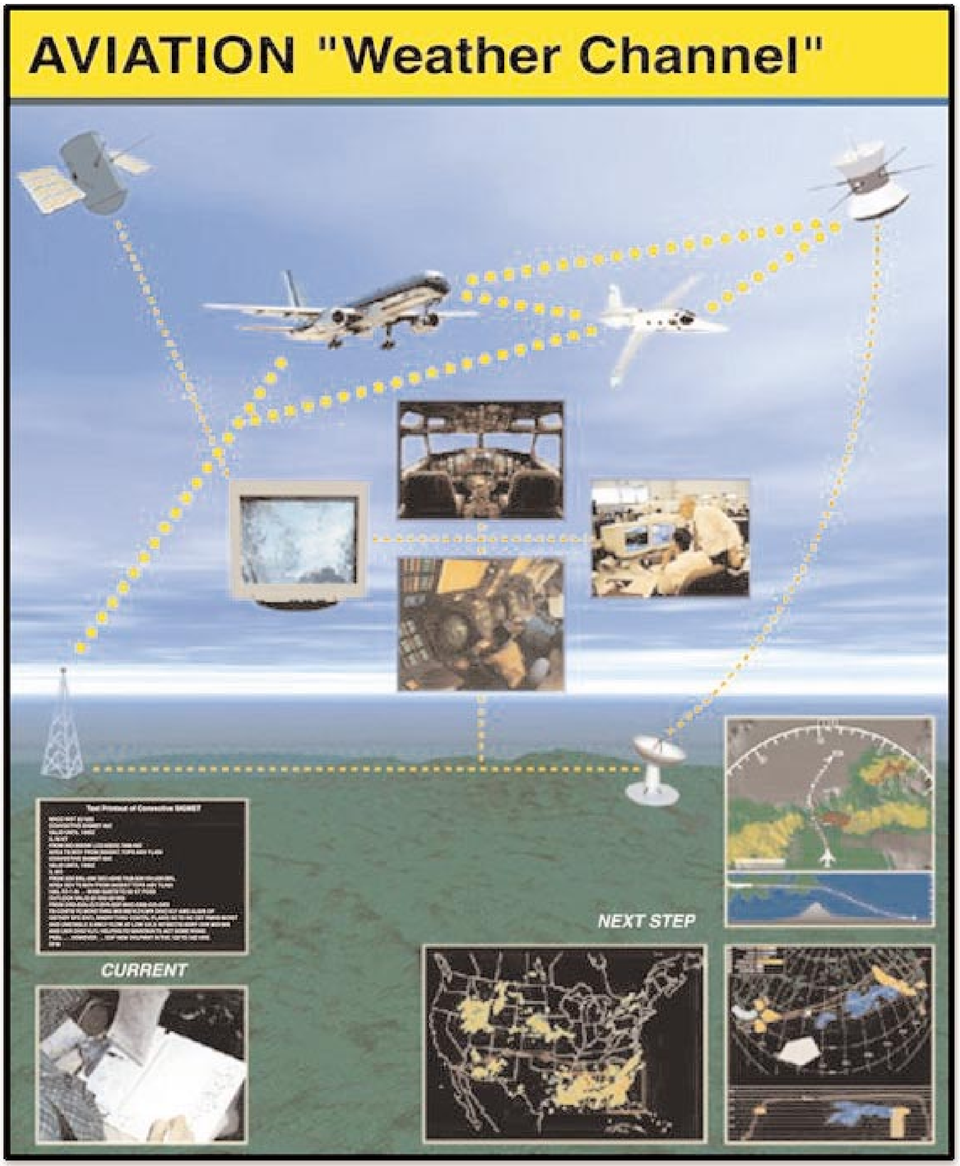


Figure 3-NASA-6. Communication and distribution channels for Aviation weather information.

Aviation Safety Program

NASA's Aviation Safety Program is aggressively pursuing three primary areas:

- Aviation Weather Information Distribution and Presentation: This effort includes combining the inputs from a variety of sources of weather data into a convenient, cockpit display that is simple and easy for the pilot to comprehend. It will likely be a multi-function flat panel display that will display all forms of weather, terrain and traffic hazards (Figure 3-NASA-5 and Figure 3-NASA-6).
- Synthetic Vision in the Cockpit: Synthetic Vision is electronically enhanced vision for the pilot. It combines a very detailed world wide terrain map (obtained from a recent Space Shuttle mapping mission), precise GPS navigation data, and integrity-monitoring sensors to provide a realistic view of the world through a cockpit head-up-display (HUD) or panel mounted display. The pilot will look through the HUD as he or she looks out the window. This see-through HUD will make the world look like a bright sunny day even when the airplane is approaching a fogged-in airport at midnight--one that would be shut down under today's operating rules.
- Turbulence Detection: This project is the development of aircraft-mounted, forward looking turbulence detectors that look several kilometers ahead of the aircraft using Lidar and radar sensors. A suitable cockpit warning device would alert pilots of impending encounters. There is also work in ground based detection (Figure 3-NASA-7).

NASA's Icing Research is pursuing a large number of areas that affect aircraft in flight. Primary examples of this effort are:

- The development of icing training videos and other materials will help educate pilots on all aspects of aviation icing.
- The development of improved wind tunnel and analytical techniques to predict icing accumulation patterns on wings, tails, and inlets will help designers improve future aircraft and engines.
- Forward looking, aircraft mounted detectors will detect moisture laden clouds miles ahead of the aircraft. Adding air temperature, pressure, and humidity to the data received from the sensors, computers will compute the icing potential of the approaching cloud and will display "high risk areas" to the pilot in an easily read, color cockpit display.
- Sensors that measure the accumulated ice on aircraft in-flight will automatically activate, new, low cost de-icing devices that will shed the ice before the aircraft gets in danger.
- The potential for satellite detection of icing conditions is being investigated.

General Aviation

NASA's General Aviation element is actively researching new, low power, and low cost pneumatic and electrical ice removal technology. Also in development are low cost displays that graphically show icing weather information so icing conditions can be avoided during flight planning.

Terminal Area Productivity

NASA's Terminal Area Productivity element is contributing via these areas (program ends September 30, 2000):

- Wake vortex detection/prediction to improve the efficiency of aircraft spacing.
- A heads up display that electronically displays the edges of taxiways and runways, shows ground traffic and marks clearance routes to gates and/or runways. All this is overlaid on the pilot's "real world" view out the window while stereo headphones allow the pilot to hear ground traffic from the direction the other aircraft really are. This technology will be a great aid to vision in poor visibility--especially at unfamiliar airports.
- A look down electronic display shows a bird's eye view of the airport as if the pilot were looking at the airport on a bright sunny day from about 1,000 feet above the airport. The position of all runways, taxiways, buildings, and ground traffic is clearly displayed--as is the exact route the pilot is cleared to take to get to the gate or the runway. Another huge aid to vision in bad weather.

As with virtually all of NASA's aviation research, most of the research mentioned above also helps pilots in good weather too.

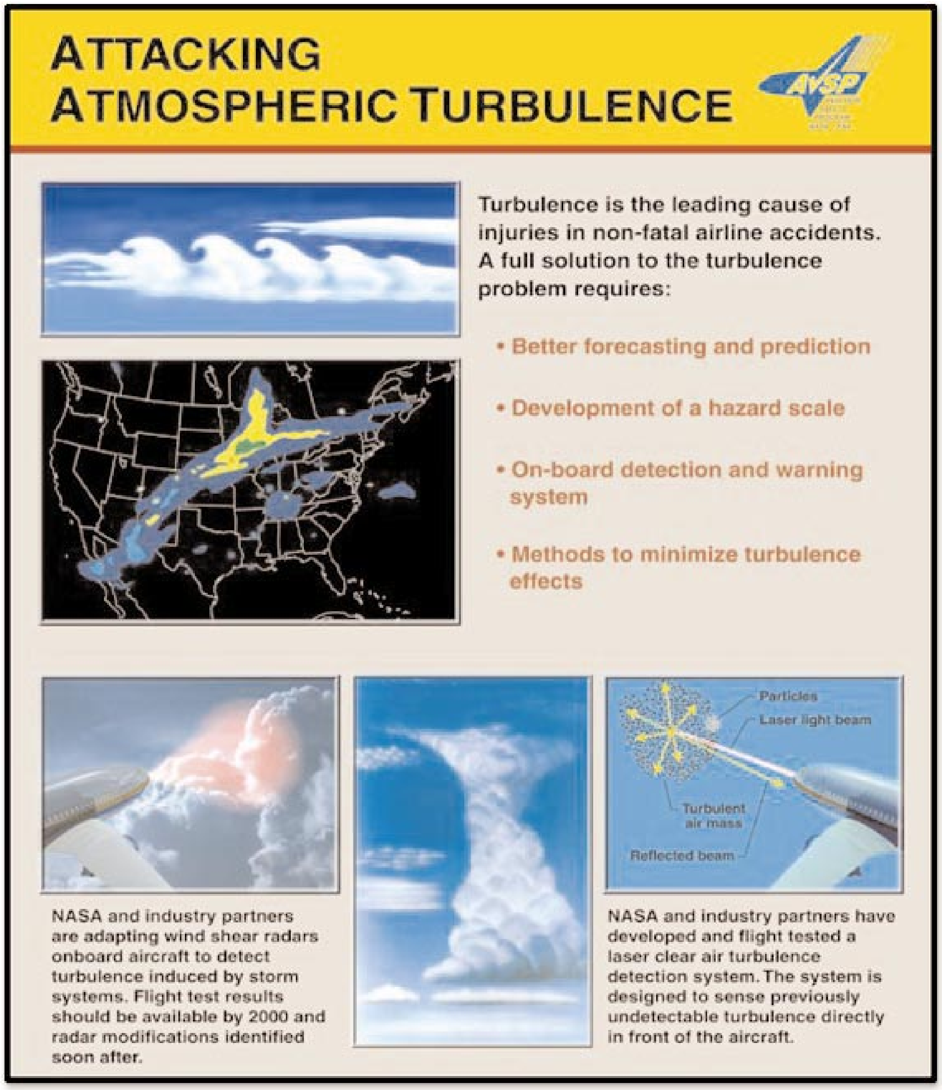


Figure 3-NASA-7. NASA's Aviation Safety Program plans to detect atmospheric turbulence through the use of advanced technologies.