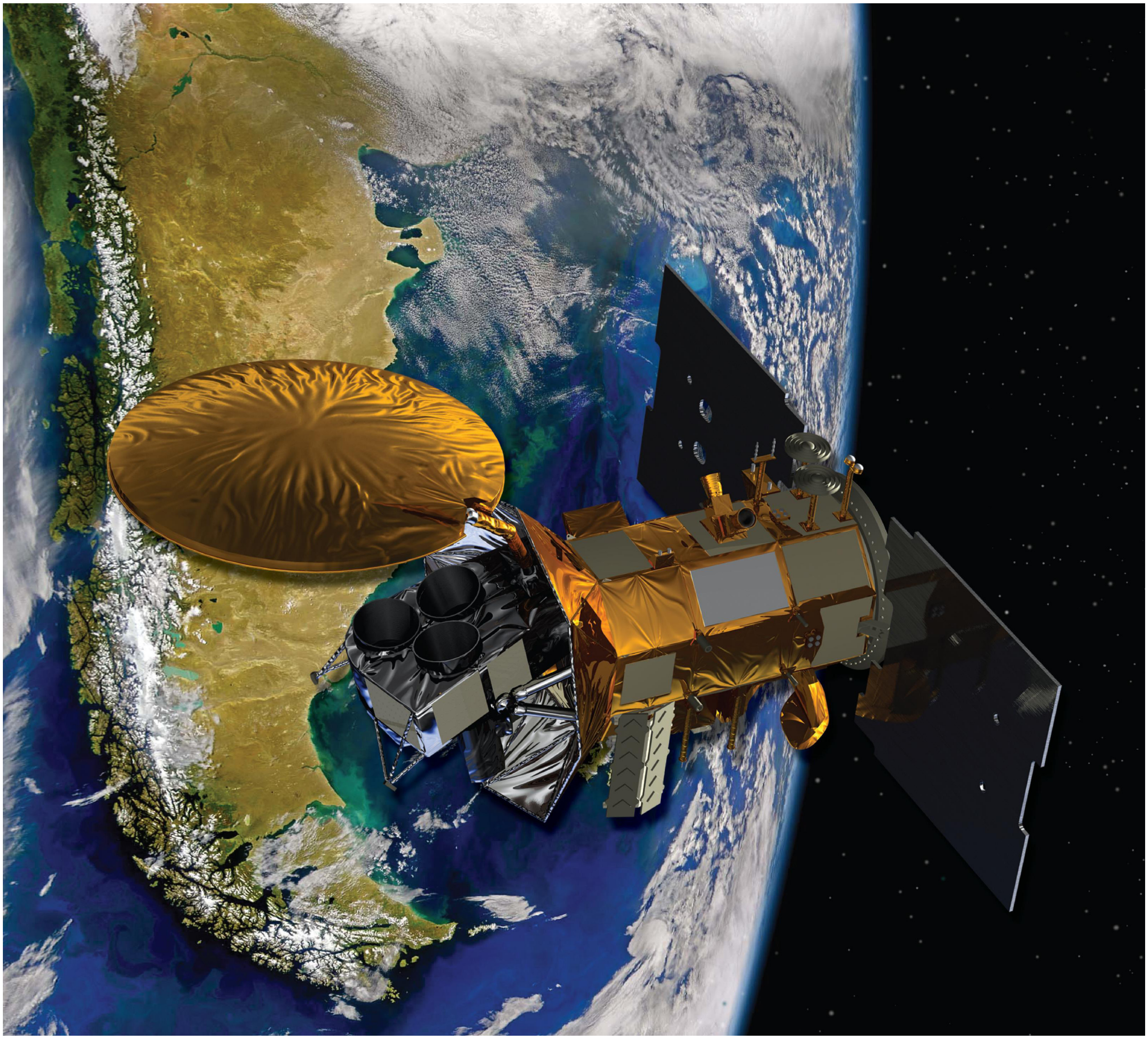
National Aeronautics and Space Administration

PRESS KIT/JUNE 2011

Aquarius/SAC-D Launch



www.nasa.gov

Contents

Media Contacts

Steve Cole NASA Headquarters, Washington	Policy/Program Management	202-358-0918 stephen.e.cole@nasa.gov
Alan Buis NASA Jet Propulsion Laboratory, Pasadena, Calif.	Aquarius Mission	818-354-0474 alan.buis@jpl.nasa.gov
Laura Sarrate Comisión Nacional de Actividades Espaciales (CONAE)	Aquarius/SAC-D Observatory	011 54 03547 431 075 lsarrate@conae.gov.ar
Jessica Rye United Launch Alliance Cape Canaveral, Fla.	Launch Vehicle	321-730-5646 Jessica.f.rye@ulalaunch.com
George Diller NASA Kennedy Space Center, Fla.	Launch Operations	321-867-2468 george.h.diller@nasa.gov

Media Services Information

NASA Television

All NASA Television Channels (Public, Education, Media, occasional HD feed and the Live Interactive Media Outlet) are available on Satellite AMC 3. Cable and satellite service providers, broadcasters and educational and scientific institutions need to re-tune receiving devices to AMC 3 to continue accessing NASA TV.

“News networks, their reporters, and other broadcast media organizations must tune their satellite receivers to the Media Channel to ensure reception of clean feeds for all mission coverage, news conferences and other agency distributed news and information. News and other media organizations will no longer be able to rely on content from the Public Channel for clean feeds of mission and other agency activities.”

For complete downlink information for Satellite AMC 3, please see “Important Information” at: www.nasa.gov/ntv .

In continental North America, Alaska and Hawaii, NASA Television’s Public, Education, Media and HD channels are MPEG-2 digital C-band signals carried by QPSK/DVB-S modulation on satellite AMC-3, transponder 15C, at 87 degrees west longitude. Downlink frequency is 4000 MHz, horizontal polarization, with a data rate of 38.86 MHz, symbol rate of 28.1115 ms/s, and 3/4 FEC. A Digital Video Broadcast (DVB)-compliant Integrated Receiver Decoder (IRD) is needed for reception.

NASA TV Multichannel Broadcast includes: Public Services Channel (Channel 101); the Education Channel (Channel 102) and the Media Services Channel (Channel 103).

For digital downlink information for each NASA TV channel, schedule information for Aquarius/SAC-D 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 on launch minus two days and of the NASA TV launch coverage will be available on “V-circuits” that may be reached by dialing 321-867-1220, -1240, -1260 or -7135.

News Conferences

A mission and science overview news conference on Aquarius/SAC-D will be held at NASA Headquarters on May 17, 2011, at 1 p.m. EDT. The news conference will be broadcast live on NASA Television.

Pre-launch readiness and mission science news conferences 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 the NASA Resident Office, Building 840, Vandenberg Air Force Base, Calif. These events will also be carried live on NASA Television.

Media advisories will be issued in advance, outlining details of these broadcasts.

Launch Media Credentials

News media interested in attending the launch should contact Jeremy Eggers, U.S. Air Force 30th Space Wing Public Affairs Office, Vandenberg Air Force Base, Calif., phone 805-606-3595, fax 805-606-4571, email Jeremy.eggers@vandenberg.af.mil .

News Center/Status Reports

The Aquarius/SAC-D News Center at the NASA Vandenberg Resident Office will be staffed beginning on launch minus seven days and may be reached at 805-605-3051. Recorded status reports will be available beginning on launch minus three days at 805-734-2693.

Internet Information

More information on the 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/aquarius .

Quick Facts

Aquarius/SAC-D Observatory

Dimensions: 8.9 feet (2.7 meters) across by 8.2 feet (2.5 meters) tall without the Aquarius instrument; almost 16.4 feet (5 meters) tall with it

Total Weight: 2,977 pounds (1,350 kilograms) — (service platform, instruments and combustibles)

Power: 1,362 watts

Primary Aquarius Science Instrument:
Aquarius Instrument Dimensions: 9 feet by 9 feet by 8 feet (2.7 meters by 2.7 meters by 2.4 meters) in a stowed position; 12.5 feet by 9 feet by 12 feet (3.8 meters by 2.7 meters by 3.7 meters) after deployment

Aquarius Instrument Weight: 705 pounds (320 kilograms)

Power: 314 watts

Mission

Launch: No earlier than June 9, 2011, at 7:20:13 a.m. PDT (10:20:13 a.m. EDT) from Space Launch Complex 2 West, Vandenberg Air Force Base, Calif.

Launch Vehicle: United Launch Alliance Delta II 7320-10C

Launch Period: Daily, within the constraints of Western Test Range availability, crew rest for consecutive launch attempts and launch vehicle servicing requirements

Launch Window: five minutes daily

Primary Mission: Aquarius, three years; SAC-D, five years

Orbit Path: near-polar, sun-synchronous, 408 miles (657 kilometers), with an ascending node mean local time of 6 p.m., orbiting Earth once every 98 minutes and repeating the same ground track every seven days, or 103 revolutions

Orbital Inclination: 98.01 degrees

NASA Investment: $287 million (design, development, launch and operations)

Mission Overview

Aquarius/Satélite de Aplicaciones Científicas (SAC)-D is a collaborative international space mission between NASA and Argentina's space agency, Comisión Nacional de Actividades Espaciales (CONAE), with participation by Brazil, Canada, France and Italy.

Aquarius, the NASA-built primary instrument on CONAE's SAC-D observatory, will provide NASA's first space-based global observations of salinity — the concentration of dissolved salt — at the ocean surface. Salinity is a key missing variable in satellite observations of Earth that will help scientists better understand the links between ocean circulation, the global cycling of freshwater and climate. Seven other SAC-D instruments will collect environmental data for a wide range of applications, including natural hazards, land processes, epidemiological studies and air quality issues. Two of the SAC-D instruments will gather information on rain, sea ice, wind speed and ocean surface temperatures that will complement Aquarius data.

Scheduled for launch no earlier than June 9, 2011, aboard a United Launch Alliance Delta II rocket from Vandenberg Air Force Base, Calif., Aquarius/SAC-D will fly in a 408-mile (657-kilometer) high, sun-synchronous, near-polar orbit, completing one orbit every 98 minutes and mapping the global open ocean once every seven days. During its three-year lifetime, the mission will provide monthly maps of global changes in ocean surface salinity with a resolution of 93 miles (150 kilometers), showing how salinity changes from month to month, season to season and year to year.

Global ocean salinity has been an area of much scientific uncertainty. Recently, a European mission (Soil Moisture and Ocean Salinity, or SMOS) began making ocean surface salinity measurements. Aquarius/SAC-D will be a significant addition to the Global Ocean Observing System, which coordinates instruments and sensors to measure the global ocean, including salinity.

Because ocean surface salinity varies from place to place and over time, scientists can use it to trace the ocean's role in Earth's water cycle. For example, more than 86 percent of global evaporation and more than 78 percent of global precipitation occur over the ocean. By measuring changes in ocean surface salinity caused by these processes, as well as by ice melting and river runoff, Aquarius/SAC-D will provide new insights into how the massive natural exchange of freshwater between the ocean, atmosphere and sea ice is linked to ocean circulation and climate.

Knowing more about ocean surface salinity can also help scientists track ocean currents and better understand ocean circulation. Salinity, together with temperature, determines how dense and buoyant seawater is. This, in turn, drives how ocean waters are layered and mixed and how water masses are formed. Salinity has a major effect on the flow of currents that move heat from the tropics to the poles and affect global climate.

When combined with data from other sensors that measure sea level, ocean color, temperature, winds, rainfall and evaporation, Aquarius' continuous, global salinity data will give scientists a much clearer picture of how the ocean works, how it is linked to climate and how it may respond to climate change.

Studies from Aquarius will improve computer models used to forecast future climate conditions, including short-term climate events such as El Niño and La Niña.

Aquarius will measure ocean surface salinity by sensing microwave emissions from the water's surface with three passive microwave radiometer instruments. When other environmental factors are equal, these emissions indicate how salty the surface water is. An active microwave scatterometer instrument will measure ocean waves that affect the precision of the salinity measurement. Because salinity levels in the open ocean vary by only about five parts per thousand, Aquarius employs new technologies to detect changes in salinity as small as about two parts in 10,000, equivalent to about one-eighth of a teaspoon of salt in a gallon of water.

The Aquarius instrument was jointly built by NASA's Jet Propulsion Laboratory, Pasadena, Calif., and NASA's Goddard Space Flight Center, Greenbelt, Md. NASA's Launch Services Program at the Kennedy Space Center in Florida is managing the launch. JPL managed Aquarius development and will manage Aquarius through the mission's commissioning phase and archive mission data. Goddard will manage the mission's operations phase and process and generate Aquarius science data products. The Aquarius principal investigator is located at Earth & Space Research, Seattle, while the University of Maine School of Marine Science is responsible for Aquarius education and public outreach.

CONAE is managing the SAC-D portion of the mission and is providing the SAC-D spacecraft, an optical camera, a thermal camera in collaboration with Canada, a microwave radiometer, sensors developed by various Argentine institutions and the mission operations center in Argentina. France and Italy are also contributing instruments.

NASA Earth System Science Pathfinder Program

Aquarius was selected in 2001 as part of NASA's Earth System Science Pathfinder program. Overseen by NASA's Science Mission Directorate, the program sponsors missions designed to address unique, specific, highly focused requirements in Earth science research. The program is characterized by relatively low- to moderate-cost, small- to medium-sized spaceflight missions capable of being built, tested and launched quickly. The missions support a variety of scientific objectives related to Earth science, including studies of the atmosphere, ocean, land surface, polar ice regions and solid Earth. The program encompasses development and operation of remote-sensing instruments and the conduct of investigations using data from these instruments. The Earth System Science Pathfinder program office, based at NASA's Langley Research Center, Hampton, Va., is responsible for managing, directing and implementing these science investigations.

Aquarius Development

In January 2008, after a four-year development effort, NASA's Goddard Space Flight Center delivered the Aquarius radiometer to JPL for integration with the Aquarius instrument and its JPL-developed scatterometer. Electrical and mechanical integration of the Aquarius instrument took place at JPL. After tests, the instrument was shipped to INVAP S.E., a technology company in Bariloche, Argentina, in June 2009 for integration with the SAC-D service platform. The Aquarius/SAC-D observatory was then shipped to the Brazilian National Institute for Space Research's Instituto Nacional de Pesquisas Espacias (INPE) Integration and Test Laboratory, located in São José dos Campos, near São Paulo, Brazil, where it underwent final environmental testing before being shipped to Vandenberg Air Force Base, Calif., in late March 2011.

NASA-CONAE Partnership

In 1994, CONAE released high-level goals for Argentina's space program that included developing and applying advanced technological knowledge; enhancing economic and human resources; and fostering international cooperation. A major initiative was the SAC satellite series, the fourth of which is Aquarius/SAC-D. For each mission, NASA has provided launch operations and launch vehicles. Each satellite was conceived by CONAE and built by INVAP. Ground control operations for each mission have been conducted in Cordoba, Argentina. Previous missions in the SAC series include:

- SAC-A, launched aboard Space Shuttle Endeavour in 1998, which characterized the performance of equipment and technologies for future missions.

- SAC-B, launched on a Pegasus launch vehicle in 1996, which studied solar physics and astrophysics using science instruments developed by CONAE, NASA and the Italian Space Agency, Agenzia Spaziale Italiana (ASI).

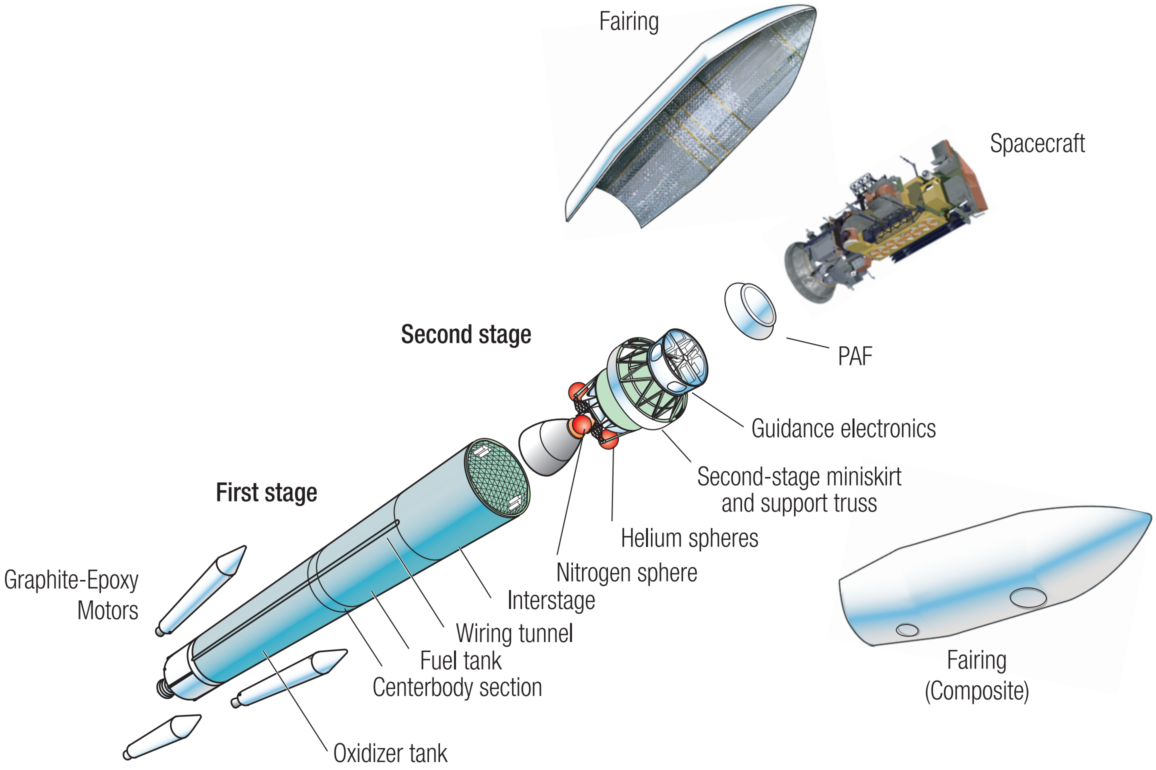
- SAC-C, launched on a Delta rocket in 2000, which focuses on Earth observations such as monitoring Argentina's soil conditions and marine ecosystems.

Launch Site and Vehicle

Aquarius/SAC-D will be launched from Space Launch Complex 2 West at Vandenberg Air Force Base, Calif., on a two-stage Delta II 7320-10C launch vehicle. This vehicle configuration has launched various NASA missions, including NOAA-N Prime, OSTM/Jason-2, NOAA-N, SWIFT and WISE.

Manufactured by United Launch Alliance, Littleton, Colo., the Delta II rocket is a modern version of the Thor intermediate-range ballistic missiles developed in the 1960s. The Delta II launch vehicle has a success rate of nearly 99 percent. Delta II payload capabilities range from 5,960 to 13,440 pounds (2.7 to 6.1 metric tons) to low-Earth orbit.

For the Aquarius/SAC-D launch, the Delta II launch vehicle has two liquid propellant stages and three strap-on solid-fuel boosters.



The first stage of the Delta II uses a Pratt & Whitney Rocketdyne RS-27A main engine. The engine provides nearly 237,000 pounds (1,054,229 newtons) of thrust by reacting RP-1 fuel (thermally stable kerosene) with liquid oxygen.

The solid-fuel boosters are built by Alliant Techsystems. Each of the boosters is 3.3 feet (1 meter) in diameter and 42.6 feet (13 meters) long; each contains 25,937 pounds (11,765 kilograms) of a propellant called hydroxyl-terminated polybutadiene and provides an average thrust of 109,135 pounds-force (486,458 newtons) at liftoff. The strap-on solid propellant rocket motors provide added boost capability during liftoff, and are equipped with ordnance thrusters and an inadvertent separation destruct system.

The Delta II's second stage is powered by a restartable Aerojet AJ10-118K engine, which produces about 9,750 pounds (43,370 newtons) 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 Aquarius/SAC-D spacecraft is attached to the second stage with a clampband, three secondary release latches and switch pads for four separation detection observatory switches. The secondary release latch system reduces the tip-off rate caused by the release of the clampband. No separation springs are required.

The spacecraft will be contained inside the top of the Delta II launch vehicle's 29.2-foot (8.9-meter) tall, 10-foot (3-meter)-diameter composite payload fairing, which encloses the second stage and payload during first-stage flight and the early portion of second-stage flight.

At launch, the Delta II will stand 126.6 feet (38.6 meters) tall atop a 15-foot-tall (4.5 meter) launch stand, and weigh approximately 166 tons (150,708 kilograms).

Launch Timing

Aquarius/SAC-D 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 do not need to be timed based on the alignment of the planets. Earth-orbiting satellites do, however, need to be launched during particular windows within any given 24-hour day in order to get into the proper orbit around Earth. Aquarius/SAC-D will fly in what is called a "sun-synchronous" orbit, flying with a 98.01-degree inclination over Earth's north and south poles. This orbit provides greater coverage over the Arctic than Antarctic.

To place the satellite into a polar orbit, it must blast off to the north or south. Vandenberg is ideal for polar launches because the Pacific Ocean lies to its south. This ensures that any spent rocket parts or debris from a possible mishap would fall in the ocean and not on populated areas.

The launch date is based only on the readiness of the satellite, the Delta II launch vehicle and the availability of the launch range at Vandenberg Air Force Base. Launch is currently scheduled for approximately 7:20:13 a.m. PDT (10:20:13 a.m. EDT) no earlier than June 9, 2011.

The Delta II must be launched during a specific daily 5-minute window to achieve the desired orbit. Launch opportunities will occur every day, subject to limitations on consecutive-day launch attempts due to crew rest requirements, launch vehicle and spacecraft servicing requirements, and the availability of the Western Test Range at Vandenberg Air Force Base.

Launch Phase

When the Delta II launches, its first-stage engine and 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 south-southwest, 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 14 seconds later it 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 six seconds later, the second stage will ignite.

Four minutes and 50 seconds after launch, the launch vehicle's nose cose, or "fairing," will separate in two halves, like a clamshell, and fall away, at an altitude of about 81 miles (130 kilometers). At this point, the Aquarius/SAC-D observatory is open to the space environment.

From liftoff until fairing separation, the Aquarius/SAC-D observatory will remain in the "off" state. The fairing separation event will turn on the power of the SAC-D's service platform by triggering an autonomous power-on sequence. The powered-on service platform elements will remain in standby configuration until the observatory separation is detected.

At about 11 minutes and 30 seconds after liftoff, the second-stage engine will temporarily stop firing, with the vehicle in a 98-by-416 mile (157-by-669 kilometer) transfer orbit. The launch vehicle and its payload will coast for 42 minutes and 40 seconds.

The second stage will perform two sets of attitude re-orientation maneuvers during the coast phase. The first maneuver will position the launch vehicle's +X axis perpendicular to the sun, using a roll/pitch sequence. Then, from launch plus 13 minutes, 50 seconds to launch plus 46 minutes, 50 seconds, the second stage will perform a "barbeque roll," which allows all parts of the second stage to receive equal exposure to the hot sun, warm Earth and cold space, rolling first at +1.5 and then at –1.5 degrees per second.

This second maneuver will point the second stage +X axis into the required spatial orientation for the restart burn, as well as attain a preferred roll orientation for telemetry coverage during the restart burn. This reorientation maneuver will be accomplished with a roll/pitch/roll maneuver.

At about 54 minutes and 10 seconds after liftoff, the second-stage engine will restart, burning 13 seconds before shutting down, and taking place in view of the tracking stations in Hartebeesthoek, South Africa and Malindi, Kenya.

Following engine cutoff, at about 53 minutes, 22 seconds after liftoff, the second stage will perform a combined roll/pitch/roll maneuver to achieve the desired observatory separation attitude, with the observatory's –Y axis pointing toward the sun and the +Z axis pointing straight down to the ground. This maneuver will last 20 seconds.

At 56 minutes, 12 seconds after liftoff, the second stage event controller will activate the spacecraft separation system. The clampband assembly that secured the observatory will be pyrotechnically released. At approximately 56 minutes, 42 seconds after liftoff, separation will occur as the secondary latches are released and the second stage performs a back-away maneuver from the spacecraft, an evasive maneuver, and evasive and depletion burns. These actions are taken to ensure there is no chance for the second stage to collide with the spacecraft, and to minimize the possibility of encountering any contamination products generated by the second stage propellant depletion burn.

Aquarius SAC-D separation will occur in view of the Malindi tracking station, which should acquire the observatory's signal about 35 seconds after separation.

A forward-mounted camera system onboard the Delta II launch vehicle's second stage will provide video of the separation event and of the spacecraft solar array deployment.

Early Orbit and Observatory Commissioning Phase

The Early Orbit and Observatory Commissioning Phase will begin at observatory separation and is scheduled to conclude by launch plus 90 days. During this phase, all primary elements of the SAC-D service platform will be assessed, the operational orbit will be attained and the observatory's basic functions will be verified.

After the service platform detects separation from the second stage, it will automatically initiate attitude control. Thirty seconds after separation, it will power on the service platform's S-band transmitter. One minute after separation, the observatory's solar array will be deployed, when the distance between the observatory and the launch vehicle second stage is greater than 82 feet (25 meters). Six minutes after separation, the S-band transmitter will be automatically turned off and will remain off until the observatory's first pass over the Svalbard, Norway, ground station, about 15 minutes after separation. All subsequent S-band transmitter turn-on and offs will be executed either by the use of time-tagged commands or telecommands from Earth.

During the observatory's early orbits, real-time housekeeping telemetry will be downloaded during each S-band ground station contact and during each X-band ground station contact.

Following the service platform checkout, propulsion subsystem functional and performance tests will begin. The observatory's precise orbit will be determined on a daily basis, and based on these results, a sequence of altitude and inclination maneuvers will be performed to place the observatory into its final operational orbit.

Checkout of the observatory's science instruments will begin 25 days after launch, assuming that the service platform has been fully checked out and the operational orbit has been reached. The checkout, which may last up to 65 days, includes instrument observations, science and instrument data collection, and instrument calibration and validation.

Aquarius commissioning is a sub-phase of the SAC-D Early Orbit and Observatory Commissioning Phase. Its objective is to transition Aquarius from its post-launch configuration to its mission mode of operations and verify the instrument is ready to begin science operations. The commissioning involves deploying the Aquarius reflector, incrementally powering up and checking out all its instruments and subsystems and collecting initial data. The commissioning also determines the health of the Aquarius instrument following the stress of launch and exposure to the space environment.

Aquarius instrument commissioning will begin 25 days after launch and assumes the service platform has been fully checked out. Ten days have been allocated for Aquarius to complete the instrument deployment and checkout phase before beginning initial data collection. When Aquarius instrument commissioning is complete, the instrument will be fully functional, operating in mission mode and collecting science data for the remainder of the Early Orbit and Commissioning Phase.

The SAC-D Microwave Radiometer, New Infrared Sensor Technology, High Sensitivity Camera, and Radio Occultation Sounder for the Atmosphere instruments will also have separate commissioning phases.

At the end of the 90-day Early Orbit and Observatory Commissioning Phase, a post-launch assessment review will be conducted to evaluate the instrument and mission system. Upon successful completion of this review, Aquarius/SAC-D science operations will begin and project management for NASA's Aquarius instrument will transition from JPL to NASA Goddard.

Science Operations Phase

Following instrument commissioning and product validation, nominal science operations will begin. The Science Operations phase lasts for the remainder of the Aquarius and SAC-D instruments' functional lives and within available mission resources. This phase is characterized by the collection of science data and by the transfer of science and engineering data to the ground.

Aquarius and SAC-D instruments will operate according to the following mission timeline:

- The Aquarius, Microwave Radiometer, Radio Occultation Sounder for the Atmosphere, Cosmic Radiation Effects and Orbital Debris and Micrometeoroids Detector, and Technology Demonstration Package instruments will be operated continuously.
- New Infrared Sensor Technology will be operated on passages over Argentina, Italy, Canada and other opportunity targets around the world.
- High Sensitivity Camera will provide imaging of Argentina, Italy and Antarctica.
- Data Collection System will collect data from ground platforms taking environmental data over Argentina, Italy and Brazil.

This phase lasts three years for Aquarius and the Microwave Radiometer, four years for the Radio Occultation Sounder for the Atmosphere and five years for the remainder of the SAC-D instruments.

During this phase, calibration maneuvers and orbit maintenance maneuvers will be performed periodically to meet requirements.

Observatory Decommissioning

At the conclusion of the Science Operations Phase, the observatory will perform a deorbit maneuver, and the Aquarius/SAC-D instruments and service platform subsystems will be powered off in preparation for eventual uncontrolled reentry. The phase will conclude with a series of deorbit maneuvers to reduce the perigee altitude of the observatory to force it to reenter the atmosphere and burn up in less than 25 years. During this time, the spacecraft is placed in a spin mode and commanded to point away from the sun, causing the batteries to discharge. If there is insufficient propellant available to perform these maneuvers, the observatory will be placed in a high-drag orientation to hasten reentry.

Mission Operations

Once Aquarius/SAC-D is on orbit, NASA and CONAE will share the data processing and distribution. Mission operations will be conducted at the CONAE ground station in Cordoba, Argentina. The CONAE Ground Segment consists of CONAE ground station facilities and services that provide observatory operations and control, service platform processing and storage, telemetry and stored data recovery and processing, science raw data storage and distribution, SAC-D science data processing and distribution, and orbit determination and maneuvering. It consists of both CONAE ground system components and foreign ground system components.

CONAE will manage telemetry from the satellite and data processing and distribution from the SAC-D instruments, and transmit raw Aquarius data to the ground system at NASA's Goddard Space Flight Center, where the data will be processed and instrument operations managed. The Aquarius data processing system will generate timely salinity products to be disseminated by and archived at NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC) at JPL.

The ground stations selected to support the Aquarius/SAC-D mission are ETC (Cordoba, Argentina), the NASA Ground Network and two Italian Space Agency ground stations. The entire network includes six tracking stations in Poker Flats, Alaska; McMurdo, Antarctica; Svalbard, Norway; Wallops, Virginia; Matera, Italy; and Malindi, Kenya.

During normal operations, the observatory will be supported only by ETC (commanding, housekeeping telemetry and science data downlinks) and Matera (science data downlinks). The Malindi ground station will support launch and orbit adjustment maneuvers.

The NASA Ground Network tracking stations will be used during launch, monthly orbit maintenance maneuvers, in support of Cold Sky Calibration and in the event of contingencies.

The Aquarius Ground System at NASA's Goddard Space Flight Center is responsible for Aquarius operations, including coordinating with the Aquarius Science Team for planning, performing instrument monitoring, developing command requests for submission for instrument control and science data processing. The Aquarius Ground System is also responsible for managing the requirements for the NASA Ground Network.

The Aquarius Ground System consists of three main segments: the Aquarius Command and Control System, which provides Aquarius instrument control function and Aquarius instrument monitoring; the Aquarius Data Processing System (the science data processing arm of the Aquarius Ground System that retrieves Aquarius science data files captured from the observatory and processes them to Level 3 science data products using algorithms provided by the science team, performs quality control of data products, matches Aquarius data with in-ocean salinity measurements, and archives and distributes files and products to the science team and general science community, and delivers source data and validated data products to JPL's PO.DAAC); and the PO.DAAC, which archives Levels 1, 2 and 3 Aquarius data products and distributes them to the scientific user community.

The Aquarius Ground System is integrated into the existing Goddard Oceans Data Processing System, which processes science data for several operational ocean-viewing projects. The Aquarius Ground System coordinates with the SAC-D Ground System's Mission Operations Control Center to retrieve downlink data and provide Aquarius command requests for integration with mission pass plans, or for real-time transmission. The Mission Operations Control Center will monitor key Aquarius instrument housekeeping telemetry during SAC-D ground station passes to perform real-time assessments of the instrument's health and status.

Aquarius Data Products

A variety of Aquarius data products will be produced for the science community, including the following:

Level 1A — reformatted unprocessed instrument data
Level 2 — derived geolocated ocean surface salinity and wind
Level 3 — time-space averaged ocean surface salinity on a standard Earth projection with 93-mile (150-kilometer) smoothing scales, produced every seven days and monthly

The time for generating Level 2 and Level 3 data products is expected to be no longer than eight days from the time the measurements are made.

Aquarius will continuously collect data over all ocean, land and ice surfaces in its field of view. All these data will be retained for use by researchers in other disciplines. For example, plans are being developed to possibly use Aquarius data for land soil moisture measurements.

Aquarius Calibration and Validation

The Aquarius team plans a six-month post-launch calibration and validation period. The Aquarius calibration/validation plan is designed to minimize the measurement error of the retrieved salinity data, improve algorithms and monitor the long-term stability of the sensors during the mission's operational phase. The plan features an extensive in-ocean surface measurement program, supplemented with additional calibration strategies primarily for monitoring long-term stability of the radiometer and scatterometer.

Aquarius data will be calibrated in several ways. Ground calibration involves the use of in-ocean surface salinity sensors on buoys and ships. The radiometer instrument will also calibrate itself on-orbit using noise diodes. The stability of the L-band scatterometer calibration will be monitored using surface buoy wind data and data from other satellite scatterometers.

A third method of calibration is called cold sky calibration. About 2-1/2 months after launch, after Aquarius produces its first monthly salinity map, the first cold sky calibration will be performed. Aquarius will be pointed away from Earth to observe thermally stable, cold regions of space to remove any non-random internal noise bias to their measurements. The trends of these calibrations will be monitored to determine the appropriate frequency of these calibration activities. cold sky calibrations will be nominally planned once a month, although they may be scheduled more or less frequently as required.

Like many other ocean-observing satellite missions, Aquarius will rely on direct measurements of ocean data from a variety of platforms to validate its data. These will include the global array of 3,000 free-drifting, automated profiling Argo floats distributed throughout the global ocean that measure the temperature and salinity of the upper 6,600 feet (2,000 meters) of the ocean, as well as volunteer observing ships and moored and drifting buoys. The system will calibrate and validate Aquarius measurements and also accumulate and format in-ocean surface salinity and sea surface temperature data, providing a valuable independent data resource for the scientific community. There will be about 2,500 coincident validation observations during each Aquarius seven-day repeat cycle. All systems are fully automated with routine data telemetry via satellite and data delivery within one day. Aquarius will focus its validation measurements in three ocean regions that represent the maximum, minimum and median global ocean surface salinity values, in the subtropical Atlantic, northeast Pacific and tropical Pacific.

All oceanographic calibration/validation data will be collected from the various sources and assembled at Earth & Space Research in Seattle, where they will be quality controlled and evaluated before being provided to the Aquarius data processors in a standardized format.

Aquarius/SAC-D Science Team

An international science team will address the mission's science objectives and goals. Among its responsibilities, the science team will advise the project on aspects of the mission that influence the scientific and operational usefulness of the data. The team has formulated a mission science plan and will oversee mission operations activities.

For a list of Aquarius U.S. Science Team members, see: http://aquarius.nasa.gov/people-scienceteam.html .

For a list of Aquarius/SAC-D international Science Team members, see:
http://aquarius.nasa.gov/science-scientific.html .

Why Study Ocean Surface Salinity?

Salt. Most of us tend to take it, as the saying goes, “with a grain of salt,” viewing it first and foremost as the most common of condiments. Salt comes in many forms, including the one we typically eat — sodium chloride — and has thousands of practical uses, from preserving food to manufacturing pharmaceuticals.

But salt is actually essential to animal life. Our bodies crave it, not just because it tastes good, but because they need it for such essential functions as respiration and digestion. Deprive your body of salt for long enough and you will not survive. Yet too much salt is unhealthy as well, leading to a variety of ailments, from stroke and heart disease to high blood pressure.

Just as salt flows through our veins, it also flows through Earth’s ocean, the lifeblood of Earth’s climate system. The ocean is approximately 3.5 percent salt (35 grams per kilogram), about 86 percent of which is sodium chloride. The concentration of dissolved salts in the ocean is referred to as salinity, and it varies across the globe.

Just as too much or too little salt in our diets affects our bodies in different ways, so too do high and low salinity have profound effects on how the ocean circulates, how freshwater cycles around our planet and how our climate works. The concentration of salt in the ocean’s surface mixed layer — the uppermost portion of the ocean that is actively exchanging water and heat with Earth’s atmosphere — is a critical driver of ocean processes and climate variability.

The global measurement of ocean surface salinity over time provides a clear way to understand these relationships. By tracking ocean surface salinity changes, we can directly monitor variations in the water cycle: land runoff, sea ice freezing and melting, evaporation and precipitation over the ocean. Global ocean surface salinity data will allow us to quantitatively improve the way these ocean-atmosphere-land-ice interactions are encoded in state-of-the-art computer models, enhancing our skill at predicting future climate conditions.

To understand salinity’s role in climate, it’s useful to begin with the ocean.

The Water Planet

Covering more than 70 percent of Earth’s surface, the ocean is our planet’s most dominant feature and the single most significant influence on Earth’s climate. This great reservoir is constantly changing and exchanging heat and moisture with the atmosphere, driving our weather and controlling slow, subtle changes in our future climate. Understanding how heat moves within the ocean and into the atmosphere is critical to understanding global climate change.

The ocean is Earth’s major storehouse for energy, in the form of heat, from the sun. It works with Earth’s atmosphere to transport this heat from Earth’s equatorial regions toward the icy poles. Winds blow across the ocean surface, driving 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 ocean has a slower, longer-lasting effect on climate.

Most of Earth’s evaporation, about 86 percent, occurs over the ocean, as does 78 percent of global precipitation. Ocean surface evaporation releases energy into the atmosphere as water vapor. Over time, water returns to the ocean and land through precipitation as rain or snow. This global cycling of water and energy helps make Earth’s climate hospitable to humans and other life forms.

What is Salinity?

Salinity is a measure of the concentration of dissolved salts in ocean water. Salinity affects, among other things, seawater’s freezing point and density. Around the globe, the salinity of the ocean surface varies over time and space, generally ranging between 32 and 37 on the Practical Salinity Scale (PSS), a measurement scale developed in 1978 to quantify the concentration of dissolved salts in water. The scale derives salinity from precise instrument measurements of seawater electrical conductivity, temperature and pressure (depth). The PSS is nearly equivalent to the number of grams of salt in one kilogram of water, or parts per thousand by weight. The average ocean surface salinity is about

35 PSS, but it can be much lower near freshwater sources, or as high as 42, in the Red Sea.

Understanding why the ocean is so salty begins with knowing how water cycles among its physical states: liquid, vapor and ice. As a liquid, water dissolves rocks and sediments and reacts with emissions from volcanoes and hydrothermal vents, creating a complex solution of mineral salts that eventually makes its way, via the water cycle, into our ocean basins. Other factors that make the ocean salty are water evaporation and sea ice formation. These “salinity-raising” factors are continually counterbalanced by processes that decrease salinity, such as the continuous input of freshwater from rivers, precipitation from rain and snow, and melting ice.

Some scientists estimate the ocean contains as much as 50 quadrillion tons (50 million billion tons) of dissolved solids. If the salt in the ocean could be removed and spread evenly over Earth’s land surface, it would form a layer more than 500 feet (152.4 meters) thick, about the height of a 40-story building. Seawater is 220 times saltier than fresh lake water. Sea salt contains more than 100 minerals, composed of 80 chemical elements. The composition of a single crystal of ocean salt is so complicated that no laboratory in the world can produce it from its basic 80 chemical elements. (From “Why is the Ocean Salty” by Herbert Swenson, U.S. Geological Survey).

While the amount of salt in the ocean is relatively constant over years and decades, ocean surface salinity varies because freshwater input and ouput — part of the global water cycle — varies from place to place.

On land, water cycle processes are tied to vegetation patterns: deserts occur in regions of high evaporation, and rain forests occur in areas of high precipitation. Similarly, over the ocean, regional differences between evaporation and precipitation are correlated with patterns of ocean surface salinity.

As is the case on continents, some ocean latitudes are “rainy,” whereas others are arid and “desert-like.” In general, latitude zones dominated by precipitation, such as the temperate regions between 40 to 50 degrees latitude in both hemispheres, near coasts and at the equator, have low ocean surface salinity. Those dominated by high evaporation, between 20 to 30 degrees latitude in both hemispheres, at ocean centers and in enclosed seas, have high ocean surface salinity.

Ocean currents can also modify ocean surface salinity patterns by transporting surface waters — and their ocean surface salinity “signature” — across latitude belts. The Gulf Stream, for example, transports warm, high-salinity water from the tropics along the Atlantic Ocean’s western boundary, then eastward toward Europe.

Salinity and Ocean Circulation

Surface winds drive currents in the upper ocean. Deep below the surface, however, ocean circulation is primarily driven by changes in seawater density, which is determined by its salinity and temperature. Seawater density, in turn, affects the formation of water masses and regulates the ocean’s three-dimensional circulation. A saltier ocean is denser and circulates differently than one with less salt. Oceanographers believe that if density-driven ocean circulation remains stable, ocean heat transport will remain in balance — and ocean heat transport plays a key role in regulating Earth’s climate.

If surface water becomes more dense, through a decrease in temperature or an increase in salinity (through ice formation and evaporation), this triggers gravitational instability (i.e., dense water overlying less-dense water) and, in certain key regions, causes surface waters to sink deep into the ocean, where it becomes part of the deep ocean circulation system. Once a sinking water mass reaches a depth at which its density matches the density of the surrounding environment, the mass flows horizontally, along “surfaces” of equal density. Conversely, de¬creases in the density of surface water, through an increase in temperature or decrease in salinity (through precipitation or melting ice) may trigger widespread decreases in seawater density, reducing its tendency to sink.

Ocean salinity’s influence on the environment can be summarized by looking at Earth’s three major latitude zones: high latitudes (60 to 90 degrees), mid-latitudes (30 to 60 degrees) and tropics (30 degrees north to 30 degrees south).

Salinity’s influence on ocean circulation and climate may be most profound at Earth’s high latitudes, where increases in ocean surface salinity (i.e., evaporation exceeding precipitation) and heat loss can increase seawater density and speed up the deep overturning ocean circulation. For example, the North Atlantic near Greenland is a primary source for sinking of cold, dense, high-salinity water masses that trigger the thermohaline (temperature-salinity) overturning circulation that extends throughout the world's ocean. This circulation moves southward to the South Atlantic and joins the Southern Ocean circulation around the African continent and into the Indian Ocean.

This deep ocean "conveyor belt" helps move large water masses and distributes heat from the tropics to the polar regions. It accounts for much of the oceanic heat transport that contributes to the stability of global climate. This is vitally important because recent studies have shown that about 90 percent of climate warming in the 20th century can be accounted for by oceanic heat uptake. Deep overturning circulation has a "memory," like a tape recorder. Events happening now will still be visible hundreds of years in the future as water masses move slowly through this giant circulation system, rising to the surface again perhaps 10, 100 or even 1,000 years later.

In recent years, scientists have been concerned over changes in ocean salinity and circulation and how they might affect deep overturning circulation and, ultimately, climate. Scientists have reported a slowdown of this circulation and its associated heat transport over the past 50 years. Scientists are debating whether this slowdown is part of a decadal oscillation or whether it reflects an abrupt ocean change that could have more permanent effects on climate. Studies of salinity records have shown that large areas of sub-polar North Atlantic deeper waters grew fresher from the late 1960s until the late 1990s, then grew somewhat saltier in the past decade. Meanwhile, the sub-tropical North Atlantic surface waters have gradually become saltier. These changes appear to be related to changes in evaporation, precipitation and ocean circulation.

Studies also show past climate shifts are linked to significant changes in the strength of thermohaline circulation. Throughout Earth's history, salinity changes due to increases in freshwater from melting glaciers have disrupted ocean circulation and caused extreme climate variability. In some instances, salinity changes have coincided with cooling episodes, such as the one triggered about 700 years ago, called The Little Age. In recent decades, studies indicate that abnormal surface salinity around the far north Atlantic, called Great Salinity Anomalies, coincided with unusual weather in Europe. Scientists don't yet know what impact these anomalies have on the thermohaline circulation, but some recent studies suggest they could affect it by as much as 30 percent.

At mid-latitudes, salinity influences the depth to which water masses sink and how far they extend through the ocean. The location and depth of these water masses controls how heat and salts are transported between the tropics and high latitudes. Like atmospheric fronts that bring unstable weather, ocean fronts — found at the interface between water masses — are areas of high activity often correlated with important fisheries, such as tuna.

In the tropics, ocean surface salinity is greatly controlled by rainfall and, in some areas, river runoff, and these sources of freshwater regulate how the ocean interacts with the atmosphere. Affecting almost half the world's human population each year, monsoons are driven by energy exchanges at the boundary between the ocean and atmosphere. Likewise, El Niño has profound effects on humankind and is — to an unknown extent — influenced by ocean salinity. In fact, recent studies indicate that understanding salinity's effect on upper ocean buoyancy may be a key to better El Niño forecasts.

In heavy rainfall and river runoff areas of the western equatorial Pacific and eastern Indian Ocean, salinity regulates how the ocean interacts with the atmosphere, forming a "barrier layer," a climatological feature common to all tropical oceans. Heavy rainfall in the tropics creates buoyant "lenses" of water that form stable layers of freshwater on the ocean surface, modifying the exchange of heat between the ocean and atmosphere by insulating deeper thermocline waters from the surface. This process alters ocean-atmosphere energy exchanges that drive the evolution of tropical season-to-season oscillations, monsoons and El Niño.

Salinity and the Water Cycle

Earth is dominated by water in all its forms. The water molecule can naturally exist as a gas (water vapor, clouds), liquid (water, rain), or solid (snow and ice) within the relatively small range of air temperatures and pressures found at Earth's surface. Two-thirds of all freshwater is locked away in ice caps at the poles, with the remainder found in lakes, rivers and underground reservoirs. The process by which water moves around Earth, from the ocean to the atmosphere to the land, and back to the ocean, is called the water cycle.

Driven by the sun's energy, water cycles continuously throughout the Earth system. As water evaporates from the ocean surface, lakes and the land surface, it rises into the atmosphere as water vapor, which then cools and condenses (i.e., changes from a gas to a liquid) to form clouds. The clouds are transported by air currents around the globe. The water droplets in them condense, and eventually fall back to Earth's surface as rain or snow. Snow can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Most precipitation falls back into the ocean or onto land where, due to gravity, it flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with stream flow moving water toward the ocean. Runoff and groundwater seepage accumulate and are stored as freshwater in lakes. Over time, though, this water keeps moving, some to reenter the ocean, where the water cycle ends and begins anew.

Monitoring ocean surface salinity is a key tracer for understanding the movement of water into and out of the ocean system and the strength of the water cycle. Changes in salinity provide strong evidence for long-term changes in precipitation and evaporation, since it tracks the differences created by varying evaporation and precipitation, runoff and ice processes, all of which affect ocean currents and ocean mixing. Those factors influence the capacity of the ocean to absorb, transport and store heat, freshwater and carbon dioxide.

Many scientists believe the global water cycle will accelerate as Earth warms. A warmer atmosphere would carry more water vapor. Ocean salinity trends indicate significant changes are already underway in the global water cycle. High-salinity, high-evaporation regions in the sub-tropics are getting saltier, while low-salinity, high-precipitation regions in the high latitudes are getting fresher. Unless ocean mixing and transport are changing, this trend provides strong evidence that the global water cycle is intensifying. An enhanced water cycle will change the distribution of salinity in the upper ocean. Such changes could significantly affect not only ocean circulation, but also our climate, for decades or even centuries.

Earth's various ocean basins have very different salinities, with the Atlantic Ocean being the saltiest of the major oceans. This is because, on average, there is more evaporation than combined rainfall and river runoff into the Atlantic, keeping its salinity higher than in the other basins.

Changes in global upper ocean salinity over the past 50 years show an average freshening concentrated in sub-polar regions and the tropics, mainly dominated by precipitation and runoff. In contrast, salinity increased in the subtropics, where evaporation dominates.

The Salinity/Climate Connection

Within Earth's changing climate, even small perturbations in ocean salinity have the potential to be of great impact. Scientists want to better understand the links between ocean salinity and climate change. Excess heat associated with the increase in global temperature during the last century is being absorbed and moved by the ocean. Surface ocean and atmospheric temperature changes may cause evaporation to intensify and, as a result, significantly alter ocean surface salinity and ocean circulation patterns. Global warming can also change precipitation patterns over our planet.

Large-scale changes in salinity could indicate that droughts and floods will become more severe, or that global warming is speeding up. Recent research in the United Kingdom suggests the amount of salt in seawater is varying in direct response to human-produced climate change. Tracking high-latitude variations in salinity will help predict climate fluctuations.

Over time, changes in salinity patterns can affect the environment. For example, an increase in salinity may affect the air-sea exchange rate of carbon dioxide, a greenhouse gas associated with climate change.

Measuring and Monitoring Ocean Surface Salinity: Past, Present and Future

The ocean's vast size, density and turbulent nature make it difficult to observe and study it in detail. A new age of satellite oceanography is being fueled by data from instruments quantifying global ocean circulation, the amount of organic material available to support sea life, sea surface winds and temperature and tropical rainfall.

Yet despite all the progress in understanding our ocean-atmosphere system, ocean surface salinity has not been measured by satellite until now. Salinity measurements are a missing variable that, along with measurements from other ocean satellites will provide a complete suite of surface observations to investigate how global ocean circulation responds to climate change.

Yet ocean surface salinity has been measured directly for centuries from ships and buoys. In the 1870s, scientists aboard the H.M.S. Challenger began measurement of salinity and temperature during a global voyage, heralding the beginning of oceanography as a science discipline.

Since then, salinity observations have been made regularly, but sparsely, limited mostly to summertime observations in shipping lanes and ocean buoys. Over the years, techniques for measuring ocean water properties have changed drastically in method and accuracy. Still, until very recently, about 25 percent of the ice-free ocean had never been sampled, including vast regions of the southern hemisphere. Nearly 75 percent of the ocean had fewer than 10 observations. Remote sensing of ocean salinity had only been accomplished through a few limited airborne measurement experiments. These types of measurements, while valuable, are not extensive enough or capable of providing constant, accurate measurements over vast distances to give the global view of salinity variability that only a satellite can provide.

The current in-ocean salinity measurement system, part of the Global Ocean Observing System, provides regular vertical profiles of salinity. It includes more than 3,000 Argo floats and volunteer observing ships.

Argo is a global array of free-drifting, battery-operated profiling floats that measure the temperature and salinity of the upper 6,500 feet (2,000 meters) of the ocean. The floats are deployed at predetermined depths. Each float reports its location, temperature and salinity every 10 days.

Argo deployments began in 2000 and reached the goal of 3,000 floats in 2007. To maintain this fleet, about 800 new floats are added each year as replacements. Argo floats produce 100,000 temperature/salinity profiles a year. Data are publicly available within 24 hours of collection. A handful of specially-designed Argo floats have also been deployed in the polar regions. In the future, the floats will be capable of sampling to depths of more than 16,400 feet (5,000 meters).

Over the past decade, Argo has successfully mapped the distribution of salinity in previously unexplored regions and examined changes in the distribution of ocean salinity over the past 20 to 30 years. Improved forecasts of El Niño events, monsoons, and other climate patterns are possible using Argo data.

The concept of measuring salinity using satellite remote sensing has been around since the 1970s, when researchers at NASA's Langley Research Center and later at NASA's Goddard Space Flight Center demonstrated that ocean surface salinity could be remotely measured using a passive microwave sensor.

By the late 1980s and into the 1990s, emerging new satellite instrument technologies made it possible to measure ocean salinity from satellites with sufficient detail and accuracy.

In 1998, Aquarius Principal Investigator Gary Lagerloef of Earth & Space Research, Seattle, coordinated a working group of international experts to provide science objectives and measurement requirements. He became part of a NASA team to develop the Aquarius mission proposal. The Aquarius mission was born when it was first proposed to NASA in 2001. The Aquarius instrument is named after the Water Bearer constellation. The mission was announced by NASA as part of its Earth System Science Pathfinder program in January 2004.

In parallel with NASA's Aquarius, the European Space Agency was developing a salinity remote sensing mission, Soil Moisture Ocean Salinity (SMOS).

SMOS, launched in November 2009, collects land and ocean measurements, including ocean surface salinity, but its primary mission is to measure soil moisture. The accuracy requirements for soil moisture measurements are less than those needed for salinity measurements, but the requirement for spatial resolution is higher. It uses an interferometric sensor with a spatial resolution of 28 miles (45 kilometers).

The Aquarius mission will overlap with SMOS. While the two missions use different measurement approaches, they provide a strong combination to study global land-sea surface responses to rainfall and evaporation using the same microwave L-band frequency. Scientists will compare and combine their data to improve our understanding of ocean surface salinity.

The design of Aquarius is optimized for the greater radiometric accuracy required for salinity measurements. In addition, unlike SMOS, Aquarius will include a scatterometer to correct for the effects of ocean waves on the salinity data.

The Aquarius and SMOS teams are exchanging co-investigators and will exchange scientific and technical information, participate in joint field campaigns, perform joint calibration and validation activities, and conduct coordinated observations that may benefit the science community by increasing spatial coverage and increasing the frequency of observations by either satellite alone.

The Salinity Processes in the Upper Ocean Regional Study (SPURS) experiment in 2012–2013 will use floats, gliders, drifters, moorings, ships, satellites (including Aquarius) and computer models to study processes controlling upper-ocean salinity. SPURS will initially focus on high-salinity regions like a region of the North Atlantic where salinity is at a maximum and has been increasing. Science objectives include determining what processes maintain the salinity maximum and influence salinity variations over time, finding where the excess salt goes and examining effects of salinity change on ocean circulation.

In Summary: What Aquarius Will Do

Aquarius will map the salinity — the concentration of salt — at the ocean surface, information critical to improving our understanding of the links between Earth's water cycle, ocean circulation and climate.

Aquarius will greatly expand on limited past direct measurements of ocean salinity. When combined with data from other sensors that measure sea level, ocean color, temperature, winds and rainfall, Aquarius' continuous, global salinity data will provide a clearer picture of how the ocean works, how it is linked to climate and how it may respond to climate change. Its measurements will provide a baseline from which to detect future changes in salinity as our climate changes.

This experimental NASA Earth System Science Pathfinder Program satellite mission will map Earth's open ocean once every seven days on a three-year mission of exploration and discovery. Aquarius will map ocean surface salinity in remote regions, revealing presently unknown features, structures and variability.

Aquarius will help scientists see how freshwater moves between the ocean and the atmosphere. It will monitor changes in the water cycle due to rainfall, evaporation, ice melting and river runoff, from season to season and year to year, and show how these changes may affect ocean circulation. Its data will improve global "water cycle budget" estimates over the ocean, where most global precipitation and evaporation occurs, as well as estimates of rainfall over the ocean. It will monitor how water forms into masses based on density, and it will investigate how the upper ocean responds to variations in rainfall in intertropical convergence zones near Earth's equator.

Scientists will use Aquarius data to investigate how salinity variations modify ocean density and influence ocean circulation and mixing from the tropics to the poles. It will be used to study ocean processes, such as how salinity affects surface currents; how ocean density layers are formed; and how ocean surface salinity changes. These factors affect the ocean's capacity as a climate reservoir to store the sun's energy.

Scientists plan to add data from Aquarius to data sets from NASA's Jason-1 and -2 satellites, NASA's GRACE, and NOAA's Argo floats to further unravel the relative contributions of glacier melting, ocean heating and changes in ocean salinity to sea level change.

Aquarius data will complement other climate research projects, such as those of the World Climate Research Program's CLImate VARiability program and the Global Ocean Observing System.

Aquarius will help improve predictions of future climate trends and short-term climate events such as El Niño and La Niña. Variations in sea level in the tropics are primarily governed by the heat content of the upper ocean, but salinity affects buoyancy, which can modify sea level. Greater salinity, like colder temperatures, increases ocean density and lowers sea surface height. In warmer, fresher waters, the density is lower, resulting in an elevation of the sea surface. During the course of an El Niño, salinity has raised sea level up to 2.4 to 3.1 inches (6 to 8 centimeters) in the western equatorial Pacific, or about half the signal typically produced by an El Niño. These sea level variations are directly related to the strength of ocean currents that transport warm water from the western to eastern equatorial Pacific during the onset of an El Niño. The salinity data can, therefore, help reduce uncertainty in modeling and predicting El Niño. If the effects of salinity aren't accounted for, sea level changes measured by satellite altimeters like NASA's Jason-1 and -2 and island sea level gauges could be erroneously attributed entirely to changes in ocean heat content, potentially affecting the accuracy of ocean climate models used to forecast El Niño.

Scientists studying the western Pacific Ocean find regional changes in the saltiness of surface ocean water correspond to changes in upper ocean heat content in the months preceding an El Niño event. When changes in salinity occur, they affect the El Niño event for the next six to 12 months. In this lag time, salinity changes have the potential to modify the layers of the ocean and affect the heat content of the western Pacific; the region where the unusual atmospheric and oceanic behavior associated with El Niño first develops. Knowing the lag time factor, computer models simulating the movement of the atmosphere may be able to accurately predict El Niño episodes.

Aquarius will employ new technologies to enable NASA's first space-based measurements of global ocean salinity. Aquarius will be able to detect changes in ocean salinity as small as 0.2 PSS, equivalent to a "pinch" (about one-eighth teaspoon) of salt in a gallon of water, or two parts in 10,000.

Aquarius observations will contribute significantly to improving the accuracy of computer models used to forecast future climate conditions, thereby reducing uncertainty in our ability to model present and future climate. Limited salinity data have not allowed researchers to fine-tune computer models to obtain a true global picture of how ocean surface salinity is influencing the ocean.

How salinity modulates the mixing of the upper ocean in tropical and high-latitude regions is not well understood or well represented in climate models. Aquarius data, when combined with data on air–sea interactions and interior ocean data from Argo, will help link ocean variability at and below the surface and improve models of ocean mixing.

Aquarius has potential to provide new insights into Arctic ice processes, though acquiring accurate salinity data in the Arctic will be challenging because sea ice interferes with the Aquarius salinity measurements near ice edge boundaries. Sea ice, or frozen seawater, has zero salinity. Polar ice melt from climate warming can cause large-scale seawater freshening in the North Atlantic that could potentially reduce the formation of deep water masses. This, in turn, could reduce the efficiency of the ocean global conveyor belt that helps regulate global climate by moving heat from the tropics to higher latitudes. Aquarius will help predict these fluctuations.

Recent drastic changes in Arctic sea ice cover have made collecting ocean surface salinity data in the Arctic more important than ever. Studies predict summer sea ice will be gone by the middle of this century and perhaps much sooner. The loss of sea ice results in more open water. As ice-covered areas with high albedo (reflectivity) get smaller, larger expanses of open water absorb more solar radiation and, in turn, melt more sea ice. In the Arctic, sea ice melt and land runoff form a shallow, cold, fresh layer separated from warmer, saltier water below by the halocline, the depth at which salinity dramatically changes.

Aquarius data may yield information about whether the halocline will break down where the ice cover recedes; whether there will be measurable open-water salinity and temperature changes at the surface, and how these changes would influence summer sea ice melting rates and the reforming of seasonal winter ice; and the fate of summer melt water. Aquarius data may also help discriminate relatively fresh melt-pond water on top of sea ice from the surrounding seawater and improve estimates of summer sea ice concentration.

Other areas where Aquarius data will be used include studies of variability in the large-scale oceanic uptake of carbon dioxide from the atmosphere; and land and ice applications, such as soil moisture studies.

Finally, Aquarius will serve as a pathfinder to demonstrate the technology and scientific rationale for future long-term satellite missions to monitor ocean surface salinity.

Science Goals and Objectives

Overall Aquarius/SAC-D Observatory Objectives

The overall primary science objectives of the Aquarius/SAC-D mission are to contribute to the understanding of the total Earth system and the effects of natural and human-induced changes on the global environment. Aquarius/SAC-D science objectives address ocean circulation, the global water cycle, climate variability, land processes, land use, soil moisture, natural hazards, health applications and the cryosphere, among others.

Aquarius Goals and Objectives

The overall science goals of Aquarius are to observe, model and understand the regional and global processes that link variations in ocean salinity to climatic changes in the global water cycle, and to understand how these variations influence ocean circulation and climate.

NASA's Aquarius mission will help scientists address two key NASA Earth science research priorities:

Earth System Variability and Trends

- How are global precipitation, evaporation and the cycling of water changing?

Aquarius will measure the variability in ocean surface salinity, the primary surface tracer of freshwater that is input to and output from the ocean due to precipitation, evaporation, ice melting and river runoff. It will help us better understand how global precipitation, evaporation and the water cycle are changing.

Earth System Responses and Feedback Processes

- How can climate variations induce changes in the global ocean circulation?

Ocean surface salinity data from Aquarius, along with sea surface temperature data from other satellites, will be used by scientists to determine sea surface density. That density controls the formation of water masses in the ocean and regulates the three-dimensional circulation of the ocean.

Aquarius science objectives address the important new climate information that will be gained from salinity measurements, as well as new insights into ocean circulation and mixing processes.

- Discovery and Exploration — Aquarius will resolve unknown patterns and variations of global ocean surface salinity, particularly in the large areas of the ocean that have not previously been well sampled. Aquarius will provide a reference from which longer-term climatic ocean changes will be detected in the future.
- Water Cycle — Aquarius will measure salinity variations over space and time to determine how ocean surface water responds to variations in evaporation, precipitation, ice melt and river runoff on seasonal and year-to-year time scales.
- Ocean Circulation and Climate — Aquarius will investigate how salinity variations affect ocean density and influence density-driven ocean circulation and how the ocean transports heat. Aquarius investigations will pay particular attention to three latitude zones of interest:

  —The Tropics, where Aquarius will focus on interactions between the ocean and atmosphere and between different processes in the climate system, as well as on variations due to El Niño and La Niña.

  —The Mid-latitudes, where Aquarius will study how surface waters are formed and sink into the ocean interior.

  —The High-latitudes, where Aquarius will study salinity anomalies that influence the formation of cooler, more salty "deep water" such as that found in the ocean's large-scale "conveyor belt." These anomalies have lasting impacts on climate.

SAC-D Objectives

SAC-D science objectives are to conduct local measurements over Argentina and contribute to global investigations of the atmosphere, ocean and the effects of human and natural processes on the environment, as defined in Argentina's national space program strategic plan.

Spacecraft

The Aquarius/SAC-D observatory consists of the SAC-D service platform (or spacecraft bus), the Aquarius instrument and SAC-D instrument suite. NASA provided the Aquarius instrument, which is the primary science instrument for the mission. CONAE provided the service platform, which was built by the technology company INVAP in Bariloche, Argentina, and the SAC-D instrument suite, whose instruments were provided by CONAE and other international partners.

The Aquarius/SAC-D observatory is a three-axis stabilized, Earth-pointing, low-Earth orbit scientific satellite. Its main structure, or service platform, houses the instruments and provides power; receives and processes commands from the ground; and receives, stores and downlinks science data collected by the instruments. It is made of aluminum in a right-octagonal-shaped structure that measures about 8.9 feet (2.7 meters) across by 8.2 feet (2.5 meters) tall without the Aquarius instrument, and almost 16.4 feet (5 meters) tall with it. The Aquarius instrument is located at the end of the service platform that points away from the sun during flight. The opposite end of the satellite incorporates two diametrically opposed hinges that support the spacecraft solar array, which consists of two identical wings approximately 7.2 feet (2.2 meters) tall and 7 feet (2.15 meters) wide. The observatory, including the spacecraft, science instruments and onboard propellant, weighs approximately 2,977 pounds (1,350 kilograms).

While the SAC-D observatory is designed to last for at least five years, its resistance to radiation at its orbiting altitude of 408 miles (657 kilometers), should allow the mission to operate well beyond its nominal design lifetime.

The Aquarius/SAC-D service platform consists of the following subsystems and assemblies:

- Structure and Mechanism Subsystem
- Attitude and Orbit Control Subsystem
- Command and Data Handling Subsystem
- Electrical Power Subsystem
- Communications Subsystem
- Propulsion Subsystem
- Thermal Control
- Mass Memory
- Data Acquisition and Processing Subsystem

Structure and Mechanism Subsystem

The Structure and Mechanism Subsystem's basic function is to provide mechanical support for all SAC-D subsystem equipment hardware and the scientific payloads in order to withstand the ground, launch and orbit environments.

The shape of the service platform's structure is based on that used for CONAE's SAC-C mission, launched in 2000. The majority of subsystem equipment is housed inside. During launch, the service platform is oriented vertically and mounted onto the Delta II launch vehicle from the end opposite the Aquarius instrument. The remaining scientific instruments are attached on its side covers.

The Structure and Mechanism Subsystem is divided into a primary structure, secondary structure and mechanical assembly hardware.

The primary structure provides support for the different equipment of the platform, the connection with the launch vehicle, and the mechanical support for the scientific payloads and solar panel. It consists of a bottom payload attachment fitting that provides the structural interface with the launch vehicle; four all-aluminum, honeycomb-type platforms; an independent aluminum frame around each platform; columns on the eight corners of the structure; eight sides covered by lateral panels attached to the frames and columns; and battery frames.

The secondary structure allows for mounting of some units of the service platform subsystems and consists of supports for the four reaction wheels, hydrazine tank, radio frequency antenna, piping and thrusters, battery frame and GPS antenna.

The mechanical assembly hardware includes bolts, inserts, washers, nuts and all required parts to assemble the structural components. All these elements are made of light nonmagnetic alloys, and structural elements are either bonded or assembled using nonmagnetic qualified materials.

Attitude and Orbit Control Subsystem

The Attitude and Orbit Control Subsystem provides high stability for the spacecraft during science operations and points the instruments for science and calibration observations.

The observatory's attitude will be determined based on information provided by several sensors. Attitude control will be performed using a combination of actuators.

Attitude and Orbit Control Subsystem sensors include 12 coarse solar sensors, two four-axis magnetometers, two GPS units, two star sensors and two three-axis gyro units. Actuators include four momentum reaction wheels (one redundant), three torque-rods (single core with two coils) and eight thrusters (two independent branches).

The SAC-D mission will have several attitude control modes: stand-by, survival, safe hold, science and propulsion. Each mode uses different combinations of sensors and actuators.

Science mode is the normal mission mode. The observatory enters this mode only after being commanded by ground controllers. Attitude is estimated using gyroscopes and updates from star sensors that track the positions of stars in the sky. Position data for transforming from inertial to orbital attitude is provided by the GPS units. An onboard orbit propagator provides position data when GPS is unavailable. The reaction wheels are the primary actuators. Onboard angular momentum is maintained near zero or at a very low value. The momentum wheels will be desaturated using magnetic torque coils. This mode will also be used to perform cold sky calibration maneuvers. In science mode, the observatory will use inertial and yaw steering to maintain its desired attitude.

The observatory can transition from more complex to safer and simpler modes automatically using onboard diagnostics or by ground command. However, transitioning from safer to more complex modes must be commanded by the ground.

Reaction wheels use the momentum of spinning wheels to nudge the observatory in one direction or another. Periodically the reaction wheels accumulate too much momentum, which requires the use of three devices called magnetic torque rods — somewhat like large electromagnets — to push against Earth's magnetic field and cancel out some of the momentum in the wheels. The torque rods use information from a device called a four-axis magnetometer that senses the orientation of Earth's magnetic field.

In addition to pointing the instrument, the spacecraft must know its orbital position in order for ground processors to compute where on Earth the footprint of the instrument is located. Two onboard global positioning system receivers provide that information.

Command and Data Handling Subsystem

The Command and Data Handling subsystem decodes and distributes ground commands for loads and subsystems, processes uplink commands, manages stored commands, collects and processes telemetry data, and provides autonomous fault protection and subsystem intercommunications. It also monitors the state of the observatory and its instruments, and detects the separation of the observatory from the launch vehicle and unfolding of the solar panels. It consists of two identical units based on the 80C86 processor running at 4 megahertz. The two units share the same SAC-C type box in a backup configuration where one unit is on while the other is off.

The observatory uses stored commands to perform its normal operations and also receives commands and sequences from Earth. The software on the flight computer translates the stored and ground commands into actions for various spacecraft subsystems. The flight software also gathers science data as well as engineering telemetry for all parts of the spacecraft and continuously monitors the health and safety of the observatory.

The flight software can perform 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 preset actions to resolve the problem or put the spacecraft in a safe mode until ground controllers can respond.

Electrical Power Subsystem

The observatory's power is generated, stored and distributed by the Electrical Power Subsystem. This subsystem provides 1,362 watts of electricity when the solar panels are deployed.

The Electrical Power Subsystem's main components are: power control electronics, remote terminal unit, battery management unit, voltage regulator, pyrotechnic firing box, battery and solar arrays (two wings).

The solar arrays, built by Argentina's Atomic Energy Commission, Comision Nacional de energia Atomica, generate all power required by the observatory. There are two wings on both sides of the observatory. Each wing consists of one panel, measuring 93.5 inches by 86.16 inches (2.34 by 2.15 meters), representing a surface area of about 56 square feet (5 square meters). The observatory wingspan, when the solar arrays are fully deployed, measures approximately 19.6 feet (6 meters) from tip to tip.

The 120 ampere/hour lithium-ion battery supplies power to the observatory during eclipses and whenever power consumption exceeds power generation from the solar array. The battery also provides power in the unlikely event the observatory goes into safe hold during the period where the solar arrays are not pointed toward the sun.

Communications Subsystem

The Communications Subsystem consists of three communication channels divided into two subsystems: telemetry and command uplink and downlink channels (S-band) and stored and real-time data downlink (X-band). Its main components are two S-band transceivers, four S-band omni antennas, two X-band transmitters, two X-band helix antennas and two X-band hybrid couplers. The Telemetry and Command Channels Subsystem provides communication between the mission platform and the ground segment to ensure that the spacecraft can be monitored and controlled during all its mission phases.

SAC-D uses a 4 kilobits per second S-band link for commanding and for real-time downlink of low-rate (8-second) housekeeping telemetry. SAC-D uses a 16 megabits-per-second X-band downlink exclusively for high-rate downlink of data, including science data, stored high-rate housekeeping telemetry, and stored low- rate housekeeping telemetry generated between S-band contacts and not sent in real time. Real-time telemetry only comes down via the S-band channel. The CONAE ground station near Cordoba, Argentina, is the mission's command and control center, and the primary data downlink station, providing both S-band and X-band capability. Backup S-band commanding and telemetry is available from NASA Ground Network and Malindi ground stations. The Matera ground station provides backup X-band data downlink.

The Downlink Data Science Subsystem provides communication between the mass memory unit and ground segment to ensure receipt of instrument data. It functions to transmit telemetry to the ground and receive telecommand signals transmitted from ground stations.

Propulsion Subsystem

Aquarius/SAC-D requires onboard propulsion to correct for errors in the observatory's initial orbital altitude and inclination after launch and to maintain the observatory in its proper orbit. It is also used at the end of the mission to perform a deorbit maneuver, which is necessary to avoid having the spacecraft remain in space for a period longer than 25 years once the mission is over.

The SAC-D propulsion subsystem is a monopropellant-type blowdown system, selected for its simplicity and reliability.

The observatory adjusts its orbit by firing any combination of its eight onboard thrusters, each of which each provides about 0.225 pound (1 Newton) force of thrust. The thrusters use ultra-high-purity monopropellant hydrazine, pressurized with nitrogen through an elastomer diaphragm. The propulsion system tank can carry up to 82 quarts (77.9 liters) of propellant.

Thermal Control Subsystem

The Thermal Control Subsystem maintains the SAC-D service platform and all its subsystems, components and equipment at proper temperatures. It uses a combination of active and passive components, including electrical heaters, radiator surfaces, temperature sensors, thermostats, thermal blankets, isolation products, doublers, thermal gaskets, and paints and coatings.

The observatory's science instruments are responsible for maintaining their respective instrument-operating temperatures.

Mass Memory Subsystem

The Aquarius/SAC-D Mass Memory Subsystem is a 256-megabyte storage unit whose main purpose is to store housekeeping data, command and data handling log files and GPS raw data generated by the observatory, as well as the science data generated by the Cosmic Radiation Effects and Orbital Debris and Micrometeoroids Detector (CARMEN) and Technology Demonstration Package instruments.

Data Acquisition and Processing Subsystem

The Data Acquisition and Processing Subsystem will provide part of the interface between the New Infrared Sensor Technology, Microwave Radiometer, Data Collection System and Radio Occultation Sounder for the Atmosphere instruments and the service platform. The memory storage requirement of these instruments will be satisfied by the subsystem's mass memory. The subsystem is redundant and composed of two identical electronic boxes that never operate at the same time.

Physical and Functional Redundancies

Although Aquarius is a single-string instrument, meaning that most instrument subsystems do not have backups, the SAC-D spacecraft is fully redundant.

Instruments

Aquarius/SAC-D will carry eight science instruments: the primary Aquarius instrument, developed by NASA; and seven SAC-D instruments, contributed by Argentina, Canada, France and Italy. Two of the SAC-D instruments will complement Aquarius science measurements.

Aquarius

Aquarius was jointly developed by NASA's Jet Propulsion Laboratory, Pasadena, Calif., and NASA's Goddard Space Flight Center, Greenbelt, Md. It will make NASA's first space-based measurements of salinity — the concentration of dissolved salts — in the top 0.4 inches (1 centimeter) of the ocean surface, orbiting Earth about every 98 minutes, mapping the entire open ocean every seven days for at least three years, and producing monthly maps of the surface salinity of the global ocean with a resolution of 93 miles (150 kilometers). Aquarius data will provide scientists with a key missing variable in satellite remote studies of Earth that will help them better understand the links between ocean circulation, the global cycling of freshwater and climate.

Aquarius will measure ocean surface salinity by observing natural thermal emissions from the ocean surface with an instrument called a radiometer. At frequencies near those used in microwave ovens, the level of signal emitted depends on the salinity of the ocean water, in addition to temperature. This energy, measured as an equivalent "brightness" temperature in kelvin, is directly correlated to ocean surface salinity. Other things being equal, salty water appears cooler than freshwater. The range of brightness temperatures Aquarius will measure is approximately 4 kelvin.

Over the open ocean, salinity varies over a narrow range, from about 32 to 37 on the Practical Salinity Scale, used to describe the concentration of dissolved salts in seawater. PSS is approximately equivalent to parts per thousand. An accuracy of about 0.2 PSS, or two parts in 10,000, is needed to achieve the Aquarius mission's science goals. This is equivalent to about one-eighth of a teaspoon of salt in a gallon of water.

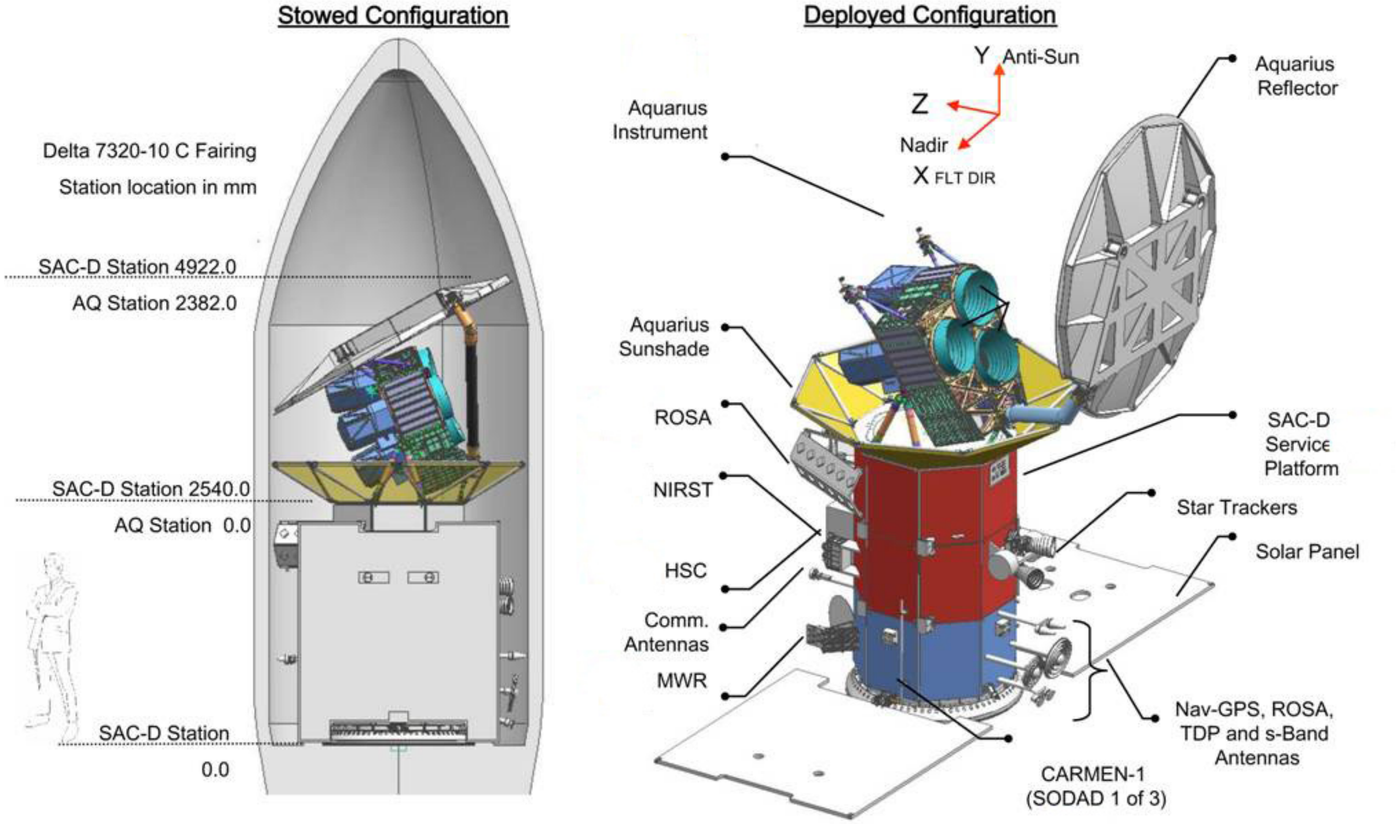
This level of accuracy corresponds to being able to detect changes in brightness temperature of about 0.1 kelvin, which is a challenging measurement for an Earth remote sensing instrument to make. The difference in the signal that comes from water with low salinity and water with high salinity is very small, and the environment of the signal is "noisy" — that is, it is affected by interference from many sources.

Among the sources of interference that Aquarius must correct for are the sun, galactic radiation, atmospheric gases, water vapor, rain, cloud liquid water, Faraday rotation (the interaction between polarized radio waves and Earth's magnetic field), the ionosphere, land, ice, temperature and the "roughness" of the ocean surface. Most geophysical errors will be corrected using the best data available during the mission from other satellites, numerical weather analyses and other available measurements or models.

Of these interference sources, ocean surface "roughness" (wind and waves) is the most significant, and can modify the emission and confuse the signal from salinity by several kelvin in high wind conditions. To correct for this, Aquarius has a built-in radar scatterometer, which will measure the effects caused by ocean waves. The scatterometer sends a radar pulse to the ocean surface that is reflected back to the spacecraft, with the strength of the echo proportional to the ocean surface roughness. Analyses performed using airborne and ship data have shown that without the simultaneous scatterometer corrections, ocean surface salinity measurement errors could be greater than 1 PSS.

The Aquarius science team will use a complicated mathematical formula known as a retrieval algorithm to translate brightness temperature data into measurements of salinity. The formula takes into account all the things that interfere with the salinity signal and eliminates their effect on the salinity measurement.

Aquarius' sensitivity is greater in low latitudes due to the effects of sea surface temperature. Sample density is greater in high latitudes due to orbital effects. To reduce errors, more samples will be averaged in higher latitudes to partially offset for the loss in sensitivity due to low sea surface temperatures.



Aquarius will achieve its highly accurate ocean surface salinity measurements through three primary methods: averaging co-located data sets, performing on-orbit calibrations, and maintaining thermal stability of the key instrument subsystems. Data averaging every seven days and every month will be a ground processing activity.

The design of Aquarius is based on more than 30 years of salinity remote sensing research. The underlying physics are well understood, the ocean surface salinity retrieval algorithms are developed and tested, and the technology has been tested in the open ocean with airborne radiometer demonstrations and extensive ground tests. The instrument design is based on existing, proven technologies integrated into a new application, and does not require any new technology development.

Aquarius will achieve a level of accuracy and stability that will be about 10 times better than anything done before for space-based observations of the ocean surface. The Aquarius instrument is extremely stable to ensure that variations in salinity are not caused by the instrument itself. Two primary elements in maintaining stability are adequate internal calibration and good temperature control.

Aquarius Components

The Aquarius instrument measures 12.5 feet by 9 feet by 12 feet (3.8 meters by 2.7 meters by 3.7 meters) with its antenna deployed, weighs 705 pounds (320 kilograms) and requires 314 watts of power on average. It consists of six subsystems: antenna, three radiometers, scatterometer, command and data handling, mechanical and thermal and power distribution.

Antenna

The Aquarius antenna is an 8.2-foot (2.5-meter)-diameter, solid, offset parabola reflector antenna, built by Alliant Techsystems, Minneapolis, Minn. Three 20-inch (50-centimeter)-diameter feed horns are arranged to form an equilateral triangle around a focus point, pointing across track at angles of 25.8, 33.8 and 40.3 degrees that point away from the sun to avoid solar contamination of the science measurement. The three beams do not point exactly across track — the inner and outer beams point slightly forward, and the middle beam points slightly aft.

The three beams scan the ocean surface in a mechanically stable "pushbroom" configuration with a combined total swath width of 242 miles (390 kilometers) that permits complete global coverage of the ocean every seven days and enough samples in a month to achieve the mission's salinity accuracy requirements. The footprint sizes of the three beams are 47 by 58 miles (76 by 94 kilometers), 52 by 75 miles (84 by 120 kilometers) and 60 by 97 miles (96 by 156 kilometers). The feed for each beam is shared by the Aquarius radiometers and scatterometer, which alternate operations so that the sensors look at the same piece of ocean nearly simultaneously. The reflector is deployed in two stages shortly after observatory separation using a constant rate spring and damper for each stage.

Radiometers

Connected to each of the three antenna feed horns is a cone-shaped, L-band microwave polarimetric radiometer to measure the brightness temperature of microwave emissions from the ocean surface with a center frequency of 1.413 gigahertz. The 1.413 gigahertz frequency was selected because of its sensitivity to salinity and because it is in a radio frequency band protected for scientific use for radio astronomy and Earth remote sensing, although stray signals from radar and other sources occasionally cause interference. Ocean surface salinity sensitivity is almost negligible at frequencies above 3 gigahertz, and at frequencies lower than 1.4 gigahertz, the larger required antenna size, ionospheric effects and radio frequency interference make the measurement impractical.

The Aquarius radiometers were built by NASA's Goddard Space Flight Center. Their design is based on research conducted under NASA's Instrument Incubator Program.

Scatterometer

The Aquarius L-band, polarimetric scatterometer provides information to correct for ocean surface roughness and shares the antenna with the radiometers. Built by NASA's Jet Propulsion Laboratory, it has a 232-mile (373-kilometer)-wide swath. It transmits in a protected 1260 megahertz frequency, has a 4 megahertz bandwidth, and makes 5.6 measurements per second in vertical and horizontal polarizations.

Instrument Control and Data System

The Aquarius instrument control and data system provides onboard storage and data processing for the instrument and interfaces with the SAC-D service platform, receiving all commands routed through the service platform's command and data handling subsystem. Aquarius uses the Rad6000 DRAM (volatile memory) to store science data. Of the total 128 megabytes of RAD6000 DRAM, 110 megabytes are allocated for storing Aquarius science packets, which include both science data and high-rate housekeeping telemetry data. The storage allocation represents enough space for approximately 15.8 hours of Aquarius science data.

Thermal

Aquarius achieves thermal stability by using four active thermal control regions, one for each of the ortho mode transducer assembly/radiometer front end radiators and one for the radiometer back end/scatterometer radiator.

The observatory's orbit provides a stable thermal environment, and reflected solar radiation is avoided by pointing the instrument away from the sun toward the shaded side of Earth.

Operational Modes

Aquarius has three operational modes. In observation mode, the instrument is on continuously, providing the most stable environment for its electronics. Standby mode will be used following launch and during in-flight events. In standby, all systems will be off except the command and data system. Survival mode is triggered by a spacecraft emergency and will turn instrument power off, with the exception of survival heaters.

Aquarius operational modes are largely independent of SAC-D service platform modes. However, if the demand for electrical current on the service platform becomes greater than the supply, Aquarius may be placed into either standby or survival mode. If there is an in-flight anomaly with the Aquarius instrument, there are a number of diagnostic sub-modes between standby and observation modes the Aquarius Operations team can implement. Aquarius plans to operate in observation mode during the majority of the mission.

Ground Control

The ground station in Cordoba, Argentina, is the primary ground station for Aquarius. In addition to the Cordoba ground station, the Italian Space Agency ground station in Matera, Italy, will augment X-band station coverage to avoid having station coverage gaps of greater than six hours. This second station minimizes the potential loss of data due to Cordoba station outages, bad weather or data downlink errors. On average, there are four passes per day planned over the Cordoba ground station.

Data Processing

Stored Aquarius science and ancillary data are routed from the ground station to the SAC-D Mission Operations Center in Cordoba. Once receiving the data, the Mission Operations Center then provides the data to the Aquarius Ground System at NASA's Goddard Space Flight Center, where it is processed into monthly ocean surface salinity maps and other science data products.

SAC-D Instrument Suite

The SAC-D instruments have the following multiple objectives:

- Measurement of rain rates, surface wind speeds, water vapor and cloud liquid water over the ocean, which will enhance the results of the Aquarius measurements
- Measurement of the physical parameters of high-temperature events on the ground caused by biomass fires and volcanic eruptions
- Measurement of sea surface temperature
- Measurement of the temperature and humidity profile of the troposphere and stratosphere
- Measurement of sea ice concentration
- Measurement of lighting and light intensity over urban areas, as well as polar auroras
- Receipt and storage of meteorological and environmental data generated by ground-based measurement systems for later transmission to the Cordoba Ground Station and distribution to the user community
- Validation of a newly developed GPS receiver for position, velocity and time determination and an inertial reference unit to measure intertial angular velocity
- Detection of micrometeoroids and orbital debris to understand how they cause space damage and evaluate orbital debris and its evolution

Microwave Radiometer

The SAC-D Microwave Radiometer is provided by CONAE and was built by IAR, Argentina's Institute of Radio Astronomy, located near Villa Elisa, in the Buenos Aires province. The Microwave Radiometer will contribute to climate and hydrological forecasting by measuring rain, wind speed, cloud liquid water vapor and sea ice concentration in a swath pattern that overlaps that of Aquarius. Its data will complement and enhance the accuracy of Aquarius data. It measures surface brightness temperature. It consists of two radiometers: one at 23.8 gigahertz (K-band) and a second, polarimetric one at 36.5 gigahertz (Ka-band). Each radiometer consists of an antenna (a reflector and eight feed horns arranged in a pushbroom configuration), providing a swath width of about 236 miles (380 kilometers), a resolution of approximately 29 miles (47 kilometers) and a sensitivity of 0.5 kelvin. It points its footprints at the same swath as the Aquarius instrument at incidence angles between 52 and 58 degrees and views toward the night side of the orbit to avoid unwanted effects of solar reflections. The 36.5 gigahertz radiometer receiver has two reception channels for the two polarizations, H and V. The 23.8 gigahertz radiometer consists of one simple receiver that acquires the V polarization.

New Infrared Sensor Technology

The SAC-D New Infrared Sensor Technology instrument was developed by CONAE in collaboration with the Canadian Space Agency. It is a narrow-swath infrared imager that will detect forest fires and other thermal events on land and will also measure sea surface temperatures over selected targets to support Aquarius instrument corrections. NIRST will measure forest fires with enough accuracy and resolution to determine characteristics of the fires, such as temperature and released energy.

NIRST has two linear microbolometric arrays that are sensitive to the mid-wave infrared and long-wave infrared spectral bands, respectively. Both sensors simultaneously scan the same ground area with the two spectral bands to measure fire characteristics in the thermal range between 300 and 700 kelvin. In addition, the longwave infrared array detects waves in two different spectral bands centered at 10.85 and 11.85 microns, respectively, to make sea surface temperature measurements in the thermal range from 250 to 500 kelvin.

NIRST has a swath width of 113 miles (182 kilometers) and a resolution of 1,148 feet, or 350 meters (when pointing straight down to the ground). To widen its scanning possibilities so it can observe targets of interest, NIRST can be tilted by plus or minus 30 degrees, providing an equivalent swath width of 584 miles (940 kilometers).

High Sensitivity Camera

The SAC-D High Sensitivity Camera is provided by CONAE. It will make nighttime images of urban light intensities, volcanic eruptions, lightning storms, fires and polar auroras. The camera will operate in real-time over Argentina, and in stored mode over other targets around the world.

The camera is based on time-delay integration charge-coupled device technology. It points straight down to the ground and measures radiance at the top of the atmosphere in the visible range of the electromagnetic spectrum, from 450 to 610 nanometers. It collects data in darkness to avoid sensor saturation from sunlight reflection and atmospheric scattering effects.

The camera has electro optical and electronics components. The electro optical component consists of two cameras with independent optical systems, each with a field of view of 36.8 degrees and an angle between system optical axes of 35 degrees. The total resulting field of view is 71.8 degrees with a small overlap of 1.82 degrees in the center. The center of the total field of view points straight down to the ground and has a resolution of 656 feet (200 meters). The electronics component provides timing and control signals to the electro optical component, receives commands from the service platform and transmits science data and housekeeping data to the service platform. It has a science data storage capability of 96 megabytes.

Cosmic Radiation Effects and Orbital Debris and Micrometeoroids Detector CARMEN-1 (ICARE-NG and SODAD) CNES

The Cosmic Radiation Effects and Orbital Debris and Micrometeoroids Detector (CARMEN) payload is provided by the French Space Agency (Centre National d'Etudes Spatiales, or CNES) and consists of the ICARE instrument and three SODAD detectors.

ICARE's SPECTRE module will measure the flux of radiation in the space environment. It has three independent measurement channels with solid-state silicon detectors that are sensitive to various particles such as electrons, protons and heavy ions. ICARE also includes an independent subsystem called EXPERIENCE that will study the effect of cosmic radiation on various electronics components.

SODAD will detect micrometeoroids and orbital debris in space. It has four sensors.

Radio Occultation Sounder for the Atmosphere

The Radio Occultation Sounder for the Atmosphere (ROSA) was provided by the Italian Space Agency (Agenzia Spaziale Italiana, or ASI). It will measure atmospheric temperature and humidity profiles by measuring the bending of radio signals from the U.S. global positioning system as the signals pass through Earth's atmosphere, a technology known as radio occultation. It consists of an integrated GPS receiver that will collect accurate Doppler measurements at both 1575 megahertz and 1226 megahertz GPS frequencies. The GPS signals are acquired through a navigation antenna and two sounding (radio occultation) antennae. The data are stored onboard and transmitted later to the ground for processing and use in atmospheric research.

Data Collection System

The Data Collection System instrument on SAC-D, provided by CONAE, receives and stores environmental data transmitted by hundreds of data collection platforms on or near the ground and is equipped with environmental sensors. It will be used as an environmental monitoring system following emergencies and natural or human-caused disasters, provide data for aquifer management, acquire rain and humidity data for agricultural use, and detect the presence of pollutants in the lower atmosphere.

The Data Collection System is highly reliable, uses low power and is low maintenance. The instrument is composed of a receiver and signal processing unit, UHF receiving antenna, harness and structural fittings set. It has a transmitting frequency of 401.55 megahertz (UHF). It transmits information without needing to know the satellite's position or accurate time. Its receiver tries to recover the information and, if successful, stores it onboard. The recovered data are then downloaded to a ground station for preprocessing and further distribution to users.

Technology Demonstration Package

The Technology Demonstration Package, provided by CONAE, is a prototype of a combined inertial reference unit to measure the spacecraft's tri-axial inertial angular rate and a GPS receiver to provide spacecraft position, velocity and time data. Its objective is to demonstrate in-flight performance of both sensors and to provide baseline sensors for future CONAE missions.

It consists of a fiber optics package, Technology Demonstration Package electronic box and GPS receiver antenna support and antenna.

Program/Project Management

Aquarius is jointly managed for NASA's Science Mission Directorate, Washington, by NASA's Jet Propulsion Laboratory, Pasadena, Calif., and NASA's Goddard Space Flight Center, Greenbelt, Md. JPL managed Aquarius development and will manage Aquarius through the mission's commissioning phase. Goddard will manage the mission following the commissioning phase.

At NASA Headquarters, Edward Weiler is the associate administrator for the Science Mission Directorate, and Charles J. Gay is deputy associate administrator. Mike Freilich is the Earth Science division director within the Science Mission Directorate. Jack Kaye is associate director for research within the Earth Science division. Stephen Volz is the associate director for flight programs within the Science Mission Directorate. Eric Ianson is the Aquarius program executive. Eric Lindstrom is the Aquarius program scientist.

The Aquarius mission is led by principal investigator Gary Lagerloef of Earth & Space Research, a scientific institution based in Seattle. David Le Vine of NASA's Goddard Space Flight Center is the deputy principal investigator. Yi Chao of JPL is the mission's project scientist.

At JPL, Amit Sen is the Aquarius project manager through the mission's commissioning phase, and Yuhsyen Shen is the Aquarius deputy project manager. The California Institute of Technology in Pasadena, Calif., manages JPL for NASA.

At Goddard, Gene Feldman is the Aquarius ground system and mission operations manager and will become the Aquarius project manager following the mission's commissioning phase.

At CONAE, Conrado Varotto is CONAE's executive director, while Daniel Caruso is the SAC-D project manager and Sandra Torrusio is the SAC-D principal investigator.

At NASA's Langley Research Center, Frank Peri is the NASA Earth System Science Pathfinder Office program manager.

At NASA's Kennedy Space Center, the NASA Launch Services Program is responsible for government oversight of launch vehicle preparations at Vandenberg; the engineering, certification and testing of the Delta II 7320-10C launch vehicle; spacecraft ground support and integration with the Delta II 7320-10C; the Space Launch Complex 2 West pad facilities; countdown management; launch vehicle tracking; data acquisition; and telemetry monitoring.