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) weather operations program is to provide the specialized meteorological data and techniques 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 (ELV) programs. The greatest challenge is to observe and forecast 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), co-located with the Air Force's Range Weather Operations, provides a facility to develop, 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 Space Center's (KSC) frequent thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program-Space Shuttle, DOD, and commercial. The AMU has focused special attention on evaluating mesoscale numerical models. The AMU functions under a joint NASA, Air Force, and National Weather Service (NWS) Memorandum of Understanding. AMU tasks during Fiscal Year (FY) 2003 include:

Task: Statistical Forecast Guidance for the Shuttle Landing Facility (SLF) Towers

Goal: Calculate climatologies and probabilities for the 10-minute peak winds at the SLF and create a PC-based graphical user interface (GUI) to access the data.

Status: Task complete and GUI now operational and in use at the Spaceflight Meteorology Group (SMG).

Task: Doppler miniSODAR™ System (DmSS) Evaluation

Goal: Compare data from the DmSS near SLC-37 to wind data from the nearest tall tower to determine the reliability and quality of DmSS data for operational wind analysis.

Status Analysis of a large sample of both mean and peak winds identified several sources of systematic error in both quantities. A report is being prepared.

Task: Analyze Automated Meteorological Profiling System (AMPS) Moisture Profiles

Goal: Evaluate differences in moisture profiles between AMPS and the Meteorological Sounding System (MSS), and determine their impact on indices used for thunderstorm forecasting.

Status: Completed memorandum detailing analysis of the 20 dual-sensor AMPS/MSS profiles taken in July and August 2002. There were no apparent differences between the AMPS and MSS stability indices computed from warm-season data, even though relative humidity (RH) profile differences indicated that AMPS would show the atmosphere to be more unstable. The AMU resolved this paradox by finding a weak temperature difference between AMPS and MSS that counteracts the RH differences. No changes need to be made to the stability indices calculated from AMPS data.

Task: Verification of Numerical Weather Prediction Models

Goal: Develop an automated method that will verify specific weather phenomena in high-resolution models in order to improve upon traditional verification techniques.

Status: Completed final report describing new Contour Error Map (CEM) method. A journal article is in preparation. The CEM is an automated method developed to identify sea-breeze characteristics in observed and model forecast wind fields, and verify the model-predicted sea breezes. Results from the CEM compared well to a meteorological analysis of observed and model forecast sea-breeze locations over the Cape Canaveral, Florida area. A phenomenological-based method like the CEM can save time and resources when verifying model forecasts against observed data, and can help improve the quality of verification results by focusing on a specific phenomenon.

Task: Range Standardization and Automation (RSA) Support

Goal: Help the Eastern Range assess and evaluate proposed designs and implementations of the weather systems upgrade by the RSA and SLRSC contractors.

Status: Ongoing task. AMU participates in design reviews, acceptance tests and other functions as required.

The KSC Weather Office is improving the KSC and Eastern Range weather infrastructures and conducting research to improve operational processes and facilities. In FY 2003, KSC began transmitting Visibility and Soil Moisture data to JSC/SMG from five suites of newly installed sensors west of KSC to aid in the forecast of morning fog that could impact Shuttle landings. The Weather Office also continued to direct the analysis of data gathering from KSC's major field research program called the Lightning Launch Commit Criteria (LLCC) program. The LLCC program used an aircraft equipped with field mills and cloud physics sensors, in combination with several ground based radars and other sensors, to collect the data necessary to relax the lightning launch constraints while making them even safer. LLCC was cooperatively funded by the Shuttle program, NASA ELVs and the USAF. The team includes more than 50 personnel from eleven organizations including other Governmental agencies, NASA Centers, universities and their contractors. The initial set of new launch rules is expected by early FY 2004.

The KSC Weather Office, SMG at JSC, and the AMU continue to work on projects managed by the Range Standardization and Automation (RSA) program and under the new Spacelift Range Systems Contract (SLRS-C). RSA is a major Air Force program to modernize the Eastern and Western Range infrastructure. SLRS-C will provide sustaining engineering for the systems RSA provides. Deliveries of weather sensors, models, and control and display systems began in FY 2000 and will conclude in late 2004. Modernization of the KSC 50 MHz Doppler Radar Wind Profiler (DRWP) and its electronic components and is planned for late FY 2003 and early FY 2004. Upon completion, DRWP will be transferred to the Eastern Range. KSC also obtained Air Force funding to improve the drainage of the DRWP antenna field that flooded during very heavy rains. SLRSC also conducted an Engineering Study to replace and modernize the weather instrumentation at the Shuttle Landing Facility (SLF). Upon completion, NASA will transfer the entire system to Eastern Range ownership.

Many issues remain with RSA's pending changes to the Eastern and Western Ranges' meteorological infrastructures. Thus the Air Force and NASA weather communities continued to expend significant resources to solve potential major RSA deficiencies since NASA KSC, JSC and MSFC depend heavily on this infrastructure for their weather support. A major success was the RSA contractor's decision to discard their proposed Control and Display (C&D) system, and instead partner with NOAA's Forecast Systems Lab to deliver a COTS AWIPS (Automated Weather Information System). This would provide Range Weather Operations with a very capable system that is cost effective, and compatible with both future AWIPS upgrades and with SMG. However, Air Force budget redirection seriously threatens cancellation of the entire RSA weather system. A decision is pending. Cancellation would seriously degrade long term weather support to the American Space Program.

The Radio Automatic Theodolite System (RATS) used to provide upper level winds, temperatures and humidity at the Shuttle Transatlantic Abort Landing (TAL) sites in Spain, Morocco, and Gambia, became obsolete when the manufacture announced cessation of sonde production. A replacement system called TASS (TAL Atmospheric sounding System), a Global Positioning System (GPS) based Sippican W9000, was selected, procured, integrated and tested with the help of the Eastern Range. The system is now installed and operational. The Eastern Range owns, operates and maintains the system for NASA.

The KSC Weather Office funded development of a new lightning detection system capable of locating lightning strikes in 4D with an accuracy of <5 meters (a considerable improvement over the 250-300 meter accuracy of our current lightning location system.) Called SOLLO (Sonic Lightning Locator), it uses a sensor to detect the time of arrival of the electromagnetic pulse from a lightning strike, and then one elevated detector and three surface based detectors to measure the time of arrival of thunder from the lightning, to very accurately calculate the location of the lightning strike. SOLLO also calculates the amperage, rise time, and polarity of the strike. During FY 2003, KSC is installing SOLLO at the Shuttle Launch Complex, the International Space Station Building, and a new technology development and testing facility.

The entire NASA and Eastern Range weather communities (KSC, JSC, MSFC, GSFC, LRC, and 45th Weather Squadron) were deeply involved supporting the Space Shuttle Columbia accident investigation. Weather analyses were crucial to: identifying likely debris locations over the western and central United States; characterizing the atmosphere during reentry beginning at the very data sparse upper Mesosphere; identifying possible anomalous wind shears during launch ascent; analyzing Columbia's exposure to the atmosphere during the 39 days Columbia was on the launch pad; and numerous engineering studies. NOAA/NWS also provided considerable help.

SUPPORTING RESEARCH

The NASA's Earth Science Enterprise (ESE) sponsors the supporting research activities. NASA uses the vantage point of space to observe Earth and understand both how it is changing and the consequences for life. The Earth System Science Theme works with the science community to answer questions on the frontiers of science that have profound societal importance, and for which remote sensing of the Earth can make a defining contribution. The program funds research at the Nation's universities, conducts research at NASA Centers, and collaborates with other research agencies and the U.S. Climate Change Science Program Office/U.S. Global Change Research Program, and the National Research Council to define these questions and lay the scientific foundation for prioritizing and approaching them. The program is answering the scientific community's call for comprehensive observation of the Earth's major components. Research results contribute to the development of sound environmental policy and economic investment decisions. With the FY 2004 budget request, NASA will continue its progress in answering key scientific questions and demonstrating practical applications in response to national priorities.

The NASA Earth System Science program is driven by the recognition of the societal importance of the natural variability of the Earth system and the

realization that humans are no longer passive participants in global change, but are instead causing significant changes in atmospheric composition, land use and land cover, and water resources.

Our satellites are examining the global water cycle, including the roles of precipitation and ice. Understanding how water cycles through the Earth system of oceans, atmosphere, land, and ice is essential for assessing the future of fresh water availability in the U.S. Southwest and other thirsty regions of the globe. NASA is also studying the seasonal rhythm of terrestrial and marine ecosystems on a global scale for the first time. This view of the seasonal uptake and release of carbon provides us with new insights into the role of ecosystems in the carbon cycle. This research helps us assess the impact of global change on food and fiber production.

The FY 2004 budget reflects the alignment of the Earth System Science program with the President's call for action through the U.S. Climate Change Research Initiative (CCRI). In support of this effort, we are accelerating the development and launch of an advanced polarimeter to increase our understanding of black carbon soot and other aerosols as causes of climate change. The Earth Systems Science theme increases public awareness and understanding of how the Earth functions as a system, and enables the use of Earth science information and results in teaching and learning at all levels of education. We also build capacity for productive use of Earth science results, technology, and information in resolving everyday practical problems via the Earth Science Applications theme.

Earth System Science employs a constellation of more than 15 Earth observing satellites routinely making measurements with over 80 remote sensing instruments to observe the Earth. This information is used to analyze, model, and improve our understanding of the Earth system.

NASA works with the science community to identify questions on the frontiers of science that have profound societal importance, and to which remote sensing of the Earth can make a defining contribution. These science questions become the foundation of a research strategy, which defines requirements for scientific observations, and a roadmap for combining the technology, observations, modeling efforts, basic research, and partnerships needed to answer the questions over time. The roadmaps listed below can be seen at: *http://earth.nasa.gov/roadmaps*

- Atmospheric Composition - Understand the trace constituent and particulate composition of the Earth's atmosphere and predict its future evolution.
- Carbon Cycle, Ecosystems, and Biogeochemistry - Understand and predict changes in the Earth's terrestrial and marine ecosystems and biogeochemical cycles.
- Water & Energy Cycles - Characterize and predict trends and changes in the global water and energy cycles.
- Earth Surface and Interior Structure - Utilize state-of-the-art measurements and advanced modeling techniques to understand and predict changes in the Earth's surface and interior.
- Climate Variability and Change - Develop integrated models of the ocean, air, cryosphere and land surface, and apply to retrospective and

future studies of climate variability and change.

- Weather - Develop the technology, observational and modeling capacity needed to improve daily and extreme weather forecasting (e.g. hurricanes, tornadoes).

The Earth Science Research Program at NASA studies the Earth as a whole system, utilizing measurements made by Earth satellites, as well as by Suborbital and Airborne assets. These observations, enhanced by the work of the Mission Science Teams and Algorithm Development activities, enlarge the Earth system knowledge base and are incorporated into models in order to improve our ability to predict climate, weather, and natural hazards. Computing capabilities funded through the Research Program's Information Systems effort further support these improvements. The program also selects and funds over 1,200 U.S. scientific research tasks through the Research and Analysis activity. Scientists from seventeen other nations, funded by their own countries and collaborating with U.S. researchers, are also part of the 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 our understanding of our planet. In FY 2004, NASA Earth Science Research Program will continue to provide the technology, observations, and modeling results that contribute towards the provision of answers to the questions society poses about our home planet. Link to project homepage for more information: *http://www.earth.nasa.gov/science/index.html.*

In the previous fiscal year progress was made in many areas, Including:

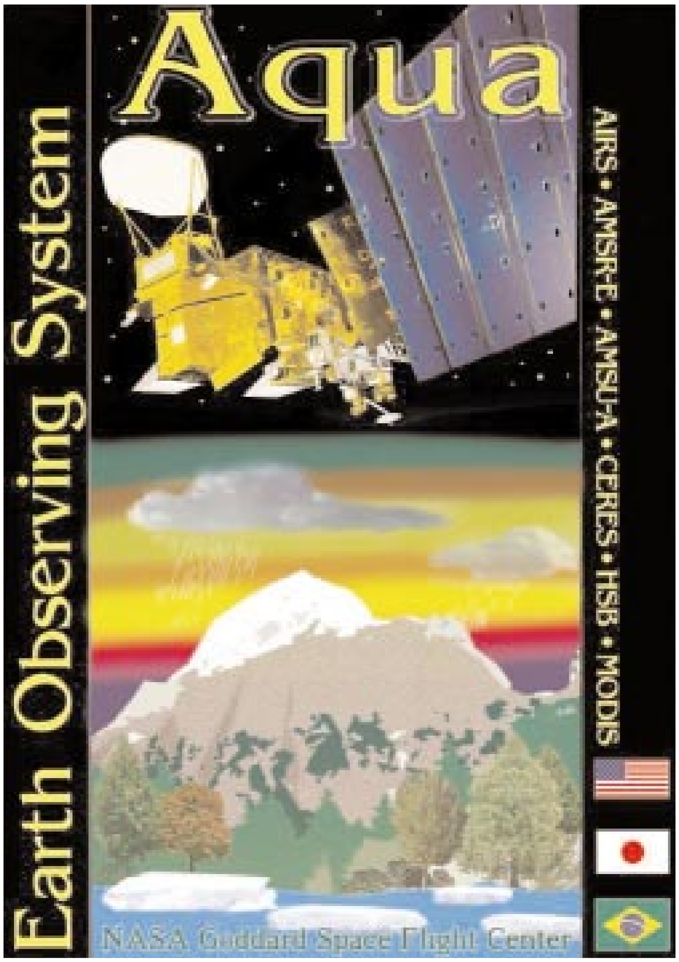
- Polar Ice Sheets: Knowledge about the ice-covered regions in Greenland and Antarctica provided us with the ability to make a quantitative assessment of changes in ice cover. This knowledge will aide scientists in their ability to test climate models, and will also improve our ability to provide assessments of potentially hazardous changes in sea level and sea ice distributions.
- Atmospheric Aerosols: The most comprehensive evaluation of the global distribution and properties of atmospheric aerosols became available in FY 2002. The current data provides information not just on aerosol presence, but on the nature of the aerosol particle, including whether or not it can have a net warming or cooling effect on the local climate, and how it interacts with the climate. Combined with ground-based data, this information can help scientists understand aerosol impacts on local weather, agricultural productivity, and air quality.
- Clouds: NASA made great progress in linking satellite and in situ measurements of clouds with their effects on atmospheric radiation. Detailed in situ observations of clouds were made during a NASA-led campaign in which one airborne platform used a suite of more than two dozen instruments to make comprehensive measurement of cloud particle properties. The results should improve information about cloud particle distributions and properties, understanding of satellite remote sensing of clouds, and characterization of cloud formation in climate models.
- Precipitation Studies: Data from over six years of operation of the Tropical Rainfall Measuring Mission (TRMM) satellite are now available, and as a result, uncertainty about the global rainfall distribution in the tropics has been reduced by a factor of two, and our knowledge of the variation in precipitation from year to year has been enhanced.

The following operating missions have met prime objectives and are in extended mission phases.

- Total Ozone Mapping Spectrometer (TOMS) 1996-2004
- Upper Atmosphere Research Satellite (UARS) 1991-2003
- Tropical Rainfall Measuring Mission (TRMM) 1997-2004
- Earth Radiation Budget Satellite (ERBS) 1986-2003
- Topex 1992-2003

During FY 2003, NASA launched two satellite missions, IceSat and SORCE. The NASA SeaWinds instrument was also launched as part of the Japanese ADEOS-II satellite mission.

The SeaWinds scatterometer is a specialized microwave radar that measures near-surface wind velocity under all weather and cloud conditions over Earth's oceans. It will use a Ku Band microwave radar with a rotating antenna to determine radar scattering globally and to infer wind velocity (speed and direction) over 90 percent of the ice-free ocean surface every two days with a resolution of 25km. SeaWinds will acquire all-weather, high-resolution measurements of near-surface winds over the global oceans. It will determine atmospheric forcing, ocean response and will characterize air-sea interaction mechanisms on various spatial and temporal scales. SeaWinds will also combine wind data with measurements from scientific instruments in other disciplines to understand mechanisms of global climate change and weather patterns. SeaWinds will improve weather forecasts near coastlines by using wind data in numerical weather and wave prediction models that will also improve storm warning and monitoring. The SeaWinds missions provide long-term, high-resolution, ocean surface wind data (both speed and direction) used for studies of ocean circulation, climate and air-sea interaction. These measurements are crucial to understanding and predicting severe weather patterns and climate changes. SeaWinds data will increase our knowledge of global ocean circulation over inter-annual and decadal time scales; the effects of hydrological processes on climate; and the relationship of variations in weather, precipitation, and water resources to climate variation. This instrument is a follow-on mission to QuickSCAT and will continue the data series initiated in 1996 by the NSCAT instrument.



The objectives of the ICESat mission will be achieved via a laser altimetry instrument, the Geoscience Laser Altimeter System (GLAS), which is an Nd:YAG laser with 1064 and 532 nm output. The instrument was placed into a 600 km, 94° inclination orbit by a Delta II (Model 7320) Expendable Launch Vehicle (ELV) in January 2003. The spacecraft accommodates the GLAS instrument, which has a mass of less than 300kg and power capacity of 330 W. The ICESat and GLAS instrument have a design lifetime of 3 years. The Ice, Clouds and land Elevation Satellite (ICESat) Project provides a subset of the EOS measurements, primarily land ice and sea ice products, for which an orbit is required that maximizes polar coverage over the ice sheets. The primary objective of the ICESat mission is to measure ice sheet height and volume change for long-term climate variability studies, providing a 3-year data set of ice sheet topography. The Ice, Cloud and Elevation Satellite (ICESat) will measure changes in Earth's ice sheets to support long-term climate variability studies, providing a 3-year data set of ice sheet topography. ICESat will also measure height profiles of clouds and aerosols, land elevations and vegetation cover, and approximate sea ice thickness. The continuous satellite observations will detect interannual changes in the surface mass balance and determine whether they are due to recent or long-term changes in climate.

The Solar Radiation and Climate Experiment (SORCE) will provide measurements of the Sun's energy input (including x ray, ultraviolet, visible, near-infared, and total solar radiation) to the Earth's atmosphere. The measurements provided by SORCE specifically address long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and UV-B radiation. These measurements are critical to studies of the Sun, its effect on our Earth system, and its influence on humankind. SORCE measures the Sun's output with the use of radiometers, spectrometers, photodiodes, detectors, and bolometers engineered into instruments mounted on a satellite observatory. Spectral measurements identify the irradiance of the Sun by characterizing the Sun's energy and emissions in the form of color that can then be translated into quantities and elements of matter. Data obtained by the SORCE experiment will be used to model the Sun's output and to explain and predict the effect of the Sun's radiation on the Earth's atmosphere and climate. The Total Solar Irradiance (TSI) measurement is a continuation of the first space-borne measurements begun by Nimbus 7 in 1978. Currently, three spacecraft are sustaining the TSI database: ACRIMSAT, the Upper Atmosphere Research Satellite (UARS), and the Solar Heliospheric Observer (SOHO) a Space Science mission. Continued and uninterrupted population and monitoring of the TSI data set will provide insight into the role of solar forcing on long-term climate changes. These measurements will continue the spectrally resolved solar irradiance measurements being made from UARS since 1991, as well as earlier missions for TSI measurements, and will add additional capability. They will be used to further understand the effects of solar variability on long-term global climate change and influences on the stratospheric ozone layer. Additionally, the spectral measurements in the 200-300 nm and 1,500 nm spectral regions will fulfill the NPOESS operational requirements as part of a tri-agency partnership among NASA, NOAA, and DOD.

Major planned events in FY 2004 include launches of Aura, Cloudsat and Calipso satellites. Aura will study Earth's ozone, air quality, and climate. Cloudsat will measure the structure of clouds to better quantify their key role in the Earth's water cycle and climate system. Calipso, with Aura and the advanced polarimeter, will study the role of aerosols in climate, reducing uncertainties in climate models. Satellite observations will be used to provide daily and seasonal global atmospheric water vapor, rainfall, snowfall, sea-ice, and ice-sheet maps. These observations will be made with the intention of improving the scientific understanding and models of water cycle through the Earth system. NASA will also use satellite-derived localized temperature and moisture profiles, with unprecedented accuracy and global coverage, to improve predictive capabilities of regional weather models.

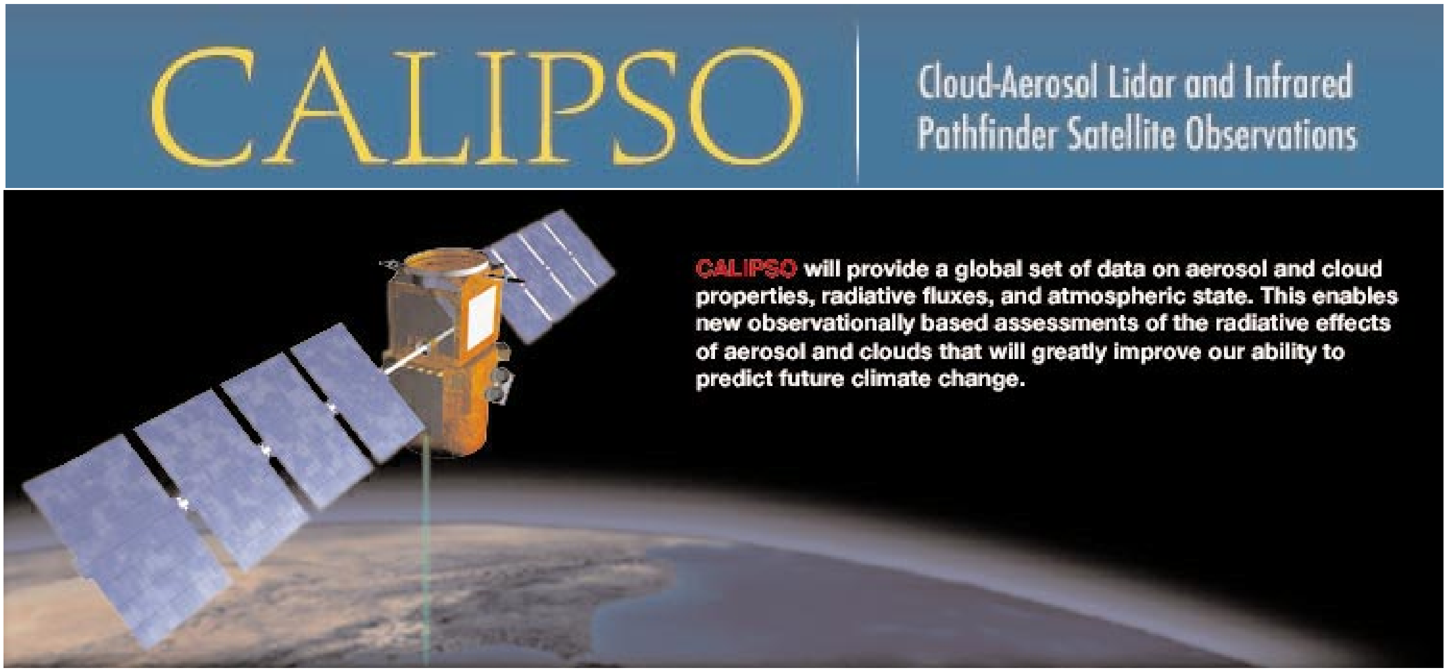
Aura is the third major satellite in the Earth Observing System constellation. The first and second missions, Terra (Figure 3-NASA-1) and Aqua, are designed to study the land, oceans, and the Earth's radiation budget. Aura's chemistry measurements will follow up on measurements which NASA pioneered with its Nimbus 7 satellite (1978), continued with NASA's Upper Atmosphere Research Satellite (1991), and the Total Ozone Mapping Spectrometer (TOMS) series of missions. The satellite will be launched in January 2004 and operate for five or more years. The Aura mission will study the Earth's ozone, air quality, and climate, providing answers to the following questions: (1) Is the ozone layer, which shields us from the Sun's ultraviolet radiation, recovering? The release of chlorofluorocarbons (CFC's) has caused a dramatic decrease in the ozone layer during the last two decades, especially over Earth's polar regions, but detection of stratospheric ozone depletion led to the regulation and phasing-out of CFC production worldwide. (2) Is global air quality getting worse? The chemistry of Earth's lower atmosphere, the troposphere, is changing. At this level of the atmosphere, ozone pollution, an extremely toxic byproduct of agricultural burning, deforestation, urban activity, and industry, is increasing worldwide. (3) How is Earth's climate changing? Ozone and water vapor in the upper troposphere and lower stratosphere are important "greenhouse gases," playing a significant role in regulating our climate. Understanding how water vapor and ozone vary will reveal how these constituents moderate global temperature increases.

Figure 3-NASA-1. EOS TERRA satellite captures the extent of Hurricane Isabel's impact on the East Coast on September 18, 2004

CloudSat is designed to measure the vertical structure of clouds from space. This satellite will fly a millimeter-wave (94 GHz) radar that is capable of seeing a large fraction of clouds and precipitation, from very thin cirrus clouds to thunderstorms producing heavy precipitation. CloudSat will furnish data needed to evaluate and improve the way clouds are represented in global models, thereby contributing to better predictions of clouds and a more complete knowledge of their role in climate change. It is a collaborative mission among NASA, the Canadian Space Agency (CSA), and the U.S. Air Force. CSA is contributing instrument components and the U.S. Air Force is contributing ground operations. Cloudsat will answer the following science question: What are the effects of clouds and surface hydrologic processes on Earth's climate? Clouds are the key component of the Earth's hydrological cycle, and they dominate the planet's solar and thermal radiation budgets. Even small changes in their abundance or distribution could significantly alter the climate. These considerations lead scientists to believe that the main uncertainties in climate model simulations are due to the difficulties in adequately representing clouds and their radiative properties.

The observations made by this satellite will improve cloud modeling, contributing to better predictions of cloud formation and distribution and to a better understanding of the role of clouds in Earth's climate system.

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) mission will address the role of clouds and aerosols in the Earth's radiation budget, providing key measurements to improve climate predictions. Climate models predict a significant global warming in response to



the rising concentrations of carbon dioxide and other greenhouse gases in the atmosphere, but uncertainties in the modeled radiative effects of aerosols (small suspended particles) and clouds contribute to the overall uncertainty in the predictions of the climate models. Current predictive capabilities must be improved to enable policy makers to reach balanced decisions on mitigation strategies. The mission will fly a 3-channel lidar (a laser) in formation with Aqua and CloudSat to obtain coincident observations of radiative fluxes and the atmosphere. This set of measurements is essential for quantification of global aerosol and cloud radiative effects. CALIPSO consists of a partnership between NASA and France's Centre Nationale D'Etudes Spatiale (CNES). CNES is providing a PROTEUS spacecraft, the imaging infrared radiometer (IIR) and spacecraft mission operations. This mission will improve our ability to predict the future state of Earth's climate. Together, CALIPSO and Aqua provide: (1) a global measurement suite from which the first observationally-based estimates of aerosol direct radiative forcing of climate can be made, (2) a dramatically improved empirical basis for assessing aerosol indirect radiative forcing of climate, (3) a factor of 2 improvement in the accuracy of satellite estimates of long-wave radiative fluxes at the Earth's surface and in the atmosphere, and (4) a new ability to assess cloud-radiation feedback in the climate system. CALIPSO is co-manifested with CloudSat and is scheduled to launch no earlier than October 2004.

As mentioned earlier, the Earth System Science employs a constellation of more than 15 Earth observing satellites routinely making measurements with over 80 remote sensing instruments to observe the Earth. These instruments are providing important measurements to understand how the land, oceans, atmosphere, ice caps, and life forms interact as a system in influencing climate change. The unprecedented volume of data coming down is being collected, processed, and distributed by NASA's EOS Data and Information System (EOSDIS). EOSDIS manages data from NASA's Earth science research satellites and field measurement programs, providing data archiving, distribution, and information management services.

OSDIS commands and controls EOS satellites and instruments, and generates useful products from orbital observations. EOSDIS success criteria are to successfully support the ground operations of the EOS missions: Terra, Aqua, Aura, and ICESat, including spacecraft and instrument control, data acquisition, and telemetry processing; to operate the eight Distributed Active Archive Centers, which archive and distribute the data; and to support science investigator-led processing. The success criteria are to add the additional capabilities for new missions in an evolutionary manner, incorporating applicable new technologies that result in cost-effective operations. It supports the development and evolution of new and existing science data processing, archiving, and distribution functions. EOSDIS Development also supports new Earth Science Enterprise missions and the evolution of existing systems to support new missions. Specifically, it will support the Enterprise approach for the next decade, the Strategic Evolution of ESE Data Systems (SEEDS), currently being formulated. EOSDIS Development also supports the evolution of TRMM's processing system to an integrated Precipitation Processing System, capable of handling global precipitation data, as a SEEDS prototype. It will support the science data system development for new missions including the NPOESS Prep Project (NPP) (Figure 3-NASA-2).

The Earth Science Enterprise formed the Earth Science Technology Office (ESTO) to provide strategic, science driven technology assessments and the development of requirements. ESTO integrates and prioritizes these requirements among various implementing programs and projects by maintaining a link between science/ applications objectives and technology investments. ESTO aggressively pursues promising scientific and engineering concepts and ensures that the program maintains an effective balance of instrument and information systems investments. ESTO implements the ESE focused technology program, which includes: the Instrument Incubator Program (IIP) to develop new instruments and measurement techniques at the system level; Advanced Technology Initiatives (ATI), which develop technologies required for next generation, space-based missions; Advanced Information Systems Technology (AIST), to develop end-to-end information technologies for future missions; Computational Technologies (CT), to develop and apply high performance computing technologies for Earth and space science; and Advanced Platform Technology (APT). The New Millennium Program (NMP) validates innovative measurement concepts, enabling instrument technologies, and space platform technologies required for future missions. The focused technology program also supports Integrated Product Development Teams. ESTO will leverage technology investments through internal NASA program synergy and external partnerships. These efforts will include: Information Systems (IS), Small Business Innovative Research (SBIR), Space Based Technology (SBT), NASA Institute of Advanced Concepts (NIAC), Revolutionary Aero Space Concepts (RASC), and other agencies' (e.g., DOD) programs.

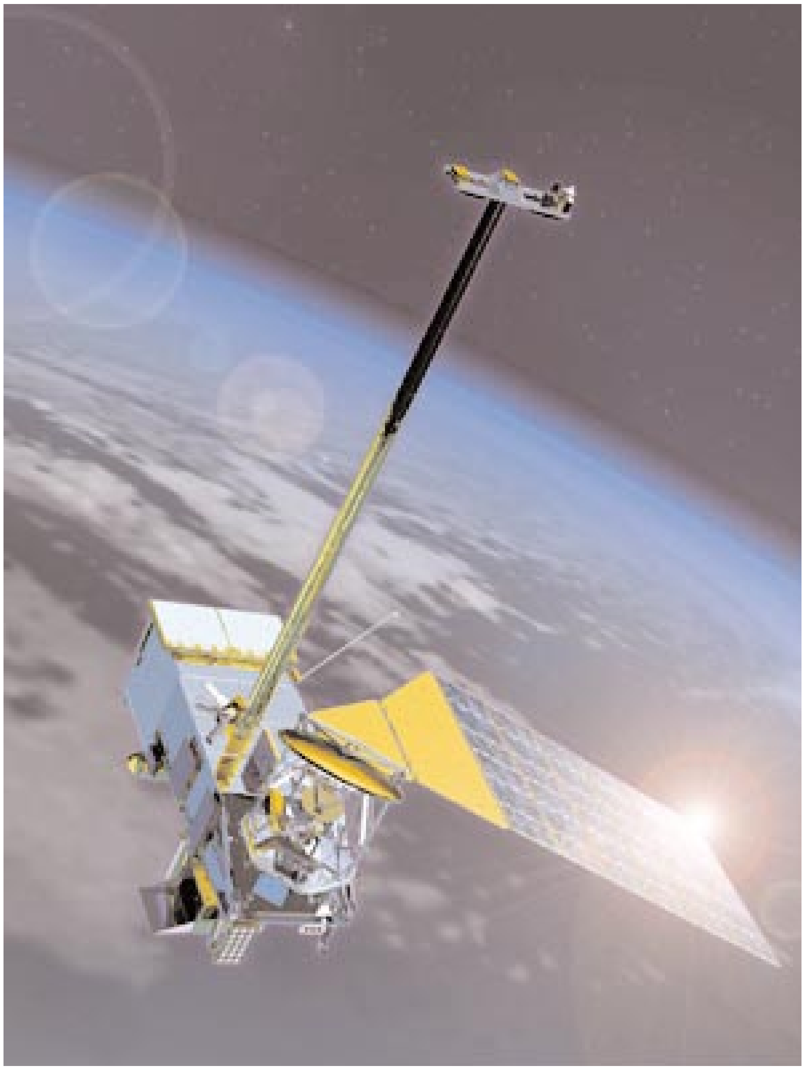


Figure 3-NASA-2. Artist's concept of NPOESS orbiter.

SPACE WEATHER

The Living With A Star (LWS) Program (Figure 3-NASA-3) addresses the linkage between three fundamental questions of the NASA solar-terrestrial physics program's the Sun Earth Connection (SEC) program:

- *How and why does the sun vary?*
- *How does the Earth respond to solar variations?*
- *How does solar variability affect life and society?*

The SEC Program strives to understand the physical processes and connections that control the dynamics of the Sun-Earth connected system. The system dynamics are driven by violent solar bursts, long term solar variability, and instabilities of the magnetized Earth-space, geospace. LWS is grounded in service to humanity and it's technological systems. It is based on solving the specific problem of being able to predict solar variations and the effects of those variations on humanity and human systems. LWS will integrate results from existing and future space missions as they contribute to the SEC system level goals. The program is based on providing the understanding necessary to predict what will happen where and when to the heliosphere, geospace, and Earth's climate given observations of conditions on the Sun.

While both existing SEC programs and LWS are basic research, there are some significant differences in concept and approach. The primary difference is that in addition to the traditional input from the space science community, LWS derives requirements from Earth science, human spaceflight, industry and other federal agencies (National Space Weather Program, Office of the Secretary of Defense Space Weather Architecture, DOD, NOAA, FAA). The LWS Program has characteristic features: there is a significant component that deals with specification models; what is the environment as a function of space and time. This is an important need for industry that must build spacecraft that survive, and to provide anomaly resolution. There is a need for human spaceflight radiation protection. Finally, there is the issue of prediction, which is the more traditional science.

The program priorities are (numbers indicate priority rank):

(1) Solar influences on Global Change: Global change is the single most important environmental problem facing humanity. This issue involves major national and international policies because of the potential economic impacts of global change and/or mitigation actions. Objectives:

- Determine how and why the Sun varies (for assessment of past and future role in global climate change).
- Identify and understand mechanisms by which solar variability affects terrestrial climate (and possibly weather).

(2) Space environmental "climate" data (e.g., specification models):

- Needed for design of cost-effective systems with minimal or no sensitivity to space weather.
- The goal is to have economical "all weather" systems; not to be dependent on predictions.

(3) Nowcasting space environment:

- For rapid anomaly resolution for space and communication/navigation systems--if an anomaly is due to a known space environmental effect, it is often possible to get back into operation rapidly. If it is due to an unknown cause, it may be necessary to do detailed failure analysis--requiring extended downtime of the affected system.
- Astronauts safety--in the event of significant radiation, astronauts can move to shielded areas.

(4) Prediction of:

- Solar Proton Events (astronaut/airline flight safety). Goals: (a) reliable warnings (minimize false alarm rate) and (b) reliable forecast of "all clear" periods for EVA's.
- Prediction of geomagnetic storms for applications where effective mitigation is possible (e.g. electric power grid). Goals--reliable forecasts (storm is coming) and very reliable shorter term (~hour) warnings to minimize unnecessary mitigation by reducing capacity, etc. which can reduce system efficiency.
- Predictions of space environment for operation and utilization of space systems. Goals: (a) reliably forecast availability/accuracy/sensitivity of communication and navigation systems susceptible to space weather (e.g., ionospheric scintillations) and (b) enable optimization of systems and the allocation of resources during times of extreme space weather conditions.

In summary, LWS will characterize the space environment with the aim being to help spacecraft designers and operators, and address astronaut health and safety. LWS will produce the system knowledge to predict solar effects on climate, and solar/geospace effects on human systems in space and on the ground.

The approach to achieving our goals is to treat the Sun, heliosphere, and geospace as a system. The key to dealing with the problem as a system is to understand that physics-based models will be the "glue" that holds the system together. It is assumed that ultimately reliable and serviceable models combined with key observations of the SEC system will allow the prediction of what will happen--where and when. Model requirements will drive what observations are needed for boundary conditions and "truth" tests of the models.

The present approach to implementing a systems-based program is to define the management structure along scientific problem lines. The space environment research area includes the effects of solar variability on climate and global change as well as specification of radiation and density models. The space storms area includes the specification of the environment on a more real-time or nowcasting and event basis. Included as well is the ultimate goal of the LWS, the physical understanding of the end-to-end Sun-Earth system, enabling reliable predictive capability of storm effects. The program has the following elements: (1) a Space Weather Research Network

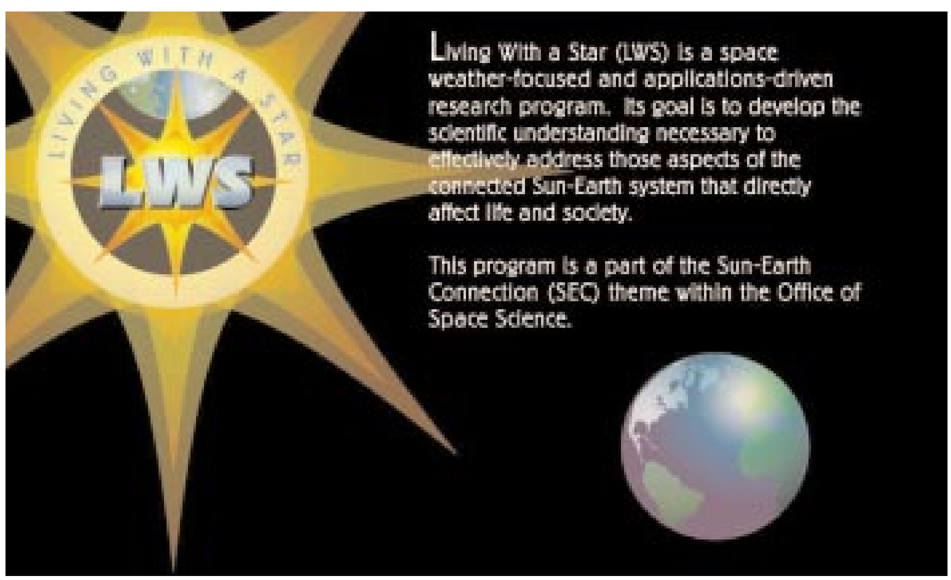


Figure 3-NASA-3. NASA's Goddard Space Flight Center hosts a web site for the "Living With A Star" program (*http://lws.gsfc.nasa.gov/*).

of solar-terrestrial spacecraft; (2) a theory, modeling, and data analysis program; and (3) Space Environment Testbeds (SET) for flight testing radiation-hardened and radiation-tolerant systems in the Earth's space environment. Vital to the success of LWS and critical to the satisfaction of national needs is the development of partnerships with national and international agencies and industry.

Implementation of LWS will proceed in two phases. The first phase will include: (1) a geosynchronous spacecraft that will observe the Sun from its interior (via helioseismology techniques) to the outermost extensions of its atmosphere where solar activity produces the variable solar output of electromagnetic radiation, solar wind, and energetic particles, and (2) the Geospace Mission, a set of spacecraft to understand geospace as a function of time and the effects of solar events and local instabilities on its evolution. The second phase will add a set of heliospheric spacecraft to determine the state of the solar wind and the propagation of events.

AVIATION SAFETY PROGRAM

NASA's Aviation Safety Program is aggressively pursuing several areas that will provide weather information, avoidance, and mitigation technologies, and education and training aids. The following elements are included:

- Aviation Weather Information (AWIN) develops technologies that provide high fidelity, timely, and intuitive information to pilots to enable the detection and avoidance of atmospheric hazards (Figure 3-NASA-4).
- Weather Information Communications (WINCOM) develops advanced communication technologies and architectural concepts to provide weather information, avoidance, and mitigation technologies, icing design and analysis tools, icing education and training aids, and accurate and timely weather information to the cockpit for both national and international flight.
- Turbulence Prediction and Warning System (TPAWS) develops airborne turbulence warning systems and associated crew procedures to mitigate upsets from all types of turbulence encounters, including clear air turbulence (CAT).
- Aircraft Icing (AI) addresses critical technology gaps in ice prediction, detection, avoidance, and mitigation capability to reduce safety hazards, aviation system throughput impacts, cost of air travel, and design cycle time.

The project will:

- develop validated analytical and experimental tools for design and certification/qualification of aircraft systems in icing;
- develop improved predictions, forecasting, and resolution of inflight icing conditions;

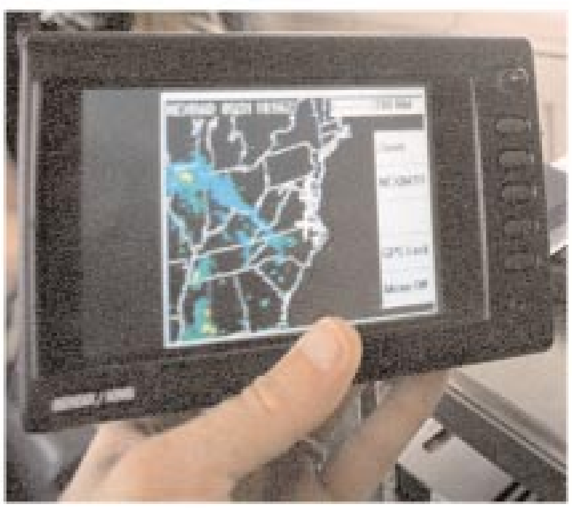


Figure 3-NASA-4. NASA and aviation industry vendors have developed an initial Aviation Weather Information (AWIN) system which is graphical and intuitive for ease of use. Designed to replace bulky, text printouts, AWIN will put graphical weather information in the cockpit.

- better understand the effects of ice contamination on aircraft performance, stability and control, and handling qualities;
- develop ice protection systems, including ice sensing, prevention, and removal;
- develop methods for avoiding in-flight icing hazardous conditions by using remote sensing technologies and flight deck information management; and
- develop icing related educational materials and training aids for pilots, airline operators, and dispatchers.

Synthetic Vision Systems (SVS): NASA is developing "synthetic" (electronically enhanced) vision for the pilot (Figure 3-NASA-5). It combines a very detailed worldwide terrain map (obtained from Space Shuttle mapping missions), precise GPS navigation data, and integrity-monitoring sensors to provide a 3-dimensional, realistic view of the world through a cockpit head-up-display (HUD) or instrument 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. NASA believes that improving the pilot's situational awareness will largely eliminate controlled-flight-into-terrain (CFIT) and runway incursion accidents. NASA is also evaluating the use of modified weather radar and FLIR for runway object detection.

Limited visibility is the single most critical factor affecting both the safety and capacity of worldwide aviation operations. In commercial aviation, over 30 percent of all fatal accidents worldwide, and the leading cause of total fatalities, are categorized as controlled flight into terrain -- accidents in which a functioning aircraft impacts terrain or obstacles that the flight crew could not see. In addition, the largest general aviation accident category is 'Continued Flight into Instrument Meteorological Conditions', in which low-experience pilots continue to fly into deteriorating weather and visibility conditions and either collide with unexpected terrain or lose control of the

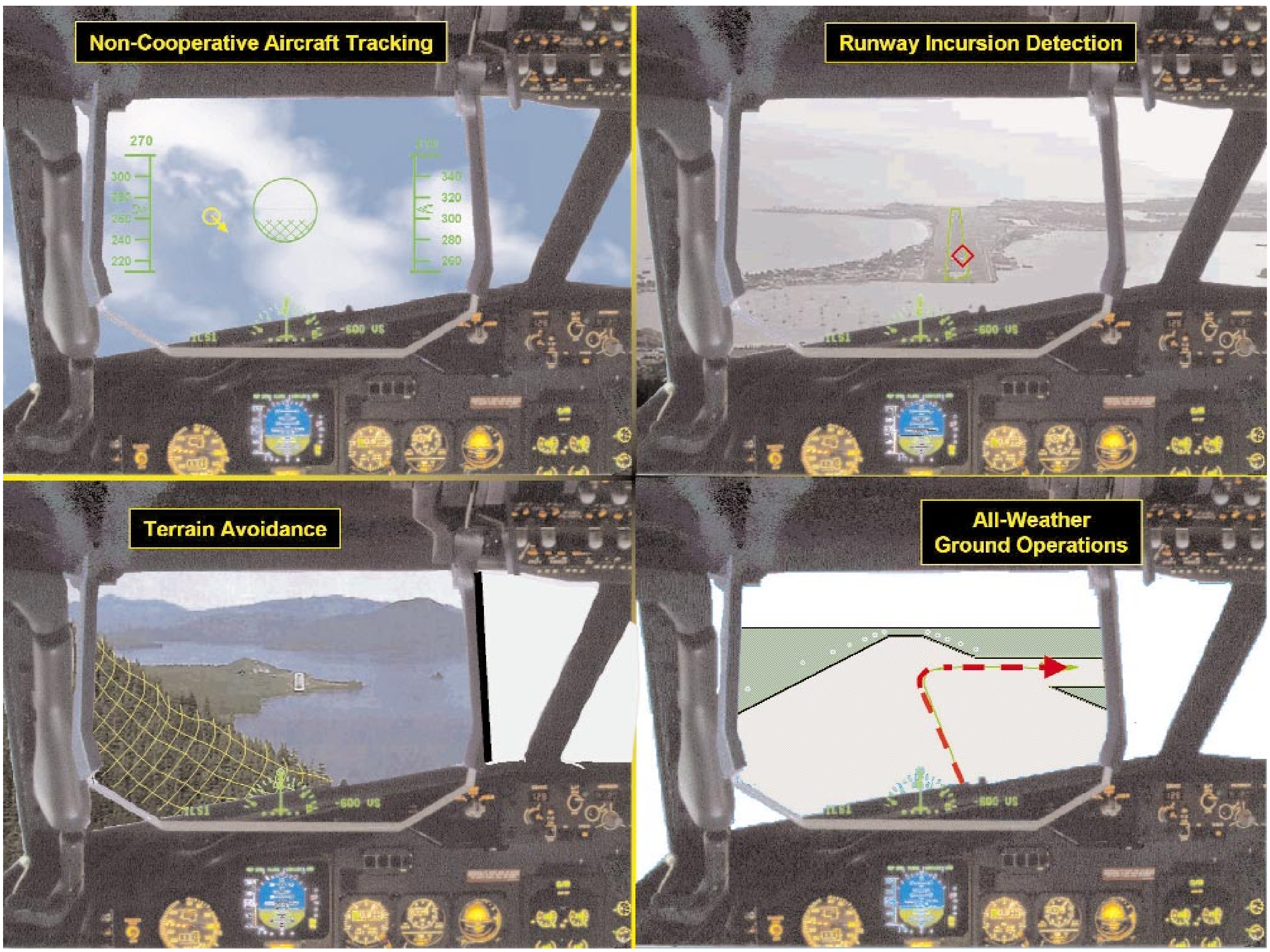


Figure 3-NASA-5. Four examples of synthetic vision systems which enhance a pilot's vision through heads-up displays.

vehicle because of the lack of familiar external cues. The goal of the synthetic vision work is to achieve VMC capability in IMC (to Category IIIB).

GENERAL AVIATION

NASA's Small Aircraft Transportation System (SATS) research program will demonstrate technology to safely guide a small aircraft in near all-weather conditions to virtually any small airport in non-radar, non-towered airspace (Figure 3-NASA-6). The elements are:

- Higher Volume Operation at Non-Towered/Non-Radar Airports will enable simultaneous operations by multiple aircraft in non-radar airspace at and around small non-towered airports in near all weather conditions through the use of vehicle-to-vehicle collaborative sequencing and self-separation algorithms and automated flight path management systems.
- Lower Landing Minimums at Minimally Equipped Landing Facilities will provide precision approach and landing guidance, through the use of graphical flight path guidance and artificial vision, to any touchdown zone at any landing facility while avoiding land acquisition and approach lighting costs, as well as ground-based precision guidance systems, such as ILS.
- Increase Single-pilot crew Safety and Mission Reliability will increase single-pilot safety, precision, and mission completion through the use of human-centered automation, intuitive and easy to follow flight path guidance superimposed on a depiction of the outside world, software enabled flight controls, and onboard flight planning/management systems.
- En Route Procedures and Systems for Integrated Fleet Operations will provide an analytical assessment of the impact of automated flight path management systems designed to facilitate operations at non-towered airports and in non-radar airspace on the integration of SATS equipped aircraft into the higher en route air traffic flows and controlled terminal airspace.

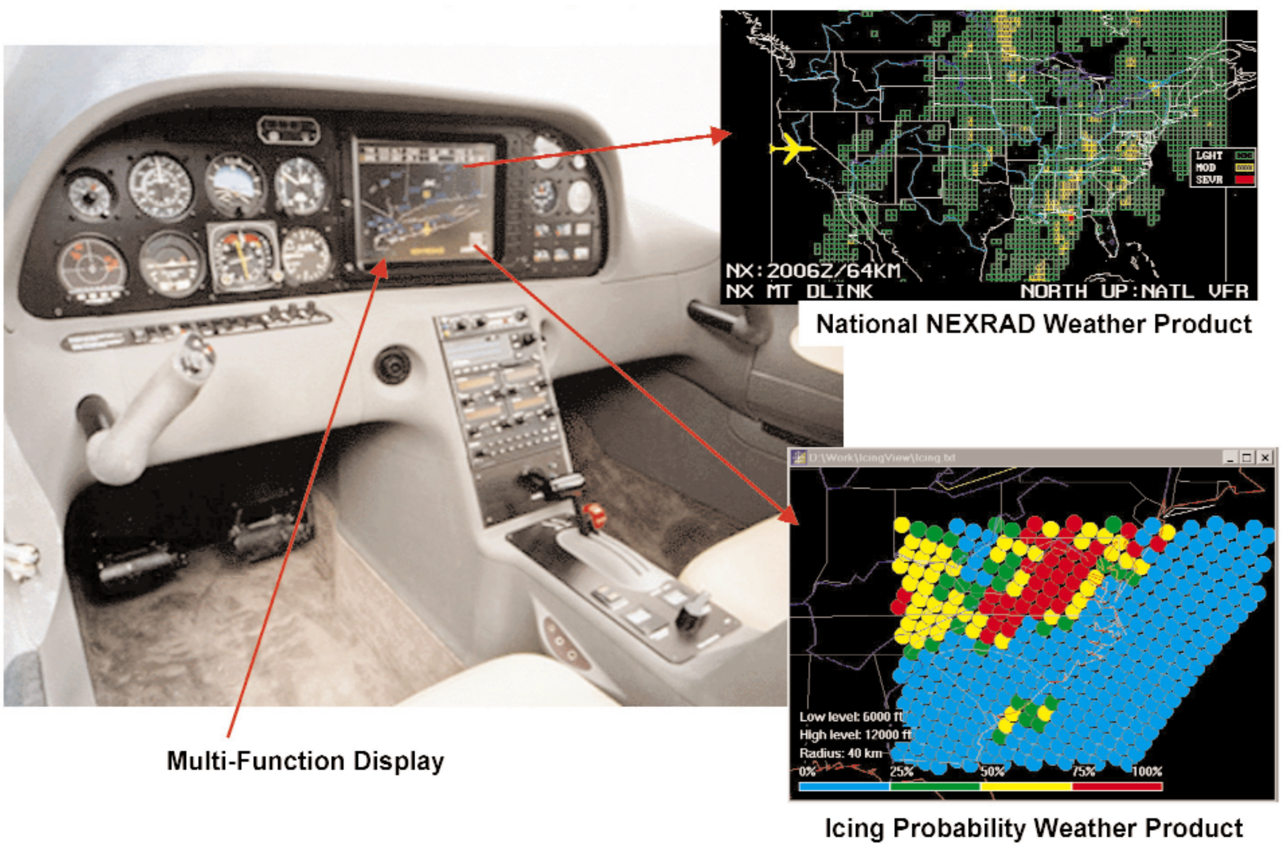


Figure 3-NASA-6. General Aviation cockpit display of weather information.