NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Terra: Flagship of the Earth Observing System

Press Kit
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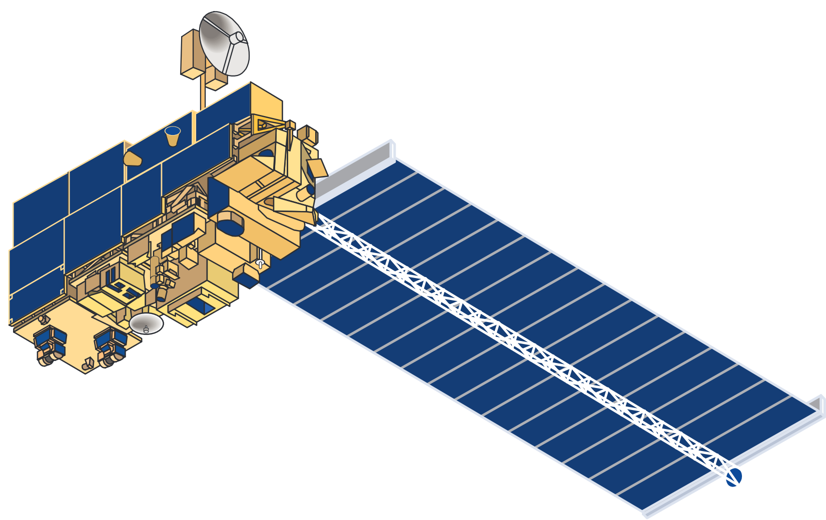

Contacts

Dave Steitz NASA Headquarters	Policy/Program Office	(202) 358-1730
Allen Kenitzer Goddard Space Flight Center	TERRA Mission PAO	(301) 286-2806
George Diller Kennedy Space Center	Launch Operations	(407) 867-2468
Keith Henry Langley Research Center	CERES PAO	(757) 864-6120
Diane Ainsworth Jet Propulsion Laboratory	ASTER/MISR PAO	(818) 354-0850
Marion Neiman Canadian Space Agency	MOPITT PAO	(613) 990-8662

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TERRA SPACECRAFT TO LEAD THE WAY

NASA will launch and deploy the “flagship” to the Earth Observing System series of satellites, part of a precedent setting program designed to provide daily information on the health of the Planet. The Terra spacecraft, formerly known as “EOS AM-1,” is scheduled for launch Dec. 16, 1999.

Terra begins a new generation of Earth science - one that studies the Earth’s land, oceans, air, ice and life as a total global system. Terra will carry a complement of five synergistic state-of-the-art instruments. Researchers now recognize that the Earth - land, oceans, life, and atmosphere - operates as a system - one part impacting the other. EOS will help us to understand how the complex coupled Earth system of air, land, water and life is linked. A series of 10 spacecraft, known as the first EOS series, are scheduled for launch into the next decade.

“After years of anxious anticipation we’re extremely excited about this mission,” said Dr. Ghassem Asrar, NASA associate administrator for the Office of Earth Science, NASA Headquarters, Washington, DC. “The Terra mission has nearly unlimited potential to improve scientific understanding of global climate change.”

The EOS series spacecraft are the cornerstone of NASA’s Earth Science Enterprise, a long-term coordinated research effort to study the Earth as a global system and the effects of natural and human-induced changes on the global environment. Terra will use this unique perspective from space to observe the Earth’s continents, oceans, and atmosphere with measurement accuracy and capability never before flown. This approach enables scientists to study the interactions among these three components of the Earth system, which determine the cycling of water and nutrients on Earth.

“Terra will simultaneously study clouds, water vapor, aerosol particles, trace gases, terrestrial and oceanic properties, the interaction between them and their effect on atmospheric radiation and climate,” said Dr. Yoram Kaufman, Terra project scientist. “Moreover, Terra will observe changes in Earth’s radiation budget (a measurement of all the inputs and outputs of the Earth’s radiative energy), together with measurements of changes in land/ocean surface and interaction with the atmosphere through exchanges of energy, carbon, and water. Clearly comprehending these interactive processes is essential to understanding global climate change,” he said.

A polar-orbiting spacecraft, Terra is scheduled for launch aboard an Atlas-Centaur IIAS expendable launch vehicle from Vandenberg Air Force Base, Calif. The 25-minute launch window opens at 1:33 p.m. EST (10:33 a.m. PST). Separation of the spacecraft from its launch vehicle will occur about 14 minutes after launch.

Once in its final orbital position, the satellite will orbit the Earth at an altitude of approximately 438 miles (705 kilometers) with a Sun-synchronous 98-degree inclination and descend across the equator at 10:30 a.m. Because Terra emphasizes observations of terrestrial surface features, its orbit is designed to cross the equator at this time when cloud cover, which obscures the land surface, is at its daily minimum. The orbit will be adjusted so that it covers the complete Earth every 16 days. This orbit will be maintained with periodic adjustments during the six-year life of the mission.

The spacecraft was built by Lockheed Martin Missiles and Space in Valley Forge, Pa. The five instruments onboard Terra include the Clouds and the Earth's Radiant Energy System (CERES), the Multi-angle Imaging SpectroRadiometer (MISR), the Moderate-Resolution Imaging Spectroradiometer (MODIS), the Measurements of Pollution in The Troposphere (MOPITT), and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument.

The CERES instruments, provided by NASA's Langley Research Center, Hampton, Va., and built by TRW, Redondo Beach, Calif., perform measurements of the Earth's "radiation budget," the process that maintains a balance between the energy that reaches the Earth from the sun, and the energy that goes from Earth back out to space. The critical components that affect the Earth's energy balance are the planet's surface, atmosphere, aerosols, and clouds.

MISR, built and provided by NASA's Jet Propulsion Laboratory, Pasadena, Calif., will measure the variation of surface and cloud properties, and particles in the atmosphere, with cameras pointed in nine simultaneous different viewing directions. MISR will monitor monthly, seasonal, and long-term interactions between sunlight and these components of Earth's environment. Over a seven-minute period, points on the Earth within a 224 mile (360 kilometer) wide swath will be observed successively at all nine angles.

The Moderate-Resolution Imaging Spectroradiometer (MODIS), provided by NASA's Goddard Space Flight Center, Greenbelt, Md., and built by the Raytheon (formerly Hughes) Santa Barbara Remote Sensing, Santa Barbara, Calif., will measure the atmosphere, land and ocean processes, (including surface temperature of both the land and ocean), ocean color, global vegetation, cloud characteristics, temperature and moisture profiles, and snow cover. MODIS will view the entire surface (land, oceans, clouds, aerosols, etc.) of the Earth every 1-2 days at a "moderate resolution" of one-quarter to one kilometer.

The Measurements Of Pollution In The Troposphere (MOPITT) instrument, provided by the Canadian Space Agency and built by COM DEV International of Cambridge, Ontario, will map carbon monoxide and methane concentrations at altitudes between 10 miles and the ground. MOPITT is an infrared gas correlation radiometer and will produce maps over the entire globe every 4-16 days. From these measurements the sources, motions and sinks of these gases can be determined.

The ASTER instrument, provided by Japan's Ministry of International Trade and Industry and built by NEC, Mitsubishi Electronics Company and Fujitsu, Ltd., will measure cloud properties, vegetation index, surface mineralogy, soil properties, surface temperature, and surface topography for selected regions of the Earth.

Hundreds of scientists from the U.S. and abroad are prepared to take full advantage of Terra observations to address key scientific issues and their environmental policy impacts.

Every 1 to 2 days Terra instruments will collect data over the entire Earth's surface, making measurements across a wide spectrum ranging from visible to infrared light. This research ideally will help scientists develop computer models of atmospheric, oceanic, and terrestrial dynamics and subsequently gain a better understanding of these complex systems and how they interact. With this information, scientists will improve their ability to predict significant changes in Earth's environment before they occur.

Terra will collect and archive an unprecedented quantity of high-quality multispectral data each day. The data will, for the first time, provide a high-resolution multi-faceted view of both seasonal and interannual changes in the terrestrial environment.

The Terra Project Office, located at Goddard, manages Terra development for NASA's Office of Earth Science in Washington, D.C. Goddard is responsible for the development of the satellite and the development and operation of the ground operations system. Spacecraft operations will be performed at a Mission Operations Center at Goddard.

Terra is part of a global research program known as NASA's Earth Science Enterprise, a long-term program that is studying changes in Earth's global environment.

NASA recognizes that the knowledge and data derived from Terra have significant practical value to society, and plans to foster increased access to, and use of, the information to make better, more informed decisions related to National needs which affect every American -- health and safety, economic wellbeing, and qualify of life in our communities.

A goal of the Earth Science Enterprise is to expand knowledge of the Earth System, from the unique vantage point of space. Earth Science Enterprise data, which will be distributed to researchers worldwide at the cost of reproduction, is essential to people making informed decisions about their environment.

End of General Release

Media Services Information for Terra's Launch

NASA Television Transmission

NASA Television is broadcast on the satellite GE-2, transponder 9C, C band, 85 degrees west longitude, frequency 3880.0 MHz, vertical polarization, audio monaural at 6.8 MHz. On launch day, television coverage will begin at 10:30 a.m. Pacific Time (1:30 p.m. Eastern Time) and continue through spacecraft separation 14 minutes after liftoff. The schedule for television transmissions for Terra will be available on the NASA Television homepage at http://www.nasa.gov/ntv/.

Audio

Audio only of the launch will be available on the V circuits that may be reached by dialing 407/867-1220, 1240, 1260, 7135, 4003, 4920.

Briefings

A pre-launch briefing at Vandenberg Air Force Base is scheduled on L-1 at 1 p.m. Pacific Standard Time (4:00 p.m. Eastern Time). The briefing will be carried on NASA Television and the audio V circuits.

News Center/Status Reports

The Terra News Center at the NASA Vandenberg Resident Office will open on L-3 days and may be reached at (805) 605-3051. Recorded status reports will be available beginning July 26 at (805) 734-2693, or at (301) 286-NEWS.

Launch Media Credentialing

Media desiring launch accreditation information should contact the U. S. Air Force Public Affairs Office at Vandenberg AFB, Calif., by close of business on L-2, (two days before launch) at:

Telephone: 805-606-3595
FAX: 805-606-8303
E-mail: pubaffairs@plans.vafb.af.mil

Requests must be on the letterhead of the news organization and must specify the editor making the assignment to cover the launch.

Internet Information

Extensive information on the Terra mission, including an electronic copy of this press kit, press releases, facts sheets, status reports and images, is available from the Terra World Wide Web home page at http://terra.nasa.gov/.

Terra Quick Facts

The Terra spacecraft consists of a spacecraft platform provided under a NASA contract with Lockheed Martin Missiles and Space, Valley Forge, Pa., and five instruments procured under a NASA contract with several U.S. and international corporations.

Spacecraft
Dimensions: 22 feet long (6.8 meters) and 11.5 feet (3.5 meters) in diameter
Weight: 11,442 pounds (5,190 kilograms)
Science Instruments: CERES (2), MODIS, MOPITT, ASTER, and MISR
Power: Gallium arsenide solar array, will provide 2,530 watts of load power (average)
Instrument Data Rate: 18,545 kilobits per second average
Design Lifetime: Six years

Orbit: 438 nautical miles (705 kilometers), inclination – 98 degrees to the equator

Launch Site: Western Test Range, Vandenberg Air Force Base, Calif.

Launch Vehicle: Atlas IIAS, Lockheed Martin Astronautics, Denver.

Mission
Planned Launch Date: Dec. 16, 1999
Launch Time: 1:33 p.m. EST (10:33 a.m. PST) (25 minute window)
Spacecraft Separation: Launch + 14 minutes
First Acquisition of Terra Signal: 7 minutes after launch and occurs in through the Tracking and Data Relay Satellite System (TDRSS).

Cost: $1.3 billion, including spacecraft, U.S. instruments and launch vehicle (does not include ground system cost nor the cost of the Canadian or Japanese instruments. Ground operations, including science operations, people, computer hardware/software, etc., for the six year mission will cost approximately $120 million.)

TERRA
THE EARTH OBSERVING SYSTEM
(EOS) AM-1

Earth System Science

Beginning in the 1960s, NASA pioneered the study of the atmosphere from the unique perspective of space with the launch of its Television Infrared Observation Satellite (TIROS-1). Thanks to new satellite and computer technologies, it is now possible to study the Earth as a global system. *Earth System Science* integrates many disciplines of scientific research that focus on understanding the planet as a whole, its integral parts and how its parts interact. Through their research, scientists are better understanding and improving their forecasting of short-term climate phenomena. For instance, NOAA scientists predicted the onset of the 1997-98 El Niño about 10 months before it occurred. Although we are gaining new insights into El Niño, we are currently unable to fully understand the large-scale impacts of the phenomenon, thus diminishing our ability to respond both before and after the event.

Long-term weather and climate prediction is a greater challenge that requires the collection of better data over longer periods. Since climate changes occur over vast ranges of space and time, their causes and effects are often difficult to measure and understand. Scientists must obtain long-term data if they are to reach a clearer understanding of the interactions among the Earth's physical and biological systems. NASA's Earth Observing System(EOS) will help us to understand the complex links among air, land, water and life within the Earth system.

What is Terra?

NASA's commitment to studying the Earth as a global system continues with the Terra spacecraft (originally called EOS AM-1), representing a key contribution by NASA to the U.S. Global Change Research Program. Terra is the flagship in a series of EOS spacecraft. Terra carries five state-of-the-art instrument sets with measurement and accuracy capabilities never flown before, enabling it to observe the cycling of water, trace gases, energy, and nutrients throughout the Earth's climate system. This comprehensive approach to data collection enables scientists to study the interactions among the four spheres of the Earth system – the oceans, lands, atmosphere, and biosphere.

Terra simultaneously will study clouds, water vapor, small particles in the atmosphere (called "aerosol" particles), trace gases, land surface and oceanic properties, as well as the interaction between them and their effect on the Earth's energy budget and climate. Moreover, Terra will observe changes in the Earth's radiation energy budget - which is the amount of incoming energy from the sun minus outgoing energy from reflected sunlight and emitted heat. If we are to succeed in building predictive computer models of these complex interactions, we must clearly comprehend global climatic processes and parameters.

Mission Facts

NASA's Goddard Space Flight Center, Greenbelt, Md., provided the spacecraft or "bus" and one instrument (MODIS). Under Goddard management, Lockheed Martin assembled and tested the Terra spacecraft at its production facility in Valley Forge, Pa.

A polar-orbiting spacecraft, Terra is scheduled for launch in late 1999 aboard an Atlas IIAS launch vehicle from Vandenberg Air force Base, Calif. Synchronized with the sun, Terra's descending orbit will cross the equator at 10:30 a.m. local time during each orbit—hence the original term "AM." Clouds typically form over tropical land in the afternoon as the surface warms, creating updrafts; hence, Terra's morning view will provide clearer images of the Earth's lands. The satellite will orbit the Earth once every 99 minutes at an inclination of 98 degrees relative to the equator, at a mean altitude of 438 nautical miles (705 kilometers). Over the tropical oceans, there are fewer clouds in the afternoon. Terra will be followed by its "PM" spacecraft counterpart in the year 2000. EOS PM-1 will fly in an *ascending* orbit with a 1:30 p.m. equatorial crossing time, thus complementing and extending Terra's measurement capabilities.

Terra is a joint project between the United States, Japan, and Canada. The U.S. provided the spacecraft and three instruments developed by NASA Field Centers—the Clouds and the Earth's Radiant Energy System (CERES), the Multi-angle Imaging SpectroRadiometer (MISR), and the Moderate-resolution Imaging Spectroradiometer (MODIS). Langley Research Center, Hampton, Va. provided two CERES units, the Jet Propulsion Laboratory, Pasadena, Calif., provided MISR, and Goddard Space Flight Center provided the MODIS instrument. The Japanese Ministry of International Trade and Industry provided the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The Canadian Space Agency provided an instrument called Measurements of Pollution In The Troposphere (MOPITT).

NASA's Kennedy Space Center, Fla., will conduct launch operations using the Atlas launch vehicle under a contract with Lockheed Martin Astronautics, Denver.

Goddard will operate Terra via the Tracking and Data Relay Satellite System. It also will receive, process, and disseminate science data through the geographically distributed Earth Observing System Data and Information System (EOSDIS). EOS is managed by Goddard for NASA's Earth Science Enterprise, Washington, D.C.

The Instruments

The ASTER instrument will measure cloud properties, vegetation index, surface mineralogy, soil properties, and surface temperature and topography for selected regions of the Earth at very high resolution (up to 15 x 15 square meters per pixel). Additionally, because two of ASTER's subsystems are tiltable, it can obtain detailed three-dimensional measurements of surface topography.

The CERES instruments will measure the reflected and radiant energy coming from the Earth’s surface and atmosphere, helping us to better determine our planet’s energy balance. The critical components that affect the Earth’s energy balance are the planet’s surface, atmosphere, aerosols, and clouds. CERES will extend the data set begun in the 1980s by NASA’s Earth Radiation Budget Experiment (ERBE).

With cameras pointed in nine different viewing directions, the MISR instrument will measure every part of the Earth system that scatters light differently at different angles: clouds, Earth's surface, and particles floating in the atmosphere. Measuring the reflective characteristics of each of these will help us learn about their changing physicalproperties, as well as quantify their impacts on Earth's energy budget. MISR will also provide unique three-dimensional views of clouds and volcanic plumes.

The MODIS instrument will measure the atmosphere, land, and ocean processes. This includes surface temperature (both the land and ocean), ocean color, global vegetation, cloud characteristics, snow cover, and temperature and moisture profiles. MODIS is capable of viewing the entire globe daily at moderate resolutions, ranging from 250-meters square to 1-kilometer square (about 0.386 square miles) pixels. MODIS is a global-scale, multi-spectral instrument useful for addressing questions in many scientific disciplines.

The MOPITT instrument is an infrared gas-correlation radiometer that will measure gaseous concentrations of carbon monoxide and methane (important air pollutants) in the lower atmosphere (troposphere), the lowest 10 miles of the atmosphere. MOPITT will provide global data on these pollutants as to their location on the planet and the season.

NASA supports about 800 scientists from the United States and abroad to meet global change research objectives using Terra data.

Goals and Objectives

NASA’s Earth Science Enterprise identified several high-priority measurements that EOS should perform to facilitate a better understanding of the components of the Earth system—the atmosphere, the land, the oceans, the polar ice caps, and the global energy budget. The specific objectives of Terra include:

• providing the first global "snapshot" of numerous Earth surface and atmospheric characteristics, the initial set of measurements that will begin a 15-year monitoring program;

• improving the ability to detect human impacts on climate by identifying “fingerprints” of human activity;

• providing observations that will improve forecasts of the timing and the geographical distribution of severe climate events, such as drought and floods;

• improving seasonal and interannual weather predictions using Terra data;

• developing methods for disaster prediction, characterization, and risk reduction from wildfires, volcanoes, floods, and droughts; and

• beginning long-term monitoring of the Earth system to detect changes in global climate and the environment.

Data Processing and Distribution

Terra will provide the first major part of a 15-year environmental dataset focusing on global change. The Terra instruments will produce more than 850 gigabytes of data per day, which is 100,000 volumes of encyclopedias (or 85 personal computer hard disks at 10 gigabytes each) per day. This massive amount of information will be handled using the Earth Observing System Data and Information System (EOSDIS) being developed by the Goddard Space Flight Center with prime contractors Raytheon Systems Company and TRW. EOSDIS has components distributed throughout the U.S. The Terra data will be processed, archived, and distributed using distributed components of EOSDIS: Science Investigator-led Processing Systems, and Distributed Active Archive Centers. EOSDIS will provide the high-performance computing resources needed to process, store, and rapidly transmit petabytes (millions of gigabytes) of the incoming data. EOSDIS uses an “open” architecture to allow insertion of new technology while enabling the system to support the changing mission and science needs throughout the EOS Program.

A New Perspective

Complemented by aircraft and ground-based measurements, Terra data will enable scientists to distinguish between natural and human-induced changes. The EOS series of spacecraft are the cornerstone of NASA’s Earth Science Enterprise, a long-term research effort to study the Earth as a global environment.

For more information on EOS science, access the EOS Project Science Office Homepage at http://eospso.gsfc.nasa.gov. For further information on the spacecraft, access the Terra Project Homepage at http://eos-am.gsfc.nasa.gov. For details on the science goals, objectives, and new science results after launch, see http://terra.nasa.gov; or, visit the Earth Observatory web page for an interactive learning experience at http://earthobservatory.nasa.gov.

Terra Science Objectives

The launch of Terra marks the beginning of comprehensive monitoring of the atmosphere, the oceans, the Earth's continents, and the global "heat engine" that drives climate from a single space-based platform. Data from the five Terra instruments will create continuous, long-term records of the state of the land, ocean, and atmosphere. Together with data from satellite systems launched by NASA and other countries, Terra will inaugurate a new self-consistent data record that will be gathered over the next 15 years.

The science objectives of the Earth Observing System program are to provide global observations and scientific understanding of land cover change and global productivity, seasonal-to-interannual climate predictions, natural hazards, long-term climate variability, and atmospheric ozone. Observations by the Terra instruments will:

- provide the first global and seasonal measurements of the Earth system, including such critical functions as biological productivity of the land and oceans, snow and ice, surface temperature, clouds, water vapor, and land cover;

- improve our ability to detect human impacts on the Earth system and climate, identify the "fingerprint" of human activity on climate, and predict climate change by using the new global observations in climate models;

- help develop technologies for disaster prediction, characterization, and risk reduction from wildfires, volcanoes, floods, and droughts, and

- start long-term monitoring of global climate change and environmental change.

The five Terra instruments, listed below, operate by gathering sunlight reflected by the Earth or heat emitted by the Earth. This "radiant energy" is collected by the instruments and is focused onto specially designed detectors that are sensitive to selected regions of the electromagnetic spectrum, ranging from visible light to heat. The information produced by these detectors is transmitted back to Earth and processed by computers into images.

Advanced Spaceborne Thermal Emission and Reflection Radiometer. ASTER will provide the highest resolution images (15-90 m) of the Terra instruments. Images can be obtained in visible, near-infrared, shortwave-infrared, and thermal infrared wavelengths. ASTER consists of three separate telescope systems, each of which can be pointed by investigators at selected targets. By pointing to the same target twice, ASTER can acquire high-resolution stereo images. The instrument operates for a limited time during each orbit.

Clouds and the Earth's Radiant Energy System. CERES consists of two broadband scanning radiometers that measure reflected sunlight, Earth-emitted thermal radiation, and total radiation. The CERES scanners operate continuously throughout the day and night portion of an orbit. The two instruments obtain a complete representation of radiation from any direction by sampling in different ways the reflected and emitted radiation.

Moderate-Resolution Imaging Spectroradiometer. MODIS will observe the entire surface of the Earth every 1-2 days with a whisk-broom scanning imaging radiometer. Its wide field of view (over 2000 km) will provide images of daylight-reflected solar radiation and day/night thermal emissions over the entire globe. MODIS will be able to see features as small as 250 m-1 km. Some of the 36 different wavelength regions that MODIS samples have never before been monitored from space. MODIS operates continuously.

Measurements of Pollution in The Troposphere. MOPITT will be the first scanning radiometer to measure from space carbon monoxide and methane concentration in the lower atmosphere. The instrument operates continuously, providing science data on both the day and night portions of an orbit.

Multi-angle Imaging SpectroRadiometer. MISR is a new type of instrument designed to view the Earth with cameras pointed at nine different angles. As the instrument flies overhead, each region of the Earth's surface is successively imaged by all nine cameras in four wavelengths. Global coverage is acquired about once every 9 days. MISR acquires 36 simultaneous images at up to 250 meters resolution, but only during the daylight portionof each orbit.

Data from the five Terra instruments will be used to produce dozens of data products on different facets of the Earth system. Some of these geophysical data products will be produced using data from more than one instrument, each with a different set of assumptions and different properties of the product. For example, aerosol properties will be measured by MODIS using its wide spectral range and 1-2 day single view coverage, and also independently by MISR using its multi-angle data, narrower spectral range, and 2-9 day coverage.

These simultaneous, carefully registered data products will allow the EOS instrument teams to develop broad science approaches to specific problems. For instance, in the case of deforestation resulting from biomass burning, fires and emitted smoke particles will be observed by MISR and MODIS, deforestation and burn scars will be observed by ASTER and MODIS, emitted trace gases (carbon monoxide and methane) will be measured by MOPITT, and the radiative forcing of climate will be observed by CERES.

Terra data products will be made available to users in the United States and throughout the world by the EOS Data and Information System (EOSDIS). EOSDIS is designed to operate a suite of polar-orbiting satellites and instruments, capture the satellite data, and generate useful Earth science data products.

Data from Terra will flow via the Tracking and Data Relay Satellite System (TDRSS) to ground stations in White Sands, N.M., where the data will be captured and recorded. The data will be forwarded to the EOS Data and Operations System at Goddard Space Flight Center where they will undergo initial processing. Data sets for four of the five instruments (MODIS, CERES, MISR, and MOPITT) will then be transferred to the appropriate Distributed Active Archive Center (DAAC) for further processing. (Initial data for the ASTER instrument will be sent to the ASTER Ground Data System in Tokyo, Japan, for further processing.) Eight DAACs representing a wide range of Earth science disciplines have been selected by NASA to carry out the responsibilities for processing, archiving, and distributing EOS and related data, and for providing a full range of user support.

Examples of Planned Terra Research

Vegetation: Landscape Changes

Cutting down forests and turning prairie into farmland affect the Earth's climate. Trees and vegetation take up carbon dioxide fromthe atmosphere, while decomposition returns the carbon dioxide to the atmosphere. Knowing how much vegetation the Earth is losing, how much is growing back, and what happens to the organic litter is critical to understanding the effects of human land use on climate. MODIS is the first satellite sensor that will take a global daily tally of human-caused land cover change.

Inez Fung of the University of California, Berkeley, and colleagues will use MODIS to monitor burning forests in the Amazon, Southeast Asia, and Africa. Burning of trees and organic material pumps carbon dioxide, carbon monoxide, methane, and aerosols into the atmosphere. Burning is generally concentrated in small areas that would be impossible to see without satellites. MODIS can also be used to watch how well plants and trees recover after a fire.

Atmosphere: Heat Flow and Climate

The Earth's climate is governed by a balance between sunlight that reaches the Earth and heat that is radiated back into space. Other factors complicate this apparently simple picture, in particular water vapor and clouds. Water vapor is the dominant greenhouse gas in the atmosphere. It traps heat radiation that would otherwise escape into space. Clouds can either reflect solar radiation back to space or absorb heat radiation.

Scientists cannot understand the radiation balance without detailed information about clouds and the greenhouse effect of water vapor. CERES will, for the first time, collect information about clouds, water vapor, and radiation simultaneously. Scientists will use the CERES data to improve their predictions about the effects of global warming on climate and to help differentiate between natural and man-made climate changes.

Since clouds can either warm or cool the atmosphere, they are a great source of uncertainty in climate prediction models. Leo Donner of Princeton University will use CERES data to improve the mathematical description of how clouds affect radiation. More realistic clouds will result in a more accurate depiction of how climate works and changes.

V. Ramanathan at Scripps Institute of Oceanography plans to use CERES measurements to predict the effect of water vapor on the climate of a warmer Earth. Most scientists predict that water vapor will magnify the effect of global warming because warmer air can hold more moisture and a warmer planet evaporates more water.

A critical question for making global predictions is to determine the climate effect of water vapor in the upper troposphere (5-10 miles high). Water vapor is three times as effective at trapping heat if it is in this region. CERES measurements will be used to distinguish the contribution to the total atmospheric greenhouse effect of this critical part of the atmosphere.

Oceans: Temperature and Climate

Oceans are the heat engines driving the Earth's climate. Warm ocean currents travel from the equator toward the polar regions, warming the coldest portions of the globe. Scientists look at sea surface temperature using satellites to determine how climate change effects the ocean and how the oceans effect climate. Sea surface temperatures also define the ocean's turbulent flow patterns, helping scientists study important ocean circulation systems like the Gulf Stream.

Timothy Liu of NASA's Jet Propulsion Laboratory will use MODIS sea surface temperature measurements to understand how the oceans interact with the atmosphere. Sea surface temperatures represent the amount of heat stored in the upper part of the ocean, which has a strong effect on climate because the atmosphere and the oceans are constantly exchanging heat. Liu will use the MODIS sea surface temperature information to make better predictions about how the Earth's climate will change.

Changes in sea surface temperature patterns are also an indication of physical processes in the ocean, such as ocean fronts, eddies, and upwelling. Understanding these phenomena is like understanding weather patterns in the atmosphere. Peter Cornillon of the University of Rhode Island has used sea surface temperature data from a National Oceanic and Atmospheric Administration satellite to explore ocean physical processes for 15 years. He will continue his research with MODIS data to look at long-term trends and how ocean circulation changes over years and decades.

Snow and Ice: Flooding and Climate Change

When warm spring days begin to melt winter snowpack in the northern United States, rivers swell and often flood the surrounding countryside. At times, the floods can be devastating. Thomas Carroll of the National Weather Service's National Operational Remote Sensing Center will use MODIS data to help map the extent of snow cover in the lower 48 United States. The snow cover maps offer detailed information to help forecast spring flooding.

MODIS will monitor snow cover globally, giving climate modelers a critical piece of information about how the amount of snow and ice on the Earth effects climate. Glen Liston of Colorado State University will use MODIS data to improve global and regional climate prediction models. When the sun shines on white snow and ice surfaces, most of the radiation is reflected back to space. Areas covered by snow cannot heat up the atmosphere like areas covered by soil or other ground cover.

The ice in the Earth's polar regions constitutes a huge reservoir of fresh water that responds relatively rapidly to climate change. If ice in the Greenland or Antarctic caps were to flow more quickly into the ocean, sea levels could rise dramatically. Fresh water from melting ice added to the salty ocean could also change the density of the ocean surface water and thereby change ocean circulation, a major component of the Earth's climate system.

Ted Scambos and Anne Nolin of the National Snow and Ice Data Center at the University of Colorado, will use MODIS to monitor the way that ice in Greenland and Antarctica is behaving, both for changes in ice flow patterns and changes in the extent of melting each summer.

Atmosphere: Tracking Air Pollution

Scientists understand much less about what happens to pollution in the lower part of the atmosphere, called the troposphere, than in the higher stratosphere. The ever-changing troposphere with its clouds and weather is much more complex and there have been very few satellite observations of chemicals in the atmosphere below an altitude of 10 miles.

Carbon monoxide is produced primarily by combustion processes such as biomass and fossil fuel burning. But even relatively pristine regions, such as the South Pacific, can have elevated levels because carbon monoxide can be transported great distances by atmospheric winds. Carbon monoxide is absorbed by other chemicals in the atmosphere; however, this may not happen for many days during which it could travel many thousands of miles from the source.

MOPITT will provide the first global measurements of carbon monoxide in the troposphere and give scientists their first opportunity to explore chemical processes in this region on a global scale. John Gille and his data processing team at the National Center for Atmospheric Research will create three-dimensional maps of carbon monoxide concentrations, much like a weather forecast, which will be updated as new data are taken.

The maps will also provide the first global scenes of how pollution is transported around the globe. Members of the MOPITT science team, including Jim Drummond of the University of Toronto, will be looking at how carbon monoxide is transported between the continents and from regions where it is released to regions where it is absorbed. Daniel Jacobs of Harvard University plans to use the maps particularly to answer questions such as how pollution in China affects North America.

Guy Brasseur at the National Center for Atmospheric Research and John McConnell at York University are working to combine the satellite data with powerful atmospheric models that will give scientists the first global pictures of how atmospheric composition varies over the seasons and at different regions and latitudes.

Other scientists will combine the space-borne measurements with measurements from aircraft and from the ground to gain a more complete picture of the chemistry of the lower atmosphere. Gary Davis of the University of Saskatchewan and Jim Drummond will combine data from an aircraft instrument similar to MOPITT with that from the space instrument to look at regions that are inaccessible to the satellite because they are either too small, or hidden under clouds.

Land Surface: Urbanization and Agriculture

ASTER will be able to measure heat coming off the ground more accurately than any previous civilian satellite sensors. Knowing the temperature of the ground can also tell scientists how much water is in the soil, an important fact for farmers and land managers.

Researchers will use ASTER along with data from Landsat satellites to study “heat islands” created by many North American cities including Los Angeles, Chicago, Atlanta, Washington, Phoenix, Salt Lake City, Sacramento, Calif., Tucson, Ariz., Baltimore, Md., and Baton Rouge, La.

Rural and agricultural regions will also benefit from ASTER's heat-sensing capability. Jim Shuttleworth of the University of Arizona said that by knowing the temperature of plants, scientists can tell if crops and natural vegetation are short of water. Moisture in the soil is a major factor effecting how plants grow. By knowing if the plant needs water, scientists can indirectly tell if there is enough moisture in the soil.

Ecosystems: Long-term Changes

By combining information from three Terra sensors, scientists will be able to see subtle changes in forest ecosystems with the changing seasons. And by using a comprehensive 20-year collection of satellite data along with new MODIS data, scientists will decipher long-term changes to global ecosystems, giving scientists a global check on the planet's vitality.

David Schimel of the National Center for Atmospheric Research will combine data from Landsat satellites and the Terra sensors MODIS, MISR, and ASTER to look at how growing seasons in the Northern Hemisphere are responding to overall global temperature and rainfall trends.

A regional study by the University of Arizona's Soroosh Sorooshian will use MODIS data to keep track of seasonal land cover changes in the Southern Colorado Basin. Sorooshian will study whether seasonal changes in vegetation growth are connected to large climate events like El Niño. Knowing how larger and smaller climate systems are related could help forecast drought and evaluate forest fire hazards.

A team lead by Compton Tucker of NASA's Goddard Space Flight Center will add MODIS data to nearly two decades of National Oceanic and Atmospheric Administration satellite observations, continuing their long-term studies of global vegetation cover and the expansion and contraction of the world's major deserts. MODIS data will be combined with the historical record of data to determine how land vegetation varies from year to year.

With twice the resolution of previous instruments, MODIS will collect much more detailed vegetation information. MODIS is also more sensitive to different types of radiation reflected by the Earth's surface, helping the sensor see vegetation more clearly. This is important in arid and semi-arid environments where green vegetation can be sparse.

Oceans: Health of Plant Life

Half of all carbon dioxide taken up by plants on Earth takes place in the oceans. Microscopic phytoplankton use carbon dioxide during photosynthesis, making the single-cell plants a major part of the global carbon cycle. Scientists will use MODIS to understand how this massive stock of plant life regulates the amount of greenhouse gases in the Earth's atmosphere. The amount, distribution, and health of phytoplankton can also tell scientists and fisherman what areas of the ocean are full of larger fish and marine mammals. MODIS is the first satellite sensor that can tell both how much phytoplankton there is and how healthy the plants are.

Satellite sensors can see microscopic phytoplankton in the oceans by detecting chlorophyll in the plants. Millions of tiny phytoplankton "bloom" and tint the blue ocean a bright green.

Kevin Arrigo of NASA's Goddard Space Flight Center, will use MODIS to study the Southern Ocean around Antarctica. Because of its remote location, satellites are the best way for scientists to study seasonal phytoplankton blooms in the ocean surrounding the frozen continent.

Mark Abbott of Oregon State University said that in addition to finding out how much phytoplankton there is, it is important to know how healthy the phytoplankton populations are. Phytoplankton absorb sunlight and either use it to grow or re-emit it as faint, red fluorescence. A lot of fluorescence coming from an area in the ocean is a sign of unhealthy phytoplankton populations, said Abbott. MODIS is the first satellite sensor that can see fluorescence from the phytoplankton blooms. Abbott plans to use MODIS to keep check of phytoplankton health in studies of the Pacific Ocean north of Hawaii and along the California and Oregon coasts.

Atmosphere: An Elusive Greenhouse Gas

Methane, one of the major greenhouse gases, is produced by both natural processes and human activities. Scientists know that methane is produced by wetlands in northern Canada and Siberia, fossil fuel extraction, rice cultivation, landfills, and herds of cattle and other livestock. But they don't know how large these sources are and where they are. Researchers will use MOPITT data to answer these basic questions.

The MOPITT science team, led by Jim Drummond of the University of Toronto and John Gille of the National Center for Atmospheric Research, will produce maps of methane concentrations in the lowest ten miles of the atmosphere over the entire globe. Methane levels in the Earth's atmosphere are low – a few molecules in a million – yet the gas makes a sizable contribution to global warming. In fact every extra molecule of methane in the atmosphere is as effective at global warming as forty molecules of carbon dioxide.

These will be the first global maps of an important chemical in the lower atmosphere that is produced by biological as well as manmade sources. The measurements will enable scientists to dramatically improve estimates of methane emissions. Methane is one of the greenhouse gases named in the Kyoto Protocol.

Inez Fung at the University of California, Berkeley says that current estimates for methane sources and sinks are based on extrapolation from a few well-studied field sites. She plans to use MOPITT data to improve our understanding of methane sources. For example, current estimates lump emissions from all wetlands together. She will use the data to look for major differences between emissions from wetlands of northern Canada and Siberia.

David Schimel of the National Center for Atmospheric Research plans to study how natural processes in the atmosphere control methane concentrations. He will compare MOPITT methane data from different years to study large-scale patterns in climate to get a fix on what natural processes in the atmosphere control methane concentrations.

Oceans: A Key Carbon-Consuming Plant

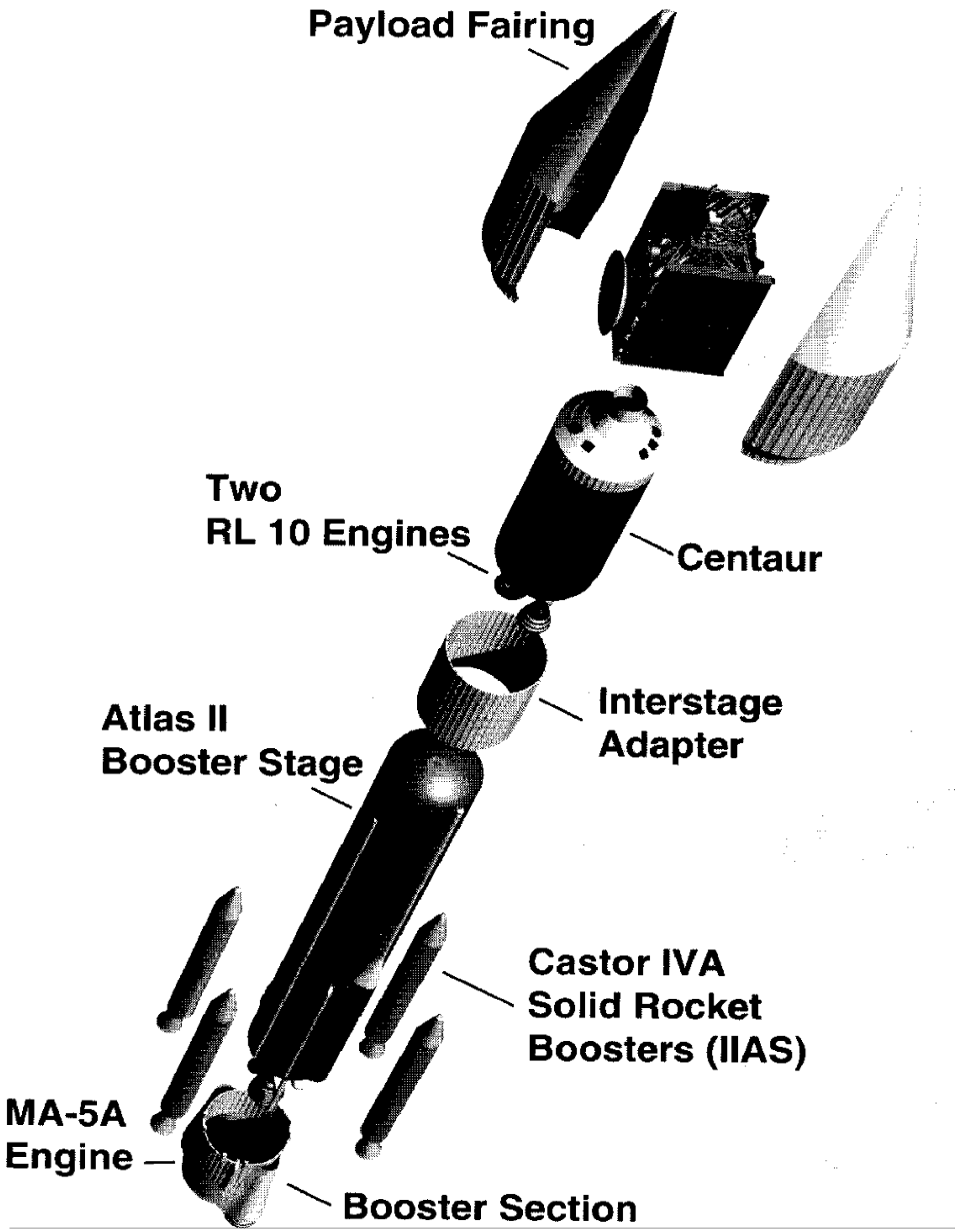
Scientists believe that one of the culprits in the "missing carbon" problem – the discrepancy between known sources of atmospheric carbon and known sinks – may be tiny microscopic plants called coccolithophores. All microscopic plants in the ocean live on carbon dioxide. But coccolithophores are the only one-celled plants that take bicarbonate—a molecule containing carbon—and turn it into fancy microscopic doilies made up of calcium carbonate, or limestone.

The plants coat themselves in an armor of the limestone discs called coccoliths. When the plants die, the coccoliths and the carbon they contain can fall to the ocean floor and build up over millions of years into thick beds of limestone. The result is the removal of carbon from the Earth's atmosphere-ocean system. MODIS will provide the first remote-sensing data designed to keep track of the carbon dioxide-consuming coccolithophores.

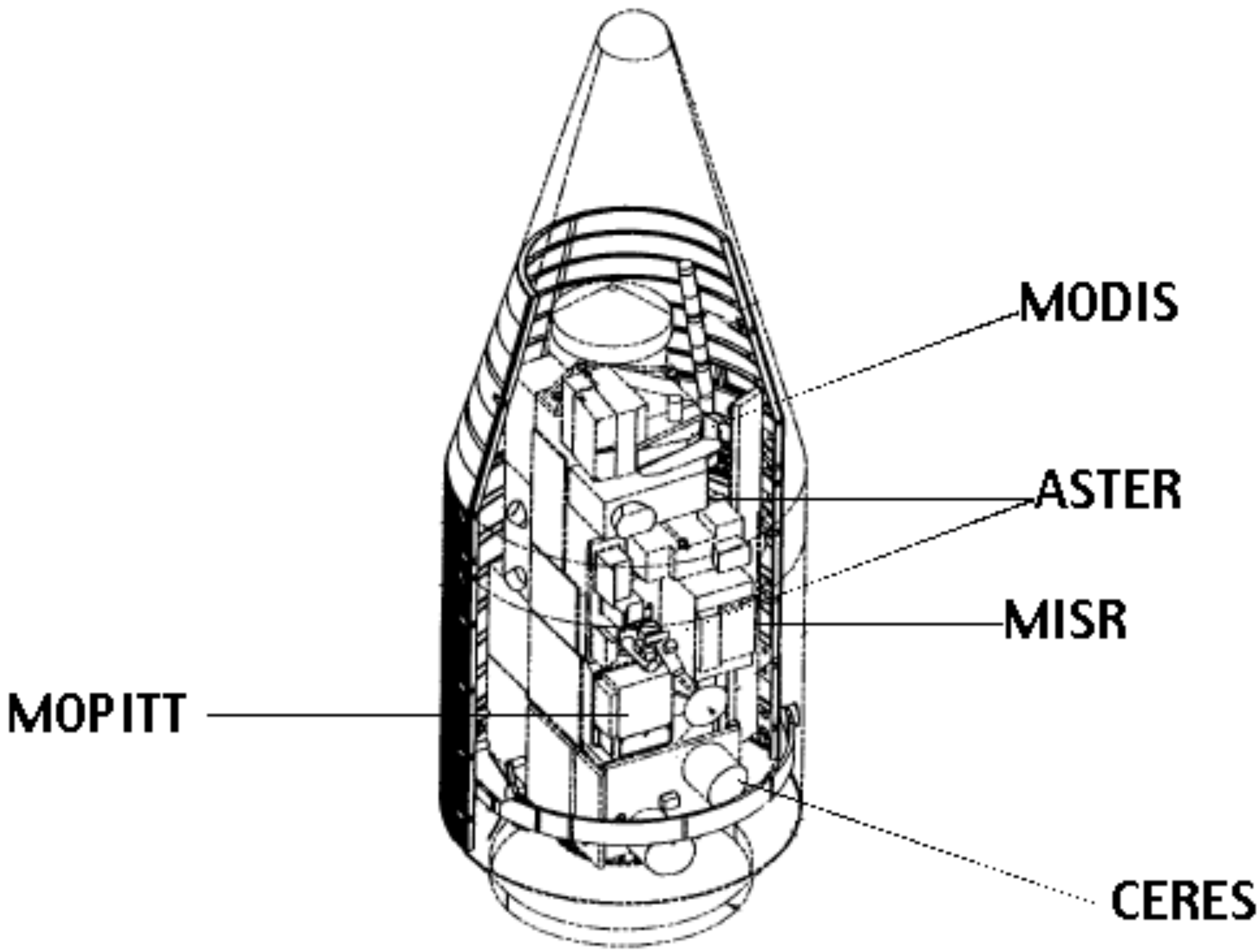
Although satellites can see phytoplankton in the oceans because chlorophyll in the microscopic plants turn the ocean green, it is not possible to tell one species of phytoplankton from another from space, except in the case of coccolithophores. William Balch of the Bigelow Laboratory said that coccoliths have been a problem for remote sensing because their presence makes it more difficult to measure how much chlorophyll the ocean contains, and therefore how much total phytoplankton is blooming. Even when the coccolithophores are not in full bloom, they account for about 10 percent of the back-scattered light reaching satellites, making chlorophyll measurements less accurate.

END

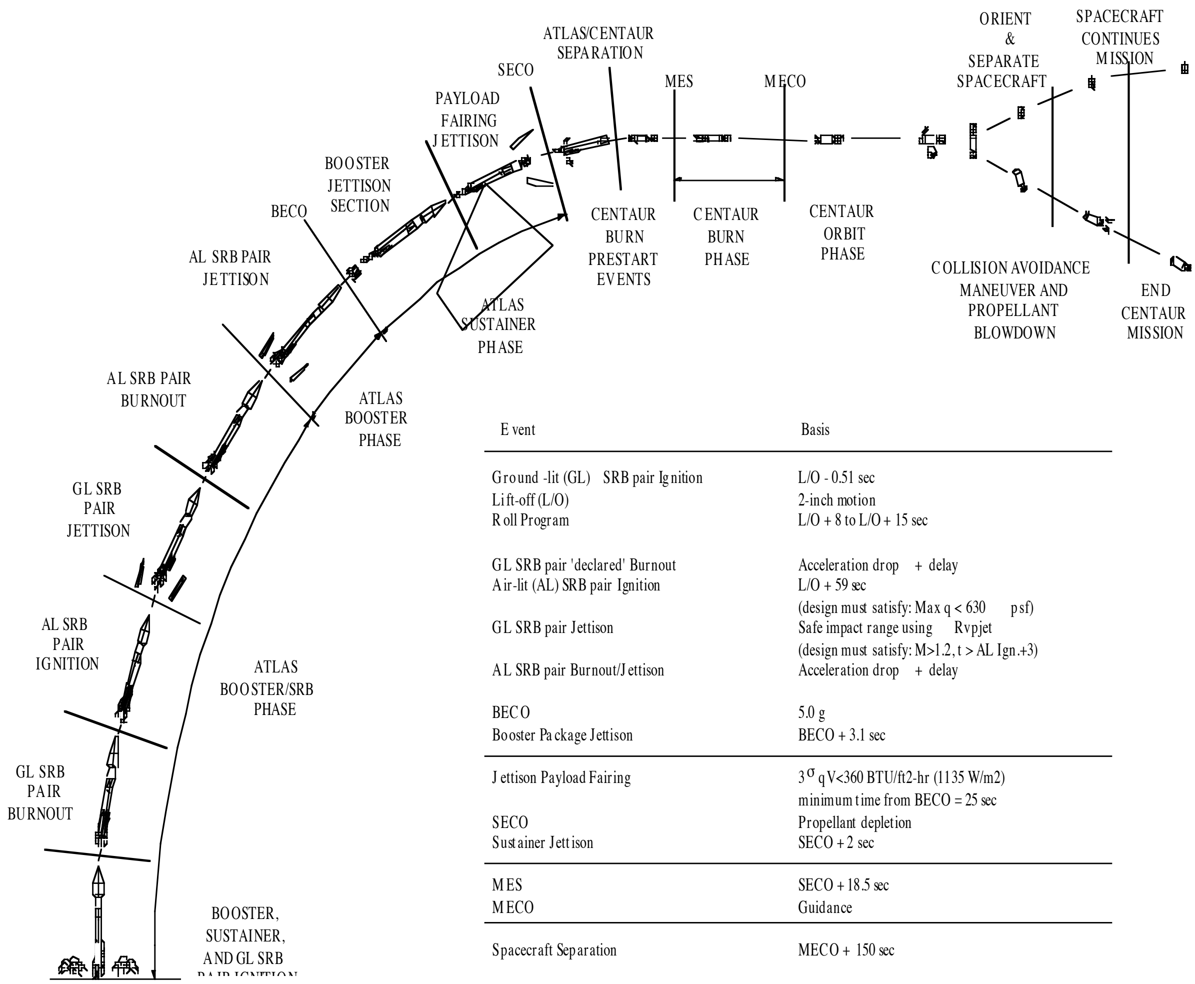
Atlas IIAS and Centaur Overview



EOS Terra Launch Configuration



Terra Launch Profile



Event	Basis
Ground -lit (GL) SRB pair Ignition	L/O - 0.51 sec
Lift-off (L/O)	2-inch motion
Roll Program	L/O + 8 to L/O + 15 sec
GL SRB pair 'declared' Burnout	Acceleration drop + delay
Air-lit (AL) SRB pair Ignition	L/O + 59 sec (design must satisfy: Max q < 630 psf)
GL SRB pair Jettison	Safe impact range using Rvpjet (design must satisfy: M>1.2, t > AL Ign.+3)
AL SRB pair Burnout/Jettison	Acceleration drop + delay
BECO	5.0 g
Booster Package Jettison	BECO + 3.1 sec
Jettison Payload Fairing	3σ qV<360 BTU/ft2-hr (1135 W/m2) minimum time from BECO = 25 sec
SECO	Propellant depletion
Sustainer Jettison	SECO + 2 sec
MES	SECO + 18.5 sec
MECO	Guidance
Spacecraft Separation	MECO + 150 sec

Legend:

MECO=	**Main Engine Cut Off**
SECO=	**Second Engine Cut Off**
GEM=	**Graphite Epoxy Motor**
SRM=	**Solid Rocket Motor**
FPS=	**Feet Per Second**
VL=	**Velocity (in feet per second)**
Alt=	**Altitude (in nautical miles)**
T=	**Time**

Orbit

The satellite will orbit the Earth almost 16 times every day, about once every 99 minutes, at an altitude of approximately 438 miles (705 kilometers). Terra will have a Sun-synchronous 98-degree inclination and a descending equatorial crossing time of 10:30 a.m.

Communication/Data

A silicon cell solar array, nickel hydrogen battery power subsystem will provide 2,530 watts of power to the satellite. The primary communication link between the Terra spacecraft and Earth Observing System Data and Information System (EOSDIS) is via the Tracking and Data Relay Satellite System (TDRSS). Command and housekeeping telemetry will be transmitted via S-band. The science data recorded onboard will be transmitted via Ku-band at 150 Megabits per second. The nominal mode of operation is to acquire two-12 minute TDRSS contacts per orbit. During each TDRSS contact, both S-band and Ku-band transmission will be used.

In the event that TDRSS communication becomes unavailable, the EOS Polar Ground Stations (EPGS) located at Poker Flats, Alaska and Spitzbergen, Norway and the Wallops Island Station, Va., will be used to support command and housekeeping telemetry via the S-band.

Besides Ku-band and S-band communication, Terra is also capable of downlinking science data via the X-band. The X-band communication can be operated in three different modes, Direct Broadcast (DB), Direct Downlink (DDL) and Direct Playback (DP). DB and DDL will be used to directly transmit real-time MODIS and ASTER science data respectively to users. In the DP mode, recorded science data can be downlinked to the EPGS and serves as a backup to the primary Ku-band communication link.

Ground System

The ground system includes a spacecraft control center, ground stations for uplinking commands and receiving data, a data handling facility and a data archive developed by the Goddard Space Flight Center in conjunction with several Distributed Active Archiving Centers (DAACs). These facilities, located at major research centers throughout the United States, will communicate with Terra, control all spacecraft and instrument operations, and will receive, process, archive, and distribute the data.

Calibration and Validation

In both the pre- and post-launch periods of Terra, EOS instrument team members and interdisciplinary investigators will conduct scientific field campaigns to verify the quality and long-term stability of the EOS sensors' measurements, as well as the validity of the derived geophysical data products. The magnitudes of any uncertainties and errors in Terra data products must be quantified, on both spatial and temporal scales, to ensure that the data are scientifically credible and maximally useful. Understanding the uncertainties and errors is also essential for future improvement of the algorithms and Earth observing systems.

To obtain the necessary correlative observations required for validation, the EOS program will use a four-pronged approach that incorporates the following:

1. surface-based (in situ) radiance observations and measurements at specific test sites obtained as part of the EOS interdisciplinary, instrument, and validation teams' investigations;

2. field experiments conducted by EOS interdisciplinary, instrument, and validation teams, as well as participation in, and support of, nationally and internationally coordinated field programs;

3. coordination with national and international observation sites and networks such as the Department of Energy (DoE) Atmospheric Radiation Measurement (ARM) Program, the National Science Foundation (NSF) Long-Term Ecological Research (LTER) sites, and the WCRP Baseline Surface Radiation Network (BSRN); and

4. airborne remote sensing measurements using specifically designed EOS instrument simulators, such as the MODIS Airborne Simulator (MAS), AirMISR, MOPITT-A, Airborne Test Radiometer (MATR), and MODIS/ASTER Airborne Simulator (MASTER), as well as community airborne instruments, such as the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS).

These highly-focused validation activities will range from calibration of the basic radiance measurements to validation of the higher-order biogeophysical products such as land cover, ocean chlorophyll content, net primary productivity, and the planetary energy budget including components of the atmosphere and surface energy budgets. Validation of the Terra science data products encompasses measurements and comparisons made on local-to-regional-to-global scales, including intercomparison of various satellite-derived parameters and the incorporation of satellite-derived information into models of the Earth system and its components.

EOSDIS will serve as the primary data system for archiving of Science Working Group for the Terra Platform (SWAMP) validation data. The EOS Project Science Office validation home page (http://eospso.gsfc.nasa.gov/ validation/) includes the Terra Instrument science team validation plans and a wealth of information on the EOS Validation program.

Program/Project Management

NASA developed Terra and is responsible for the development and launch of the satellite, and the development of the ground system. The Terra spacecraft was assembled and tested by Lockheed-Martin at its Valley Forge, Pa., production facility.

NASA Management:
Headquarters
Dr. Ghassem Asrar, Associate Administrator of the Office of Earth Science

Goddard Space Flight Center
Kevin Grady, Terra Project Manager
Dr. Yoram Kaufman, Terra Project Scientist

Canadian Space Agency Management:
Barry Wetter, Director General, Space Science Program
Dr. Robert Hum, Director, Space Science & Applications
Roger Colley, MOPITT Project Manager
Dr. David Kendall, MOPITT Project Scientist

MITI Management:
Mr.Toshinori SAEKI
Director, Aircraft, Defence Products and Space Industry Division
Machinery and Information Industries Bureau
MITI, Japan

Mr.Mitsuo INOUE
Assistant Deputy Director, Second Space Reseach and Development Section
Aircraft, Defence Products and Space Industry Division
Machinery and Information Industries Bureau
MITI, Japan

Terra Science Team Members

Yoram Kaufman
Terra Project Scientist
Code 913
NASA Goddard Space Flight Center
Greenbelt, MD 20771
301-614-6189
kaufman@climate.gsfc.nasa.gov

James Collatz
Assistant Terra Project Scientist
Code 923
NASA Goddard Space Flight Center
Greenbelt, MD 20771
301-614-6651
jcollatz@gsfc.nasa.gov

K. Jon Ranson
Terra Deputy Project Scientist
Code 923
NASA Goddard Space Flight Center
Greenbelt, MD 20771
301-614-6650
jon.ranson@gsfc.nasa.gov

Langley Research Center
Dr. Bruce Barkstrom, CERES Principal Investigator

Jet Propulsion Laboratory
David J. Diner, MISR Principal Investigator
Thomas Livermore, MISR Project Manager
Dr. Ralph Kahn, MISR scientist
Dr. Anne Kahle, ASTER Principal Investigator
Moshe Pniel, ASTER project manager
Simon Hook,ASTER scientist

Japanese Ministry of International Trade and Industry
Hiroji Tsu, ASTER Principal Investigator

University of Toronto
Dr. James Drummond, MOPITT Principal Investigator