



PRESS KIT/JUNE 2008

Ocean Surface Topography Mission/ Jason 2 Launch



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Media Services Information

NASA Television

In the continental United States, NASA Television's Public, Education and Media channels are carried by MPEG-2 digital C-band signal on AMC-6, at 72 degrees west longitude, Transponder 17C, 4040 MHz, vertical polarization. They're available in Alaska and Hawaii on an MPEG-2 digital C-band signal accessed via satellite AMC-7, transponder 18C, 137 degrees west longitude, 4060 MHz, vertical polarization. A Digital Video Broadcast-compliant Integrated Receiver Decoder with modulation of QPSK/DBV, data rate of 36.86 and FEC 3/4 is required for reception. NASA TV Multichannel Broadcast includes: Public Services Channel (Channel 101); the Education Channel (Channel 102) and the Media Services Channel (Channel 103). Analog NASA TV is no longer available.

For digital downlink information for each NASA TV channel, schedule information for OSTM/Jason 2 activities and access to NASA TV's public channel on the Web, visit <http://www.nasa.gov/ntv>.

Audio

Audio of the pre-launch news conference and launch coverage will be available on "V-circuits" that may be reached by dialing 321-867-1220, -1240, -1260 or -7135.

Webcast

NASA will air a prerecorded webcast about the mission one day before launch. The webcast will be available at: <http://www.nasa.gov/ostm>.

Briefings

Mission and science overview news conferences on OSTM/Jason 2 will be presented in a pair of news briefings broadcast on NASA Television that originate from NASA Headquarters at 11 a.m. and 12:15 p.m. EDT, respectively, on May 20, 2008.

Pre-launch readiness and mission science briefings will be held at 1 p.m. and 2 p.m. PDT (4 p.m. and 5 p.m. EDT), respectively, on launch minus two days in Building 12000, Vandenberg Air Force Base, Calif. A media advisory will be issued outlining details of these broadcasts.

Launch Media Credentials

News media interested in attending the launch should contact 2nd Lt. Raymond Geoffroy, U.S. Air Force 30th Space Wing Public Affairs Office, Vandenberg Air Force Base, Calif., phone 805-606-3595, fax 805-606-8303, email raymond.geoffroy@vandenberg.af.mil. Foreign nationals must submit accreditation requests no later than May 15. Please include full legal name, news organization, address, nationality/citizenship, passport number and date of birth. A legal photo identification will be required upon arrival at Vandenberg to cover the launch.

News Center/Status Reports

The OSTM/Jason 2 News Center at the NASA Vandenberg Resident Office will be staffed beginning launch minus four days and may be reached at 805-605-3051. Recorded status reports will be available beginning launch minus three days at 805-734-2693.

Internet Information

More information on the OSTM/Jason 2 mission, including an electronic copy of this press kit, news releases, fact sheets, status reports and images, can be found at <http://www.nasa.gov/ostm> .

Quick Facts

Spacecraft

Dimensions: 1 meter by 1 meter by 3.7 meters (3.3 feet by 3.3 feet by 12.1 feet)

Weight: 505 kilograms (1,113.3 pounds)

Power: 620 watts

Primary science instruments: Poseidon-3 radar altimeter; Advanced Microwave Radiometer; Doppler Orbitography and Radio-positioning Integrated by Satellite (Doris); Laser Retroreflector Array; Global Positioning System Payload

Passenger instruments: Environment Characterization and Modelisation-2 (Carmen-2); Time Transfer by Laser Link; Light Particle Telescope

Mission

Launch date/time: No earlier than June 15, 2008, at 1:47 a.m. PDT (4:47 a.m. EDT)

Site: Launch Complex 2W, Vandenberg Air Force Base, Calif.

Launch vehicle: United Launch Alliance Delta II 7320-10

Launch period: June 15, 2008 – August 15, 2008

Launch window: Approximately 9 minutes

Primary mission: Three years, with provision for a two-year extended mission

Orbit path: Circular, 1,336 kilometers (830 miles)

Orbital inclination: 66.05 degrees (non-sun-synchronous orbit)

Why Study Ocean Surface Topography?

Precise measurements of sea-surface height from space make it possible to map ocean surface topography, which is defined as the height of the ocean surface relative to Earth's geoid (a hypothetical Earth surface that represents the mean sea level if there were no winds, currents and most tides). They provide a tool for tracking ocean currents, which can improve our knowledge of global circulation and our understanding of climate change.

A topographic map of Earth's land masses shows the location and height of its mountains, as well as the location and depth of its valleys. It reveals where land has been smoothed over by glaciers and where volcanoes and earthquakes have carved their signatures on the landscape.

A topographic map of the surface of Earth's oceans is equally revealing, yet in a completely different way. The ocean's surface has hills and valleys, too, varying in height by as much as two meters (6.5 feet) from one place to the next. Currents flow around these hills and valleys just as wind blows around high and low pressures in the atmosphere. Shaped by currents, winds and Earth's gravity, the surface of the ocean tells a larger story about its most basic functions – how it stores vast amounts of energy from the sun, how it moves that energy around the globe and how it works together with the atmosphere to create our weather and climate. Ocean topography provides many answers to these complex questions.

The Climate Machine: Figuring Out How It Works

Covering more than 70 percent of Earth's surface, the oceans are our planet's most dominant feature. They are also Earth's major storehouse for heat from the sun. In fact, the amount of heat stored in the ocean's top three meters (10 feet) is the same as the heat stored in the entire atmosphere.

The ocean is the single most significant influence on Earth's weather and climate. This great reservoir is constantly exchanging heat and moisture with the atmosphere, driving our weather and controlling the slow, subtle changes in our future climate. Understanding how this heat moves within the oceans and into the atmosphere is critical to understanding global climate.

Working together in a complex interplay of wind and current, the ocean and the atmosphere transport heat from Earth's equatorial regions toward the icy poles. The atmosphere moves heat through a complex, worldwide pattern of winds: as winds blow across the sea surface, they drive the ocean currents. The currents, which travel more slowly than the winds, carry stored heat (along with salt, nutrients and other chemicals), slowly releasing the heat into the atmosphere. While winds create daily, short-term weather changes, the oceans have a slower, much longer-lasting effect on climate.

As the water loses its heat, it becomes cold and heavy and eventually sinks to the ocean bottom. It flows back toward the equator, where it rises to the surface again perhaps 10, 100 or even 1,000 years later. This global conveyor belt, collecting and moving heat from the warm tropics to the cold poles, drives the climate on which our lives depend.

To better understand climate and predict future climate change, we need to be able to measure how much heat is in the ocean, pinpoint where it is, and map its movement through ocean currents.

But the vast size, density and turbulent nature of the oceans make them difficult to observe and study in detail. Before the launch of Topex/Poseidon in 1992, oceanography—the scientific study of the oceans—could only make use of relatively isolated data from ships and ocean buoys to study global patterns of waves and currents, surface heights, salinity and temperatures. Such measurements, while valuable, are not extensive enough or capable of providing constant and accurate measurements over vast distances.

Radar Altimeters for Ocean Topography

Spaceborne radar altimeters have proven to be superb tools for mapping ocean-surface topography. These instruments send a microwave pulse to the ocean's surface and time how long it takes to return. A microwave radiometer corrects any delay that may be caused by water vapor in the atmosphere. Other corrections are also required to account for the influence of electrons in the ionosphere and the dry air mass of the atmosphere. Combining these data with the precise location of the spacecraft makes it possible to determine sea-surface height to within a few centimeters (about one inch). The strength and shape of the returning signal also provides information on wind speed and the height of ocean waves. These data provide scientists with information about the speed and direction of ocean currents and about the heat stored in the ocean, which, in turn, reveals global climate variations.

Spaceborne radar altimetry was first used to measure ocean surface topography by NASA's Seasat experimental satellite in 1978. It was next used on the U.S. Navy's Geosat from 1985 to 1989. In 1979, NASA and JPL began planning a project called the Ocean Topography Experiment, or Topex, to measure the height of the world's oceans. About the same time, France's space agency, the Centre Nationale d'Etudes Spatiales (CNES), was working on an oceanographic mission called Poseidon. The two agencies decided to work together and created the Topex/Poseidon mission, the first mission in a worldwide effort to study and describe the dynamics of the global ocean and their relationship to Earth's environment and climate change.

NASA provided the satellite and five instruments. For that mission, CNES furnished two instruments and the launch on an Ariane 42P rocket from French Guiana in South America. JPL was responsible for project management and communicated with the satellite through NASA's Tracking and Data Relay Satellite System. CNES and NASA processed and distributed the data to science investigators around the world.

Launched in August 1992, Topex/Poseidon measured sea-surface height over 95 percent of Earth's ice-free oceans once every 10 days. It allowed scientists to chart the height of the seas across ocean basins with an accuracy of 4 centimeters (1.5 inches). In its first month of operation, Topex/Poseidon provided more information about the surface height of Earth's oceans than had been collected by ships during the entire previous century.

The unprecedented success of Topex/Poseidon led scientists to recognize the need to sustain these high-accuracy measurements into multiple decades so that the data could be integrated into long-term climate prediction models.

The result was Jason 1, launched in December 2001 and still in operation. Unlike Topex/Poseidon, Jason 1 data are no longer experimental in nature; near-real-time products are routinely disseminated. After a cross-calibration experiment was completed in August 2002, Topex/Poseidon was maneuvered into a new orbit, making observations along tracks interleaving the Jason tracks, thereby doubling the data coverage in a tandem mission with Jason 1. This tan-

dem mission ended in October 2005 when Topex/Poseidon's highly successful mission ended due to hardware failure after 13 years of operations—history's longest Earth-orbiting radar mission.

To provide continuity in collecting these sea surface height measurements and transition collection of them to the world's weather and climate forecasting agencies, NASA and CNES have teamed with NOAA and EUMETSAT to develop and launch OSTM/Jason 2, which will carry instruments similar to those on Jason 1.

The goal of OSTM/Jason 2 is to continue the data record of global ocean surface topography begun by Topex/Poseidon and Jason 1 with the same or improved accuracy and precision. This extended data record will increase our understanding of ocean circulation and its long-term changes, which affect climate and society.

OSTM/Jason 2 will provide a bridge to permanently transition collection of these measurements to the world's weather and climate forecasting agencies, two of whom are partners on the mission. NOAA and EUMETSAT will gain experience in the field of operational satellite-based oceanography by assuming responsibility for OSTM/Jason 2's routine operation and data processing early in the mission.

Beyond OSTM/Jason 2, NOAA and EUMETSAT are already planning future operational missions such as Jason 3. The need for Jason 3 to continue the ocean surface topography data record was endorsed by the 2007 National Research Council Decadal Survey Report. Indeed, if there is as much as half a year's gap in the satellite altimeter data flow, it would become more difficult to truly gauge sea level rise trends that are threatening to flood coastal cities all over the world and even whole nations in the Pacific.

The accuracy of Topex/Poseidon, Jason 1 and the expected accuracy of OSTM/Jason 2's measurements are unmatched by any other altimetry missions. At global and ocean basin scales, only observations from these missions are accurate enough to detect global ocean changes.

Practical Applications of Ocean Surface Topography

Satellite observations of the oceans have revolutionized our understanding of global climate. They have given us our first opportunity to track major global ocean events such as El Niño and La Niña and the first overview of even larger ocean climate phenomena, such as the Pacific Decadal Oscillation—features that we have not been able to observe directly before.

Topex/Poseidon and Jason 1 were designed primarily for research, rather than real-time applications. However, with the success of Topex/Poseidon in the early 1990s, a "quick-look" data stream was established to provide near-real-time data. Currently, these quick-look data are available anywhere from five hours to two days, meeting the needs of many operational applications. About 75 percent of the wind and wave data are available within three hours.

The 15-plus years of Topex/Poseidon and Jason 1 observations, to which OSTM/Jason 2 will add, have provided numerous social and economic benefits. A comprehensive description of practical and operational applications of altimetry data is available at: <http://sealevel.jpl.nasa.gov/science/soc-benefits.html>.

Following are some of the most-established applications to date:

Offshore Operations and Navigation

Near-real-time altimetry data of currents, eddies and winds are used by sailors and many offshore industries to improve safety and efficiency. Meteorological centers run models to predict the evolution of waves and swells, providing sailors and workers at sea with regular forecasts and special weather updates when weather conditions deteriorate. Information on eddy currents in the Gulf of Mexico has been used by marine operators to schedule offshore drilling operations, with significant cost savings. Information on surface currents has also been useful for aiding ship routing and yacht racing. Navy forces use altimetry information to aid with surface and underwater navigation.

Hurricane Prediction

Satellite altimeter data are now routinely used to forecast the number and strength of hurricanes expected in a given season, and to predict the strength of individual hurricanes. Altimeter data can provide information on the potential heat stored in the oceans available to fuel and intensify tropical cyclones. The energy contained in the Loop Current in the Gulf of Mexico was a factor in the intensification of Hurricane Katrina.

El Nino-Southern Oscillation Prediction

Since 1997, satellite altimetry data have been used in NOAA's operational El Nino-Southern Oscillation analysis and forecast system. Jason 1 data are a key component of the data stream used in their models. The ability to identify and track these large ocean/atmosphere phenomena has led to better prediction of them and has allowed for better preparation to mitigate their effects.

Monitoring Rivers and Lakes

Altimeter data are used to monitor the water level of rivers and lakes around the world. The data are especially useful in remote regions where ground measurements are difficult to obtain. More advanced studies are now combining altimetry data with other remote sensing observations, modeling tools and theoretical knowledge. This is expected to lead to improved flood and drought forecasts. The data can also be used as a tool for managing regional water resources, particularly in developing nations.

Other Applications

Some other fields where satellite altimetry data have been applied include the following:

- Fisheries management – Satellite data identify ocean eddies, important features in fish migration.
- Marine mammal research – sperm whales, fur seals and other marine mammals can be tracked by knowing the location of nutrient-rich ocean eddies.
- Coral reef research – satellite observations provide a way to monitor ocean systems that are sensitive to changes in ocean temperature and currents.

- Ocean debris tracking – satellite altimetry data are used to monitor and forecast the position of drifting polluted waters, ships, and objects lost at sea.

Improving Scientific Knowledge and Weather and Climate Forecasts

OSTM/Jason 2 will advance our understanding of many ocean and climate phenomena that are still not well understood, while improving weather and climate forecasts.

Apart from seasonal cycles, which lead to an increase or decrease in sea level in each hemisphere that exceeds 15 centimeters (5.9 inches) in some areas, there are significant variations in sea level from one year to the next that are not well understood. Large-scale ocean climate patterns such as El Nino, the North Atlantic Oscillation, the Pacific Decadal Oscillation and planetary waves crossing the oceans over periods of months to years and even decades are among the mechanisms that need to be better understood. Because these phenomena operate over long time frames, very long time series of altimetry observations are needed.

In the area of tide modeling, OSTM/Jason 2 will seek to further refine our understanding of ocean tides and how they interact with coastlines, internal waves generated by tides and how tidal energy is dissipated.

Earth's oceans serve as a thermostat for our planet, keeping it from overheating. More than 80 percent of the heat from global warming over the past 50 years has been absorbed by the oceans. The rate of sea level change allows scientists to estimate how much of this heat the ocean is storing. Scientists want to know how much additional heat the oceans can absorb, and how that absorbed heat affects our global atmosphere. OSTM/Jason 2 will help them better calculate the oceans' ability to store heat, a key to understanding climate change.

Estimates of wave height and wind speed from OSTM/Jason 2 will be of great value for marine meteorology and climatology studies, as well as for forecasting ocean conditions in near-real-time.

OSTM/Jason 2 will generate short-range ocean prediction maps that forecast, a few weeks in advance, the position of currents and their intensity, and the position and scales of eddies and thermal fronts. These products will benefit a variety of applications including marine safety, marine pollution, ship routing, navy operations, oil drilling, coastal forecasting and fish stock management.

Medium-term data from OSTM/Jason 2 will also feed the world's weather prediction agencies, helping them improve numerical weather prediction models. Real-time ocean data will be analyzed in eight-hour and 12-day cycles to build ocean and atmospheric models to support three types of forecasts: medium-range (up to 15 days ahead); monthly (30 days) and seasonal (up to 12 months ahead).

Data from OSTM/Jason 2 will help scientists predict the likelihood of seasonal disruptions in rainfall and temperature for periods of up to nine months. By correlating observations of ocean variability collected over long periods with findings about severe weather occurrences such as droughts, floods and hurricanes, meteorologists can improve seasonal weather forecasting. This will help save lives and property, while supporting the planning of energy supplies, agriculture or water management, among other areas.

Mission Overview

The Ocean Surface Topography Mission/Jason 2 is an international satellite mission that will extend into the next decade the continuous climate data record of precise sea surface height measurements begun in 1992 by the joint NASA/CNES Topex/Poseidon mission and continued by the NASA/CNES Jason 1 mission in 2001. Data from the mission will be used to help scientists better understand how ocean circulation and climate change are related, and to monitor changes in global sea level. They will benefit a variety of fields, including marine meteorology and forecasting of ocean conditions; operational oceanography; seasonal forecasting; climate monitoring; and ocean, Earth system and climate research.

The mission will serve as a bridge to transition the future collection of these measurements to the world's weather and climate forecasting agencies. These agencies will use the data for short- and seasonal-to-long-range weather and climate forecasting. The mission is designed to last at least three years.

Following the same ground track as Jason 1, OSTM/Jason 2 will assume the older spacecraft's near-circular orbit at an altitude of 1,336 kilometers (830 miles) above the equator. It will complete one orbit every 112.43 minutes, and return to the same point on Earth every 10 days. It will provide ocean topography data for 95 percent of Earth's ice-free oceans, covering the globe between 66 degrees north and 66 degrees south of the equator.

Once OSTM/Jason 2 is in place, Jason 1 will be moved to the side, providing additional measurements of ocean surface topography for as long as the older spacecraft remains healthy.

On the ground, raw altimetry data will be processed into three primary products: the distance between the satellite and the sea surface, average wave height and wind speed.

Launch Site and Vehicle

OSTM/Jason 2 will be launched from Space Launch Complex 2W at Vandenberg Air Force Base, Calif., on a two-stage Delta II model 7320-10 launch vehicle. Manufactured by United Launch Alliance, the Delta II is a modern version of the Thor intermediate-range ballistic missiles developed in the 1960s. The Delta II launch vehicle has a 98 percent success rate. Delta II payload capabilities range from 2.7 to 6.1 metric tons (5,960 to 13,440 pounds) to low Earth orbit.

For the OSTM/Jason 2 launch, the Delta II launch vehicle has two liquid propellant stages and three strap-on solid-fuel boosters. The solid-fuel boosters are built by Alliant Techsystems. Each of the boosters is 1 meter (3.28 feet) in diameter and 13 meters (42.6 feet) long; each contains 11,765 kilograms (25,937 pounds) of a propellant called hydroxyl-terminated polybutadiene and provides an average thrust of 486,458 newtons (109,135 pounds-force) at liftoff.

The first stage of the Delta II uses a Rocketdyne RS-27A main engine. The engine provides nearly 1,054,229 newtons (237,000 pounds) of thrust by reacting RP-1 fuel (thermally stable kerosene) with liquid oxygen. The three solid rocket motors are 102 centimeters (40 inches) in diameter and fueled with enough hydroxyl-terminated polybutadiene solid propellant to provide about 431,478 newtons (97,000 pounds) of thrust apiece.

The Delta's second stage is powered by a restartable Aerojet AJ10-118K engine, which produces about 43,370 newtons (9,750 pounds) of thrust. The engine uses a fuel called Aerozine 50, which is a mixture of hydrazine and dimethyl hydrazine, reacted with nitrogen tetroxide as an oxidizer.

The OSTM/Jason 2 spacecraft will be contained inside the top of the Delta II launch vehicle's 8.8-meter (28.9-foot) tall payload fairing.

At launch, the Delta II will stand 38.6 meters (126.6 feet) tall and weigh 150,173 kilograms (165.5 tons).

Launch Timing

OSTM/Jason 2 will be launched at a specific time based on the science requirements of the mission. Unlike spacecraft sent to other planets, comets or asteroids, the launches of Earth-orbiting satellites such as OSTM/Jason 2 do not need to be timed based on the alignment of the planets. The only constraint is to select the time of day that will place the satellite in the proper orbit. For OSTM/Jason 2, the launch time is designed to place the satellite in an orbit plane very close to, but not exactly the same as, the orbit plane of Jason 1. The launch date is based only on the readiness of the satellites, the Delta launch vehicle and the launch range at Vandenberg Air Force Base.

Launch is currently scheduled for approximately 1:47 a.m. Pacific Time (4:47 a.m. Eastern Time) no earlier than June 15, 2008.

The launch period planned for OSTM/Jason 2 extends from June 15 to August 15. The launch window is approximately nine minutes and falls earlier by a little more than 12 minutes each day.

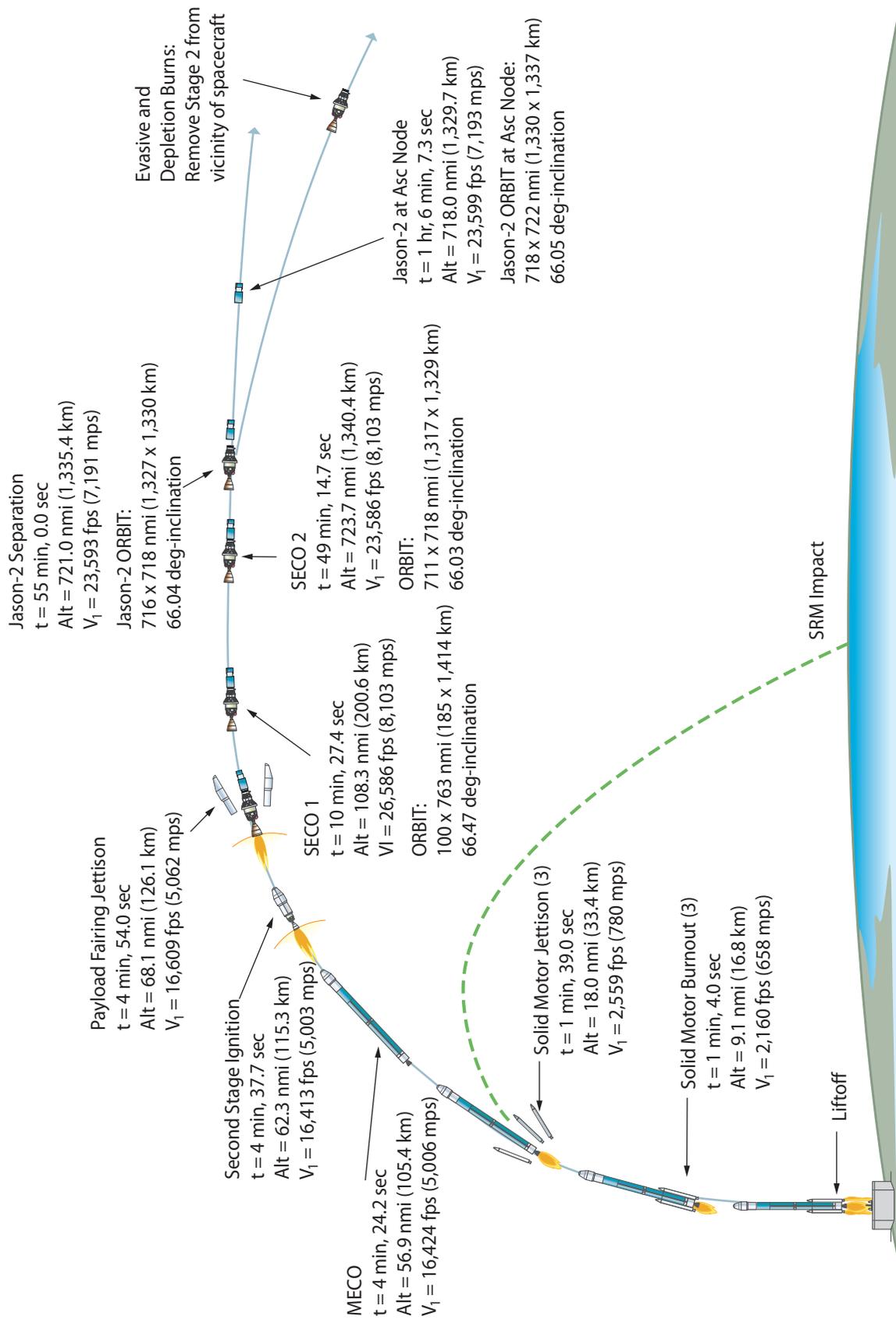
Launch Sequence

When the Delta II launches, its first-stage engine and its three strap-on boosters will ignite at the moment of liftoff and the rocket will rise vertically from the launch pad. Seven seconds later, the Delta II will tilt towards the southeast, crossing the California coastline and heading upward and out over the open Pacific Ocean. Thirty-six seconds after liftoff, the launch vehicle will reach the speed of sound, and 12 seconds later the vehicle will reach its point of maximum aerodynamic stress. Sixty-four seconds after liftoff, the strap-on boosters will burn out, and their spent casings will be jettisoned approximately 99 seconds after liftoff.

About four minutes and 24 seconds into the flight, the first-stage engine will stop firing as the launch vehicle passes west of Mexico's Baja California peninsula. About eight seconds later, the first stage will be discarded, and about five seconds later, the second stage will ignite.

Four minutes and 54 seconds after launch, the launch vehicle's nose cone, or "fairing," will separate in two halves, like a clamshell, and fall away. At about 10 minutes and 27 seconds after liftoff, the second-stage engine will temporarily stop firing, and the launch vehicle and its payload will coast for 38 minutes and 23 seconds. At this point, it will be heading south and passing between the tip of South America and Antarctica.

At about 48 minutes and 51 seconds after liftoff, the second-stage engine will restart, burning



Launch profile

24 seconds before shutting down. At this point, the spacecraft with the second stage of the Delta still attached will be in a circular parking orbit 711 by 718 nautical miles (1,317 by 1,329 kilometers) above Earth. OSTM/Jason 2 satellite separation occurs approximately 55 minutes after liftoff. The Delta II's second stage will then be reoriented in preparation for an evasive maneuver and evasive and depletion burns that ensure there is no chance for a collision with the spacecraft. Within minutes, the tracking station at Hartebeesthoek, South Africa, should pick up OSTM/Jason 2's confirmation signal.

In-orbit checkout of OSTM/Jason 2 will begin immediately after separation from the launch vehicle and concludes at launch plus 60 days.

A forward-mounted camera system onboard the Delta II launch vehicle's second stage will provide video of portions of OSTM/Jason 2's ascent. It will be turned on right before launch, then off immediately after liftoff, then on again prior to spacecraft separation, when it will be used to track the spacecraft separation and deployment of the spacecraft's solar arrays.

The Tandem Mission

OSTM/Jason 2 will enter orbit about 10 to 15 kilometers (6 to 9 miles) below Jason 1's 1,336 kilometer (830-mile) altitude. It will lag between one and 10 minutes behind Jason 1 in a nearly identical orbit. OSTM/Jason 2 will quickly deploy its solar array, power up its instruments and rotate its altimeter to point to geodetic nadir – essentially straight down, the shortest path to the ocean.

OSTM/Jason 2 will then gradually maneuver to take over the same ground track as Jason 1. First, using its thrusters, OSTM/Jason 2 will raise itself into the same orbital altitude as Jason 1. Then, it will move in close behind its predecessor, trailing it by about 60 seconds.

Then, as the two spacecraft fly in line together, they will be making nearly simultaneous measurements of the same sea surface from the same altitude, allowing direct comparison of the two measurements. Members of the science team will make careful comparisons of the data to be sure the instruments are calibrated exactly the same, a procedure expected to take about six months. Such cross-calibration is fundamental to establishing a long data record for global climate change studies.

When the cross-calibration process is complete, Jason 1 will be commanded to move aside to a parallel ground track midway between two adjacent OSTM/Jason 2 ground tracks, increasing global data coverage twofold and improving our knowledge of tides in coastal and shallow seas, as well as internal tides in the open ocean. OSTM/Jason 2 will remain in place, now seamlessly continuing the data collection begun by Topex/Poseidon in 1992.

Science operations will begin at launch plus 27 days.

Satellite Operations

The four OSTM/Jason 2 partners have jointly established and will operate a ground segment, including all facilities required to operate the satellite; acquire its telemetry; and process, distribute and archive data products.

From launch through the on-orbit checkout phase, satellite control and operations for OSTM/

Jason 2 will be handled by CNES's Satellite Control Center in Toulouse, France. During this period, the Project Operation Control Center at NOAA in Suitland, Md., will route telemetry from two U.S. Earth tracking stations in Wallops Island, Va.; and Fairbanks, Alaska. EUMETSAT provides telemetry from the Earth tracking station in Usingen, Germany to CNES in Toulouse. The NASA instruments will be monitored from the instrument control center at JPL. CNES will monitor its instruments from France.

At the end of the assessment period (expected to be about 50 days) and after a checkout period of two months, routine spacecraft operations will transfer from CNES to NOAA's Satellite Operations Control Center in Suitland, Md. The NOAA center will control the satellite and its instruments and acquire stored mission telemetry data from ground stations for the remainder of the mission. The CNES control center will continue to monitor the satellite, perform navigation functions and conduct performance analyses.

The CNES control center and the NOAA operations control center rely on a ground terminal network of three Earth terminals/stations to communicate with the satellite, passing on commands from the control and operation centers and receiving data. This Earth Terminal/Stations Network consists of the NOAA Fairbanks Command and Data Acquisition Station in Alaska, the NOAA Wallops Command and Data Acquisition Station in Virginia, and the EUMETSAT Usingen Earth Terminal in Germany.

The mission ground system consists of a CNES mission system, a EUMETSAT mission center, a NOAA mission center, a JPL mission center and passenger instrument mission centers.

During launch, the network of satellite tracking ground stations will be supplemented by tracking stations in South Africa; Kiruna, Sweden; and Kourou, French Guiana. The ground station in Hartebeesthoek, South Africa, will be used to confirm separation of OSTM/Jason 2 from the Delta II.

Science Data Processing

Once received on the ground, the raw data from OSTM/Jason 2 will be processed by both NOAA and EUMETSAT into real-time products and then distributed to operational users. Generation of other products is made by CNES. Distribution of other products is the responsibility of NOAA and CNES. NOAA and CNES will provide archival services for the OSTM/Jason 2 mission data and products.

Data Products

OSTM/Jason 2 will produce and distribute three global data products for the user community. One of these products is delivered to users in near-real-time (three hours), while the others are "offline," meaning they are delivered a few days or weeks later. They all cover the same key ocean parameters and use the same basic format, but differ according to the auxiliary data they include and the level of accuracy. The near-real-time products will be supported by EUMETSAT and NOAA, which will provide a help desk; NOAA and CNES will support the distribution of offline products and will also provide a help desk.

The three primary data products include:

□ The **Operational Geophysical Data Record** is a new operational product specifically developed for the OSTM/Jason 2 mission. It provides near-real-time data on surface wind speed and wave features, and a first estimate of sea surface height based on the data computed by OSTM/Jason 2's Doris location system. The primary purpose is to feed data to meteorological organizations carrying out near-real-time ocean condition forecasting. It will be especially useful for numerical weather prediction, including atmosphere and ocean forecasting. It will also make data on sea surface height anomalies available for ocean users. The product will be processed at the EUMETSAT and NOAA ground centers and disseminated over the EUMETCast satellite broadcasting system, as well as through data networks and the Global Telecommunication System network. Key users include the European Center for Medium-range Weather Forecasting, Météo-France, NOAA, the Met Office in the United Kingdom, MetNo (the Norwegian Meteorological Institute) and Mercator Ocean.

□ The **Interim Geophysical Data Record** provides sea surface data produced within one to one-and-a-half days of being recorded. This record includes analyzed data on sea surface height, absolute dynamic topography and velocities for larger-scale ocean currents for use in medium-range weather forecasting, seasonal forecasting and ocean weather applications. Key users include the European Center for Medium-range Weather Forecasting, NASA's Global Modeling and Assimilation Office, NOAA's Atlantic Oceanographic and Meteorological Laboratory, the European Union's Marine Environment and Security for the European Area integrated project, the Danish Meteorological Institute and Dutch clients for storm surge modeling.

□ The **Geophysical Data Record** provides fully-validated data produced within 60 days of the events being recorded and covers sea surface height, principally for climate monitoring and climate modeling. The main users are geophysical and operational oceanography climate researchers working for the Global Sea Level Observing System and the International Panel for Climate Change Assessment Report on rising sea levels.

Science Team

An international science team, established jointly by the four mission partners, will address the mission's science objectives and goals. Co-chaired by the project scientists, this Ocean Surface Topography Science Team includes all principal investigators selected by the partners, as well as the project and program scientists for each mission partner. Among its responsibilities, the team will advise the project on aspects of the mission that influence the scientific and operational usefulness of the data. The team will formulate a mission science plan, based on selected proposal investigations.

Mission Phases

The OSTM/Jason 2 mission is divided into six phases:

□ During the **Launch and Early Orbit Phase** (three days), the satellite is launched and maneuvered into its initial orbit, and satellite and instrument systems are activated and checked out.

- ❑ During the **Orbit Acquisition Phase** (about one month), the satellite is maneuvered into its operational orbit. This phase is conducted at the same time as the first half of the Assessment Phase.
- ❑ The **Assessment Phase** (two months) begins at the end of the Launch and Early Orbit Phase and ends when the satellite and instrument systems are functionally certified, the satellite is in its operational orbit, and the ground system is ready to operate routinely.
- ❑ The **Verification Phase** (at least six months) overlaps the Assessment Phase, beginning when OSTM/Jason 2 has reached its operational orbit and is flying in tandem with Jason 1, and continuing until the data received from the satellite, its instruments and data processing algorithms are satisfactorily calibrated and validated. During this phase, ground data and laser ranging data will be collected from the verification site to be used in the verification process. The length and activities of this phase depend on the availability of OSTM/Jason 2 data. A verification workshop will be held five months after the start of the phase to assess the validation of near-real-time products and to authorize delivery of these products to users. A final verification workshop will be held at the end of the Verification Phase to assess validation of offline products and authorize their release to users.
- ❑ The **Initial Routine Operations Phase** begins after completion of the Assessment Phase and ends three years after launch. Instrument data are collected and monitored continuously. Science data products from the Verification Phase are reprocessed at the end of that phase.
- ❑ Assuming useful data are still being collected, the **Extended Routine Operations Phase** extends the mission an additional two years or for any additional period that may be agreed upon by the mission partners.

Science and Engineering Objectives

The science objectives for OSTM/Jason 2 are to:

- Extend the time series of ocean surface topography measurements beyond Topex/Poseidon and Jason 1 to accomplish two decades of observations
- Provide a minimum of three years' measurement of global ocean surface topography
- Determine the variability of ocean circulation at decadal time scales from the combined data record of OSTM/Jason 2 with Topex/Poseidon and Jason 1
- Improve the measurement of time-averaged ocean circulation
- Improve the measurement of global sea-level change
- Improve open ocean tide models

The basic science goals of ocean topography missions, including OSTM/Jason 2, Jason 1 and Topex/Poseidon, are to:

- Determine general ocean circulation and understand its role in Earth's climate
- Study the variation of ocean circulation on time scales from seasonal and annual to decadal, and how these variations affect climate change
- Collaborate with other global ocean monitoring programs to produce routine models of the worldwide oceans for scientific and operational applications
- Study large-scale ocean tides
- Study geophysical processes from their effects on ocean surface topography

In addition to carrying on the groundbreaking work done by Topex/Poseidon and Jason 1, OSTM/Jason 2 is expected to:

- Measure global sea-height change and provide a continuous view of changing global ocean surface topography
- Calculate the transport of heat, water mass, nutrients and salt by the oceans
- Increase understanding of ocean circulation and seasonal changes and how the general ocean circulation changes through time
- Provide estimates of significant wave height and wind speeds over the ocean

- Improve knowledge of ocean tides and develop open-ocean tide models
- Monitor the variation of global mean sea level and its relation to global climate change

The engineering objectives for OSTM/Jason 2 are to:

- Launch into the same orbit as Jason 1
- Maintain the same 3.3-centimeter (1.3 inch) measurement accuracy of Jason 1 with a goal of improving that accuracy to 2.5 centimeters (about one inch)
- Maintain the stability of the global mean sea level measurement with long-term change in measurement accuracy less than one millimeter (.04 inches) per year over the life of the mission
- Maintain the measurement accuracy of significant wave height to 50 centimeters (19.7 inches), or 10 percent of the wave height magnitude (whichever is greater)

Spacecraft

Built in France under contract to CNES by Thales Alenia Space, OSTM/Jason 2 is the fifth of six production satellites in a new family of mini-satellites developed as part of a long-term partnership between CNES and Thales to adapt to different, smaller instrument platforms and reduce mission design costs. Jason 1 was the first satellite in the new family. The OSTM/Jason 2 spacecraft features numerous upgrades to the Jason 1 design, most of which were incorporated into and qualified on the NASA/CNES Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite launched in 2006 and currently in orbit.

The OSTM/Jason 2 spacecraft includes the satellite's main structure, or "bus," a payload instrument module and a launcher adapter. The bus is a multi-purpose platform under the trade name Proteus (Plateforme Reconfigurable pour l'Observation, les Telecommunications Et les Usages Scientifiques), based on the Calipso bus design. The bus houses most of the electronics required for the satellite to function. The payload instrument module houses and supports the OSTM/Jason 2 payload instruments and provides all required functions and interfaces.

The Proteus platform is cube-shaped – nearly 1 meter (1.093 yards) per side – with all the equipment units on four lateral panels and the lower plate. The satellite platform has a mass of 265 kilograms (584 pounds). The spacecraft measures approximately 1 meter by 1 meter by 3.7 meters (3.3 feet by 3.3 feet by 12.1 feet). It will have a total launch mass of 505 kilograms (1,113.3 pounds), including its launch adapter, balance weight and propellant. The interface with the Delta II launch vehicle is through a specific adapter bolted to the bottom of the structure. The mechanical interface with the payload is provided through four corners of the platform. The platform is a highly redundant, low-risk spacecraft based on a mature technology with a proven flight history.

While OSTM/Jason 2 is designed to last for three years, its resistance to radiation at its orbiting altitude of 1,336 kilometers (830 miles) is sufficient to ensure five years of operation. The satellite will carry 28 kilograms (62 pounds) of propellant, enough for this length of time.

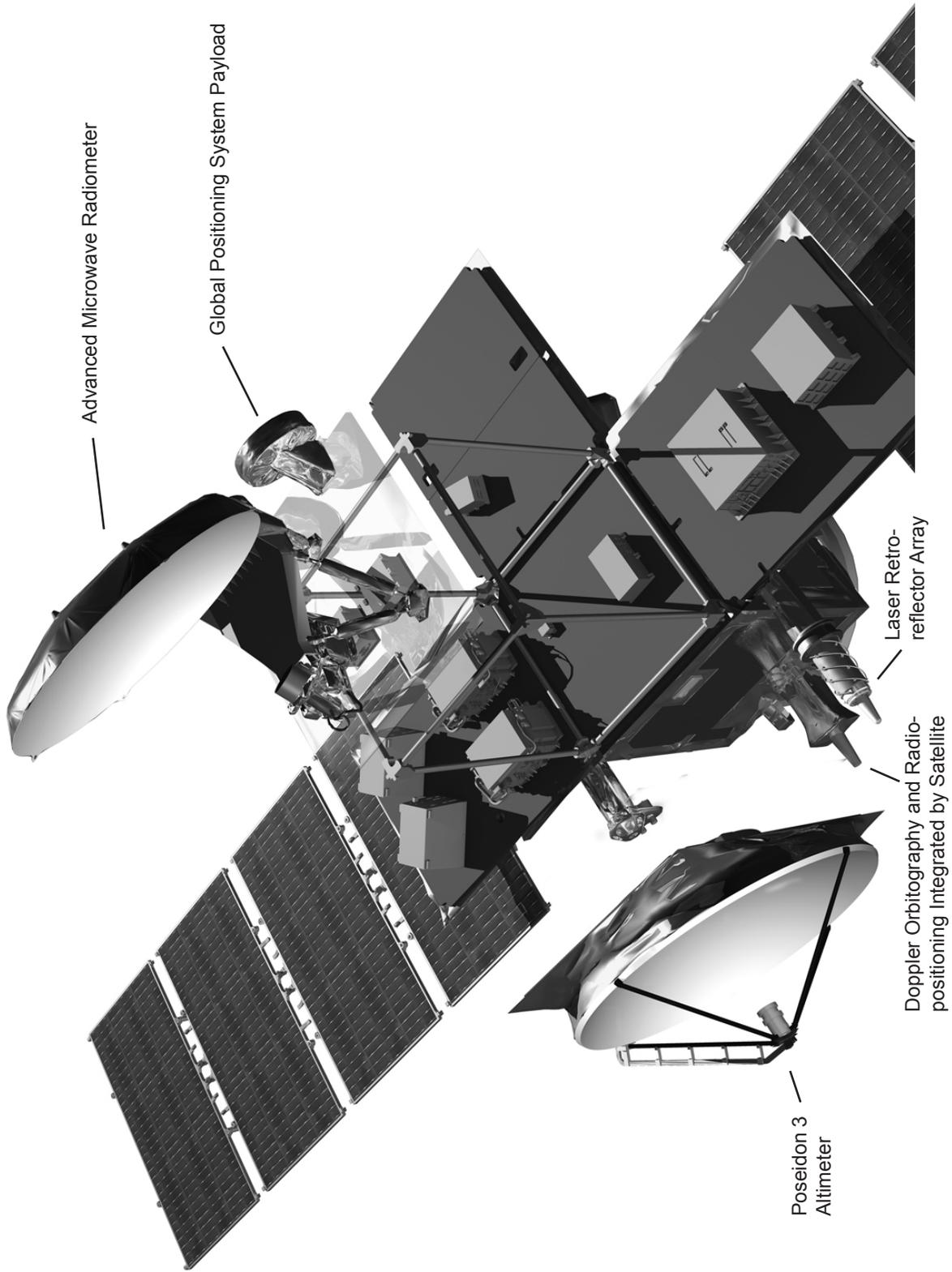
Thermal Control

The thermal control subsystem is responsible for maintaining the temperatures of each component on the spacecraft within its allowable limits. It does this using a combination of active and passive control elements. The active components are electrical heaters. The passive components are thermal radiators and thermal multilayer insulation blankets. The outer layer of the blanket is a gold-colored kapton material.

Electrical Power

All of the spacecraft's power is generated, stored and distributed by the electrical power subsystem. The 28-volt power comes from a pair of symmetrical solar wing arrays covered with silicon cells. The arrays are extended in orbit on opposite sides of the satellite's main platform. Two small drive motors keep the arrays pointed at the sun.

Each array consists of four panels, each 1.5 by 0.8 meters (5 by 2.6 feet), representing a total surface of 9.5 square meters (102 square feet). The solar array wingspan, when fully deployed,



Advanced Microwave Radiometer

Global Positioning System Payload

Poseidon 3 Altimeter

Doppler Orbitography and Radio-positioning Integrated by Satellite

Laser Retro-reflector Array

Spacecraft

measures approximately 9.7 meters (31.8 feet) from tip to tip. The solar arrays generate between 500 to 900 watts of power when in orbit.

Power is also provided during eclipses by a battery.

Flight Software

OSTM/Jason 2 receives its commands and sequences from Earth and translates them into spacecraft actions. The flight software is capable of running time-tagged commands, as well as executing immediate commands as they are received.

The flight software is responsible for a number of autonomous functions, such as attitude control and fault protection, which involve frequent internal checks to determine whether a problem has occurred. If the software senses a problem, it will automatically perform a number of pre-set actions to resolve the problem or put the spacecraft in a safe mode until ground controllers can respond.

The Proteus flight software, designed using centralized architectures, has been designed with emphasis on producing a modular, adaptable and maintainable system that can be scaled according to spacecraft and payload requirements.

Command and Data Handling

All of the spacecraft's computing functions are performed by the data handling unit. The heart of this subsystem is a computer processor known as an MA 31750. With 128 Kword of non-volatile memory, 256 Kword of random access memory and three gigabits of dynamic RAM mass memory, the subsystem runs OSTM/Jason 2's flight software and controls the spacecraft through interface electronics. It also handles all the payload data transmitted to Earth each time the satellite is in visibility of a ground station.

Interface electronics make use of computer cards to communicate with external peripherals. Onboard timekeeping is provided by the Proteus platform's GPS receiver.

The primary functions of the data handling unit are:

- Satellite mode management; automatic mode transitions and routines
- Failure detection and recovery; monitoring spacecraft health and switching to safe hold mode if necessary
- Onboard visibility; generation, maintenance and downlink of housekeeping telemetry data
- Satellite command and control, consisting of management of "telecommands" sent by ground either to hardware or software

The onboard command and data handling relies on a fully centralized system. It performs most of the tasks through the central processor executing the satellite software. It also supports the management of the communication links.

Solid-state recorders provide required data storage.

The spacecraft central processor generates a clock reference, manages spacecraft data storage and ensures telemetry frame decoding. A maximum of 1,000 time-executable commands may be uplinked and stored in any given orbit pass, although many more may be uplinked.

Telecommunications

OSTM/Jason 2 communicates with Earth through a radio transmitter and receiver, both of which operate in the microwave S-band, using two small spiral-shaped medium-gain antennas.

Guidance, Navigation and Control

In normal mode, OSTM/Jason 2 maintains its altimeter antenna always pointing vertically towards Earth's surface. The spacecraft determines its orientation at any given time using one of two star trackers in combination with two of three onboard gyroscopes. Fine-tuning of the satellite's attitude is carried out by four small gyro-like devices called reaction wheels. The spacecraft also determines its orientation using eight coarse sun sensors, a three-axis magnetometer and three magnetotorquer bars.

The star trackers can track stars of magnitude 4.3 or brighter. They process the data to recognize any star patterns as they pass through the tracker's field of view.

Propulsion

OSTM/Jason 2 can adjust its orbit by firing any combination of its four onboard thrusters, each of which provides one newton (.22 pounds) of thrust. The thrusters use hydrazine propellant.

In addition to miscellaneous tubing, thruster valves and filters, the propulsion subsystem also includes a spherical 42-centimeter diameter (16.5-inch) propellant tank containing the hydrazine, pressurized with gaseous nitrogen.

Backups

Most systems on the spacecraft are fully redundant. This means that, in the event of a device failure, there is a backup system or function to compensate.

A software fault protection system is used to protect the spacecraft from reasonable, credible faults. In case of anomaly, the software places the spacecraft in a sun-pointing safe mode, allowing time for analysis and recovery while maintaining it in an acceptable situation, with regard to power, thermal control and link budget.

Science Instruments

The spacecraft will carry a payload of five primary science instruments:

- ❑ Supplied by CNES, the **Poseidon 3 solid-state altimeter** is OSTM/Jason 2's primary instrument. It measures the distance from the satellite to Earth's surface by sending radar waves to the sea surface and measuring how long they take to bounce back. In addition to sea surface height, the instrument can be used to calculate ocean surface

current velocity and provides data on wave height and wind speed.

Derived from France's Poseidon 1 altimeter on Topex/Poseidon and the Poseidon 2 altimeter on Jason 1, the Poseidon 3 altimeter is a compact, low-power, low-mass, highly reliable radar altimeter that emits pulses at two frequencies. From the signal round-trip time, the distance between the surface and spacecraft can be calculated precisely after applying corrections for atmospheric conditions, such as water vapor, that can affect how long it takes the signals to return.

The antenna, located on the "nadir," or bottom face of the satellite, is 1.2 meters (about 4 feet) in diameter. The dual frequencies are 13.6 gigahertz, which transmits on Ku-band, and 5.3 gigahertz, which uses C-band. The second frequency is used to determine electron content in the atmosphere. These two frequencies also serve to measure the amount of rain in the atmosphere.

The instrument is capable of measuring the distance between the satellite and the sea surface with an accuracy of two centimeters (1 inch) every second along the satellite track. Poseidon 3 will be coupled with the Doris/Diode location system to improve measurements over coastal areas, inland waters and ice.

Poseidon 3 was developed for CNES by Alcatel Space Industries.

□ An essential element of OSTM/Jason 2's success is its ability to pinpoint the satellite's location in orbit. The **Doppler Orbitography and Radio-positioning Integrated by Satellite**, or Doris, system provides much of this information. The Doris instrument on OSTM/Jason 2 is an upgraded version of that aboard Jason 1.

The system includes a ground network of 60 beacons around the world that constantly record the satellite's location. As the spacecraft flies over, they send signals at two frequencies (2.03625 megahertz for precise Doppler measurement and 401.25 megahertz to correct for ionospheric effects, measurement time tagging and auxiliary data) to a receiver on the OSTM/Jason 2 satellite. The receiver picks up these signals and measures the shift in the frequency (called the Doppler shift) between the signal sent and the one received.

These measurements are sent to the Doris Orbitography Service at France's Toulouse Space Center, where the satellite's trajectory and position are calculated.

The receiver on OSTM/Jason 2 is a third-generation device with an improved capability to receive two beacons simultaneously. Improvements and additions to the Doppler system make it possible for satellites to navigate autonomously. The receiver has a function that will allow it to calculate the precise position of the satellite on the fly. Mission planners believe it will provide positioning within 10 centimeters (4 inches), which may make use of real-time altimetry data possible.

The system was developed by CNES and built by Thales. It has redundant electronics and a single antenna.

□ OSTM/Jason 2 surveys sea surface heights by measuring the time it takes for pulses generated by the onboard radar altimeter to bounce back to the satellite from the ocean

surface. Water vapor in the atmosphere can delay the return of radar pulses to the satellite, interfering with the accuracy of sea level measurements. The interference can range from five to 10 centimeters (approximately 2 to 4 inches) in cold, dry air, to 30 to 50 centimeters (approximately 12 to 20 inches) under warm, humid conditions. By measuring atmospheric water content, engineers can determine how to correct for the radar signal delay. This is done with a microwave radiometer that is tuned to frequencies sensitive to water vapor emission, the **Advanced Microwave Radiometer**.

The radiometer collects radiation emitted by the ocean surface and the atmosphere at three frequencies: 18.7, 23.4 and 34.0 gigahertz (GHz). The radiometer beam is located next to the beam of the Poseidon 3 altimeter and points straight down at the ocean surface. The signals measured by the radiometer are affected by surface winds and clouds as well as atmospheric water vapor content. The different sensitivities of the three frequencies to each of these effects allow an accurate determination of water vapor abundance. The 23.4 GHz channel is the primary water vapor sensor, the 34.0 GHz channel is used to estimate cloud liquid content, and the 18.7 GHz channel is sensitive to wind-driven variations in emission from the sea surface. The instrument provides a radiometric brightness temperature for each frequency. Brightness temperatures are processed along with calibration data to determine how much OSTM/Jason 2's radar signal is slowed by water vapor content in the atmosphere.

The Advanced Microwave Radiometer is an advanced version of the Jason 1 Microwave Radiometer. It incorporates monolithic microwave integrated circuit technologies to integrate the three receiver channels into a single module with a single, broadband, ridged waveguide input. This new design is much smaller, lighter, uses less power, and has significantly simplified interfaces with the spacecraft than the Jason 1 instrument. These improvements are expected to reduce instrument calibration uncertainties over the Jason 1 design.

The radiometer was developed, fabricated, tested and calibrated at JPL. The receivers use technology developed by TRW, and the reflector was provided by ATK Space Systems.

□ The ability to determine OSTM/Jason 2's precise position is critical to interpreting altimetry data. The **Global Positioning System Payload** receiver is one of three location systems onboard OSTM/Jason 2, and validates the measurements of and enhances the accuracy of the primary Doris location system data. They are used together to measure the satellite's position. The receiver uses the Global Positioning System (GPS) constellation of 28 navigational satellites for this purpose.

The high-performance, dual-frequency Global Positioning System Payload receiver continuously tracks the radio signals transmitted by up to 16 GPS satellites at once—at least three are needed to determine position at a given instant. The receiver measures the phase of the GPS carrier signals with better than one millimeter (1/25th of an inch) precision and measures the “pseudo-range” between OSTM/Jason 2 and each GPS spacecraft being tracked with better than 10 centimeters (4 inches) precision. (Pseudo-range is a measurement of the transmit time of the signal between satellites. The measurement contains certain timing errors, which can later be corrected to recover the true range). The Global Positioning System Payload's measurements will determine the satellite's position in near-real-time to better than 20 meters (65.6 feet), and its clock to

better than 100 nanoseconds.

To achieve the mission's orbit accuracy goal, we need detailed knowledge of OSTM/Jason 2 and its behavior so that we can model the forces that act on it. In ground processing, the receiver's GPS readings will enable continuous determination of the OSTM/Jason 2 orbit with an accuracy of one to two centimeters (approximately .4 to .8 inches). To interpret the altimetry data, we also need to know Earth's gravity field very precisely, as it is an important reference for sea-surface height. Global Positioning System Payload measurements of variations in OSTM/Jason 2's orbital motion in relation to Earth's center will improve our overall knowledge of Earth's gravity field.

The Global Positioning System Payload on OSTM/Jason 2 is a Blackjack-class instrument, identical (with minor parts substitutions) to the Turbo Rogue Space Receiver on Jason 1. It consists of fairly simple hardware, including a high-performance microprocessor and custom digital signal processing application-specific integrated circuits. The sophistication of the Global Positioning System Payload lies in nearly 100,000 lines of software, which performs the signal tracking, data measurement and enables autonomous operations. Two fully redundant receivers will be carried on OSTM/Jason 2.

The Global Positioning System Payload hardware, software and ground support equipment were designed and tested by JPL. The flight unit was fabricated by Spectrum Astro Space Systems.

□ The **Laser Retroreflector Array** is one of OSTM/Jason 2's three location systems used together to measure the satellite's position in orbit. The ability to determine a satellite's precise position in orbit is critical in interpreting altimetry data used for measuring ocean surface topography. The array is used to calibrate the other OSTM/Jason 2 location systems and to verify the altimeter's height measurements.

The array is a set of mirrors onboard the satellite that provides a target for laser-tracking measurements from ground stations. The mirrors reflect laser pulses back to their point of origin on Earth. By analyzing the round-trip time of the laser beam, mission officials can locate very precisely where the satellite is in its orbit. They analyze the laser tracking data to calculate the satellite's altitude to within a few millimeters. Because there are a small number (40) of satellite laser ranging ground stations and laser beams are sensitive to weather conditions, it is not possible to track the satellite continuously using the array of mirrors. That is why other location systems are needed onboard the satellite.

OSTM/Jason 2's reflector array consists of nine quartz corner cube reflectors arrayed on a circular structure on the satellite's "nadir," or Earth-facing, side. One of the cubes is in the center and the others are distributed around the cone-shaped circular structure. A corner cube reflector is a special type of mirror that always reflects an incoming light beam back in the direction from which it came. The retroreflectors are optimized for a wavelength of 532 nanometers in the green portion of the color spectrum, providing a field of view of about 100 degrees.

The Laser Retroreflector Array was manufactured by ITE Inc. for NASA's Goddard Space Flight Center.

These instruments will provide full redundancy and measurements for at least five years.

Passenger Instruments

Three new “passenger” instruments will be flown on OSTM/Jason 2. In addition to their own scientific objectives, these passenger instruments are expected to improve the performance of the Doris instrument.

- ❑ The **Environment Characterization and Modelisation 2** (Carmen 2) instrument, provided by CNES, will study the effects of radiation in the satellite’s environment on advanced components.
- ❑ The **Time Transfer by Laser Link** instrument, provided by CNES, will use a laser link to compare and synchronize remote ground clocks with high accuracy.
- ❑ The **Light Particle Telescope**, provided by Japan, will study radiation in the satellite’s environment.

The Legacy of Topex/Poseidon and Jason 1

With the launches of Topex/Poseidon in August 1992 and Jason 1 in December 2001, scientists have amassed a continuous record of precise sea-surface height data for studying global ocean circulation and its link to climate. While the global sea surface temperature data record is longer, it is not as closely related to ocean dynamics as ocean surface topography.

Topex/Poseidon and Jason 1 have led to major discoveries about our planet and how it works. They have changed our view of the oceans forever. Following in their footsteps, OSTM/Jason 2 will continue to build on this record of achievements.

The 15-year data record of ocean surface topography collected by these two missions has provided the first opportunity to observe and understand the global change of ocean circulation and sea level. The results have improved our understanding of the role of the ocean in climate change and improved our ability to predict weather and climate. Many of the operational applications of these data have proven beneficial to society, such as the improved predictions of the major 1997 El Nino, which saved both lives and property.

The benefits to science from these two missions have been tremendous. More than 150 research papers have been published every year using these data. The following are some of the areas where Topex/Poseidon and Jason 1 have benefited science:

Ocean Variability

The missions have taught us about the surprising variability of the ocean, how much it changes from season to season, year to year, decade to decade and on even longer time scales. The traditional notion of a quasi-steady, large-scale pattern of global ocean circulation is gone. We now know that the ocean is changing rapidly on all scales, from huge features such as El Nino and La Nina, which can cover the entire equatorial Pacific, to tiny eddies swirling off the large Gulf Stream in the Atlantic.

Changes in the height of the global ocean due to ocean currents and thermal differences vary by as much as two meters (6.5 feet) from one place to the next. Before Topex/Poseidon and Jason 1, we didn't know how much those heights fluctuated. We've learned that the height of sea surface over areas larger than the United States can move up and down by 20 centimeters (8 inches) in just 20 days. And at any instant, a large part of the ocean is full of turbulent eddies. More salt and heat is transported by these eddies than by the weak steady currents, as previously thought.

By observing the global patterns of season-to-season and year-to-year variability around the world, such as El Nino and La Nina in the Pacific, the Antarctic Circumpolar Wave and the Indian Ocean Dipole, scientists have discovered even longer patterns of variability that operate on decadal scales. These include the Pacific Decadal Oscillation, a multi-decadal oscillation of sea-surface temperature and topography between the eastern tropical Pacific and a surrounding horseshoe-like pattern extending from the central north Pacific through the western tropics to the central South Pacific. The cycles of the Pacific Decadal Oscillation influence fish populations in the North Pacific and the climate of the entire world, and regulate the frequency and strength of El Nino and La Nina. Other similar decadal patterns around the world include the North Atlantic Oscillation and large-scale subtropical swirling currents in the South Pacific and

Indian Ocean. By continuing to collect ocean topography data over an even longer timeframe, OSTM/Jason 2 and subsequent missions are likely to uncover patterns of ocean variability that operate on even longer time scales.

Sea Level Change

The issue of sea level rise was identified by the 2007 Intergovernmental Panel on Climate Change assessment as one of the most important consequences and indicators of global climate change. Measurements of sea-surface height allow us to monitor changes in global mean sea level. From Topex/Poseidon and Jason 1, we know that mean sea level has been rising by about three millimeters (.12 inches) a year since 1993. This is about twice the estimates from tide gauges for the previous century, indicating a possible recent acceleration in the rate of sea level rise.

The data record from the missions has given scientists important insights into how global sea level is affected by natural climate variability, as well as by human activities.

The ocean has absorbed more than 80 percent of the heat from global warming accumulated over the past 50 years. This heat has warmed the ocean and raised sea level. In addition, the speedup of ice melting in Greenland and Antarctica is a wild card in predicting future sea level rise. The relative contributions of ocean heating and ice melting to sea level rise can now be estimated from altimetry observations by subtracting the amount of water added to the ocean by the melting of glaciers, as measured by NASA's Gravity Recovery and Climate Experiment, or Grace, satellite mission. Combining Jason 1 and Grace data has allowed us to estimate the rate at which heat is being absorbed by the ocean, a key to understanding the ocean's role in moderating global warming. Scientists plan to add data from OSTM/Jason 2, NOAA's Argo floats and NASA's planned Aquarius mission to the Jason 1 and Grace data sets. This will help them further unravel the relative contributions of glacier melting, ocean heating and changes in ocean salinity to sea level change.

Topex/Poseidon and Jason 1 observations have also helped scientists reconstruct patterns of sea level change from one place to another over the past 100 years, giving us a perspective on how sea level varied naturally before global warming accelerated in the past several decades. Based on reconstruction of past sea level patterns using Topex/Poseidon and Jason 1 observations, scientists have found that the acceleration is likely to be part of the decadal variability of the ocean.

But 15 years of data are simply not enough to determine long-term trends of sea level change. OSTM/Jason 2 will continue to monitor sea level changes and allow us to better understand its long-term variations. The consistent data record built by the combined missions will become the first multi-decadal global record for addressing the issue of sea level rise.

Planetary Waves

Topex/Poseidon and Jason 1 have shown us the importance of planetary-scale waves, such as Rossby and Kelvin waves. No one had realized how widespread these waves are. Thousands of kilometers wide, these waves are driven by wind under the influence of Earth's rotation and are important mechanisms for transmitting climate signals across the large ocean basins. At high latitudes, they travel twice as fast as scientists believed previously, showing the ocean responds much more quickly to climate changes than was known before these missions.

Ocean Tides

Topex/Poseidon's and Jason 1's precise measurements have brought knowledge of ocean tides to an unprecedented level. The change of water level due to tidal motion in the deep ocean is known everywhere on the globe to within 2.5 centimeters (one inch). This new knowledge has revised our notions about how tides dissipate. Instead of losing all their energy over shallow seas near the coasts, as previously believed, about one third of tidal energy is actually lost to the deep ocean. There, the energy is consumed by mixing water of different properties, a fundamental mechanism in the physics governing the general circulation of the ocean. The missions have resulted in the most accurate global ocean tide models ever generated. The Tandem Mission flown by Topex/Poseidon and Jason 1, with its improved spatial resolution, contributed to a significantly improved understanding of coastal ocean dynamics.

Ocean Models

Topex/Poseidon and Jason 1 have revolutionized ocean modeling. Their observations provide the first global data for improving the performance of the numerical ocean models that are a key component of climate prediction models. For example, Topex/Poseidon data guided the development of the first model able to simulate the precise course of the Gulf Stream. Topex/Poseidon also provided the first database allowing ocean data to be incorporated into global models. The results are the most accurate estimates of ocean currents, from the ocean surface to its great depths. These data are used for applications ranging from forecasting long-term climate change to day-to-day marine operations.

Link Between Climate and Ocean Circulation

Topex/Poseidon and Jason 1 have improved our understanding of how climate variations affect global ocean circulation. New findings from altimetry data have shown that the condition of the Pacific Decadal Oscillation, the dominant feature of climate variability in the Pacific, is responsible for decadal variations in the Kuroshio ocean current (also known as the Japan Current) in the western Pacific, the world's second largest ocean current, and its associated eddies. The Kuroshio moves warm tropical waters to the mid- and high-latitudes, playing an important role in regulating the heat storage of the ocean and influencing the climate variability of the entire North Pacific. These studies have unraveled part of the mystery of the decadal variability of the North Pacific Ocean circulation.

Similar findings have been reported for major ocean variability patterns in the North Atlantic. Such findings have gone a long way toward understanding the links between ocean circulation and climate change.

Eddy Dynamics

Ocean eddies are the storms of ocean currents, similar to storms in Earth's atmosphere. About 90 percent of the kinetic energy of ocean circulation is carried by ocean eddies. While the size of ocean eddies make it difficult to study them with a single altimeter, the combined data from Topex/Poseidon, Jason 1 and Europe's European Remote Sensing Satellite and Envisat satellite altimeters have provided an unprecedented long-term view of some basic properties of ocean eddies.

Deep Ocean Circulation

Ocean circulation at great depths is important to understanding long-term climate change. To study deep ocean circulation, Jason 1 data have been combined with data from NOAA's Argo program, which consists of nearly 3,000 ocean floats deployed in global ocean drifts at pre-determined depths. Each float reports its location as well as temperature and salinity every 10 days. The resulting ocean circulation maps have shown just how complex this deep ocean circulation is.

Tsunami Dynamics

Jason 1's observation of the 2004 Indian Ocean tsunami resulting from the magnitude 9 Sumatra earthquake provided a unique data set for studying the dynamics of tsunamis. A 2007 study found that the tsunami energy generated by the earthquake's vertical displacement of the Indian Ocean floor was too small to account for the observed tsunami energy, suggesting that the bulk of the tsunami's energy actually resulted from the horizontal movement of the sea floor over the steep slope of the continental rise. This new finding has great potential for improving tsunami model predictions.

Coastal and Shallow Water Tides

The small scales of tides in coastal and shallow seas have prevented accurate determination of tides in those areas from being made by observations from a single altimeter. The Tandem Mission conducted by Topex/Poseidon and Jason 1 from September 2002 to October 2005 gave scientists twice the data coverage, providing improvements of tidal estimates in regions such as the large ocean shelf north of Australia by as much as 60 centimeters (23.6 inches) in places.

Trends in Atlantic Meridional Overturning Circulation

It is widely believed that the northward transport of upper ocean warm water to the sub-polar region of the North Atlantic Ocean is critical to the stability of global climate. In recent years, scientists have been concerned over recent changes in ocean salinity and circulation in this region, and how they might affect this circulation and, ultimately, climate. In 2005, a team of scientists reported a slowdown of this circulation and its associated transport of heat has taken place over the past 50 years. Scientists want to know whether this slowdown is part of a decadal oscillation or whether it reflects an abrupt change of the ocean, which could have more permanent effects on climate. In 2006, another team of scientists using data from Topex/Poseidon and Jason 1 found that there has been no significant change of the North Atlantic over the past decade. Further studies using OSTM/Jason 2 data will shed additional insights on this issue.

Weather Forecasting

Topex/Poseidon and Jason 1 have improved weather forecasting. With regard to hurricanes, data on how much heat the oceans hold to fuel tropical cyclone formation and intensification are now routinely used by NOAA's National Hurricane Center to improve hurricane predictions. Significant improvements of up to 20 percent have been documented in predicting the strongest hurricanes in the past few years, while the lead time for hurricane forecasts has been extended to 96 hours.

Climate Forecasts

Topex/Poseidon and Jason 1 have also improved predictions of climate variability and change. They have captured several El Nino and La Nina events and have provided unprecedented coverage for studying the details of each event. The differences between the events provide valuable information for better understanding these ocean phenomena, especially the reason for the wide range of intensity from event to event. For example, new studies have shown that the state of the upper ocean as seen from satellite altimetry and ocean buoy data plays a key role in predicting how intense an El Nino will be, as much as 14 months in advance. Scientists had enough data on the state of the Pacific 14 months before the peak of the 2006 El Nino event to forecast how big it would be.

The value and relevance of all these accomplishments will continue to grow as OSTM/Jason 2 and future satellite altimetry missions extend this vital climate data record.

Program/Project Management

The OSTM/Jason 2 mission is managed for NASA's Science Mission Directorate, Washington, by the Jet Propulsion Laboratory (JPL), Pasadena, Calif.

At NASA Headquarters, Edward Weiler is the associate administrator for the Science Mission Directorate. Charles J. Gay is deputy associate administrator for the Science Mission Directorate. Jack Kaye is associate director for research, Science Mission Directorate. Steven Neeck is the OSTM/Jason 2 program executive. Eric Lindstrom is the OSTM/Jason 2 program scientist.

At JPL, Parag Vaze is the OSTM/Jason 2 project manager. Lee-Lueng Fu is the OSTM/Jason 2 project scientist. The California Institute of Technology, Pasadena, Calif., manages JPL for NASA.

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At NASA's Kennedy Space Center, the NASA Launch Services Program is responsible for government oversight of launch vehicle preparations at Vandenberg, the engineering and testing of the Delta II launch vehicle, spacecraft ground support and integration with the Delta II, the Space Launch Complex 2 pad facilities, countdown management, launch vehicle tracking, data acquisition and telemetry monitoring.