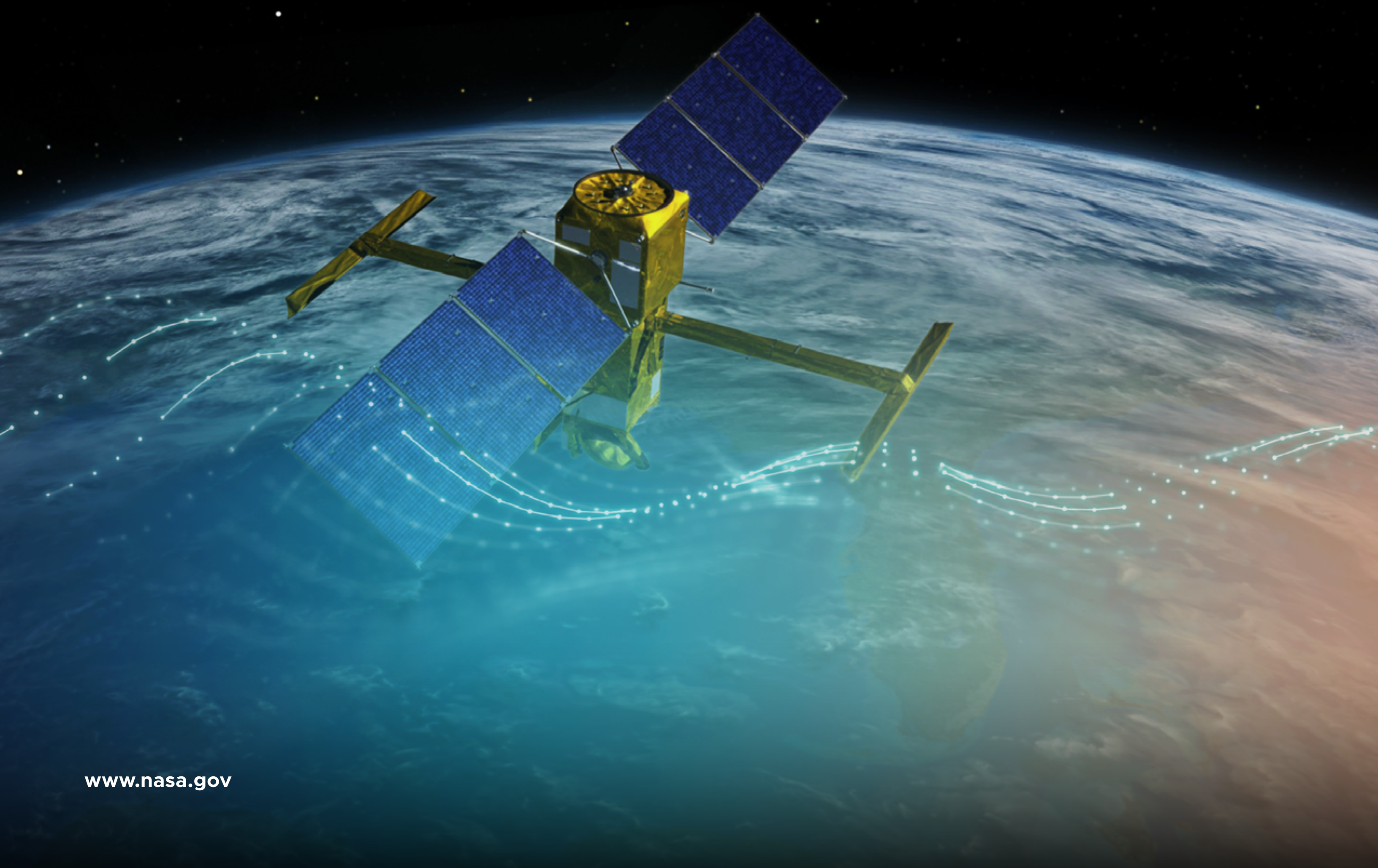
National Aeronautics and Space Administration

SWOT

Surface Water and Ocean Topography

Press Kit / November 2022



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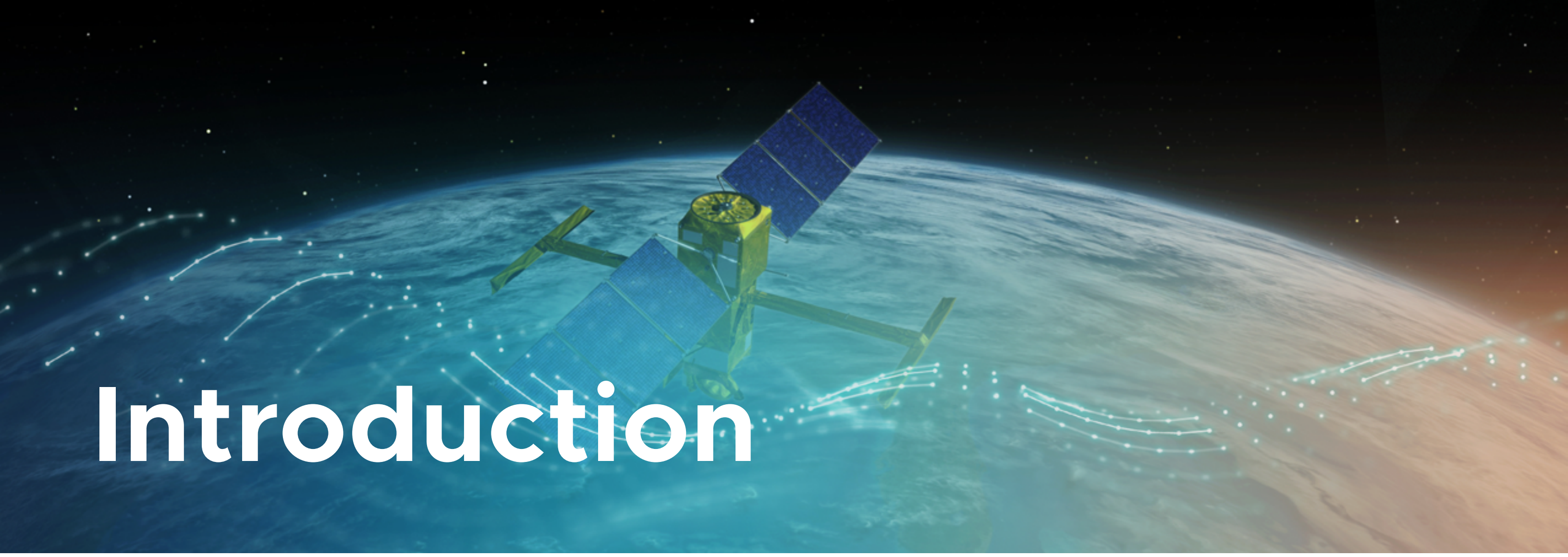


Introduction

SWOT Press Kit

The U.S.-European Surface Water and Ocean Topography (SWOT) mission to study our home planet is targeting a **December 2022** launch from Vandenberg Space Force Base in Central California. The SUV-size satellite will help researchers understand how much water flows into and out of Earth's freshwater bodies and will provide insight into the ocean's role in how climate change unfolds.

The measurements from the spacecraft's science instruments will also help communities monitor and plan for changing water resources as well as the effects of sea level rise. SWOT is a joint mission developed by NASA and the French space agency Centre National d'Études Spatiales (CNES), with contributions from the Canadian Space Agency and the UK Space Agency.

6 Things To Know About SWOT

Earth's climate is changing. NASA currently operates over two dozen Earth-observing spacecraft or space-borne instruments to study those changes, giving scientists multiple tools to analyze everything from the ocean to clouds to ice to atmospheric chemistry. The information these instruments produce can, in turn, provide invaluable insights to resource managers, decision-makers, industry, and others.

What will the upcoming U.S.-European SWOT mission enable scientists to learn that they haven't been able to before? What makes this mission significant? Here are six key details about SWOT that help answer those questions:

1. SWOT will survey nearly all water on Earth's surface for the first time.

SWOT is the first satellite mission that will observe nearly all water on the planet's surface. It will measure the height of water in Earth's lakes, rivers, reservoirs, and the ocean, giving scientists the ability to track the movement of water around the world.

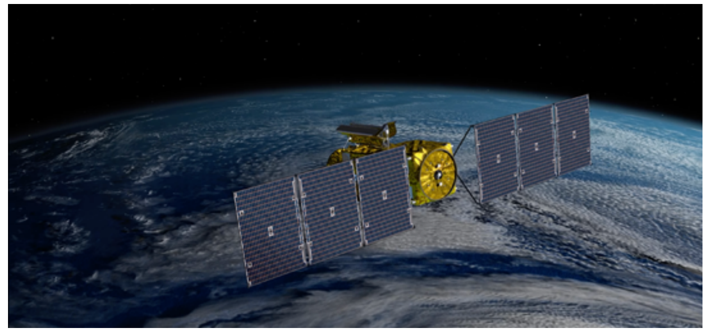


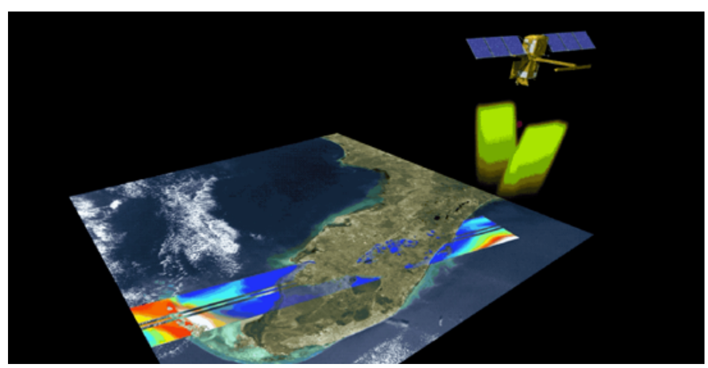
Image from Mission overview video about the international SWOT mission. Credit: NASA/JPL-Caltech/CNES/Thales Alenia Space

Water is essential for life on this planet. But it also plays a critical role in storing and moving Earth's heat and carbon, and influences the planet's weather and climate. Tracking Earth's water budget – where the water is today, where it's coming from, and where it's going to be tomorrow – is critical to understanding how the planet's water resources are changing and the impact those changes have on the local environment.

SWOT's eye in the sky will provide a truly global view of Earth's surface water, enriching humankind's understanding of how the ocean reacts to and influences climate change along with what potential hazards – including floods – lay ahead in different regions of the world.

2. SWOT will see Earth's water in higher definition than ever before.

SWOT will view Earth's oceans and surface water on land with unprecedented clarity compared to other satellites, much like a high-definition television delivers a picture far more detailed than older models. This means that SWOT will be able to "see" such ocean features as fronts and eddies that are too small for current space-based instruments to detect, which will help improve researchers' understanding of the ocean's role in climate change.



This Image shows how SWOT will collect data over the state of Florida, which is rich with rivers, lakes, and wetlands. Globally, SWOT will measure the height of water in the ocean and in lakes, rivers, and reservoirs on land. Credit: NASA/JPL-Caltech

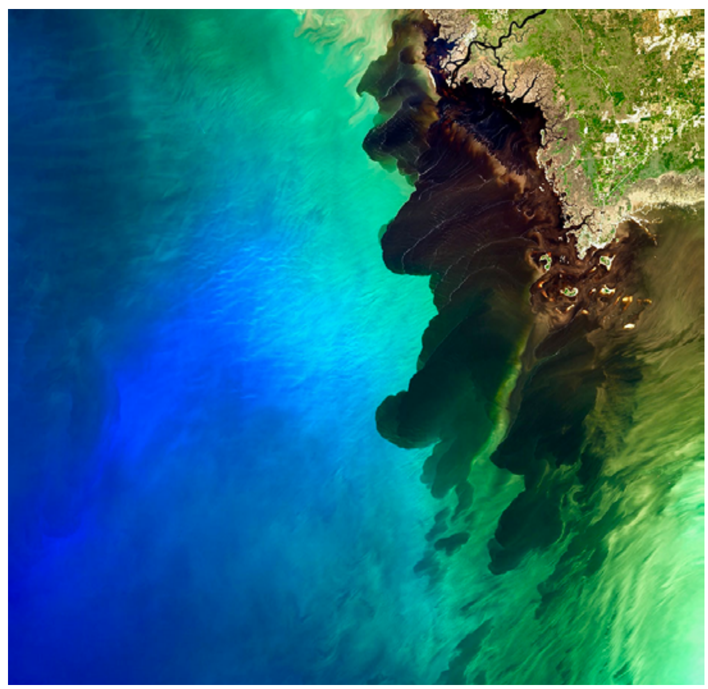
Earth's seas have absorbed more than 90% of the excess heat trapped in our atmosphere by human-caused greenhouse gas emissions. Researchers think that a lot of that heat – and the extra carbon dioxide and methane that produced it – is absorbed at short-lived ocean features, like fronts and eddies (in this case, eddies less than 60 miles, or 100 kilometers, across). Fronts are where water masses with different characteristics (such as temperature or density) collide, and eddies are circular currents. SWOT will be able to collect data on these ocean features, bringing the blurry picture of Earth's ocean into focus. Not only will the satellite show where – and how fast – sea level is rising, it will also reveal how coastlines around the world are changing.

The SWOT satellite will provide similar high-definition clarity for Earth's lakes, rivers, and reservoirs. Many big rivers remain a mystery to researchers, who are unable to outfit the water bodies with monitoring instruments for various reasons, including inaccessibility. SWOT will observe the entire length of nearly all rivers wider than 330 feet (100 meters). Likewise, where ground and satellite technologies currently provide data on only a few thousand of the largest lakes worldwide, SWOT will expand that number to over a million lakes the size of three New York City blocks (about 15 acres, or 62,500 square meters) or larger.

3. SWOT will address some of the most pressing climate change questions of our time.

An important part of predicting our future climate is determining at what point Earth's ocean stops absorbing heat and starts releasing it back into the atmosphere, where it could accelerate global warming. SWOT will provide crucial information about this global heat exchange between the ocean and the atmosphere, enabling researchers to test and improve future climate forecasts.

Climate change is also accelerating Earth's water cycle, leading to more volatile precipitation patterns, including torrential downpours and extreme droughts. That volatility can make it hard for communities to manage their water resources. The data that SWOT provides will enable scientists, engineers, water managers, and



In this image from the NASA-U.S. Geological Survey Landsat 8 satellite, the dark-brown waters of the Suwannee River meet the blue-green Gulf of Mexico along Florida's Big Bend (where the state's panhandle curves to meet its peninsula). Credit: NASA/USGS/A. Alonso others to better determine whether a region is drying out or getting wetter, and it will enable them to measure how much water flows through these areas.

Another effect of Earth's changing climate: Sea level around the world is rising slightly faster every year. However, understanding exactly how sea level is changing along coastlines – and what the future impact of those changes will be – is difficult due to gaps in the observations from current space- and Earth-based science instruments. SWOT will fill in these blank spots, offering insights into coastal sea levels that can then be used to improve computer models for sea level rise projections and coastal flood forecasting.

4. SWOT data will be used to inform decisions about our daily lives and livelihoods.

As climate change accelerates the water cycle, more communities around the world will be inundated with water while others won't have enough. SWOT data will be used to monitor drought conditions and improve flood forecasts, providing essential information to water management agencies, disaster preparedness agencies, universities, civil engineers, and others who need to track water in their local areas. SWOT data will also help industries, like shipping, by providing measurements of water levels along rivers, as well as ocean conditions, including tides, currents, and storm surges.

Image from video that shows how the SWOT mission will help communities plan for a better future by surveying the planet's salt and freshwater bodies. Credit: NASA/JPL-Caltech/CNES/Thales Alenia Space

5. SWOT builds on a long-standing international partnership and reflects NASA's commitment to working with other agencies to observe Earth and its climate.

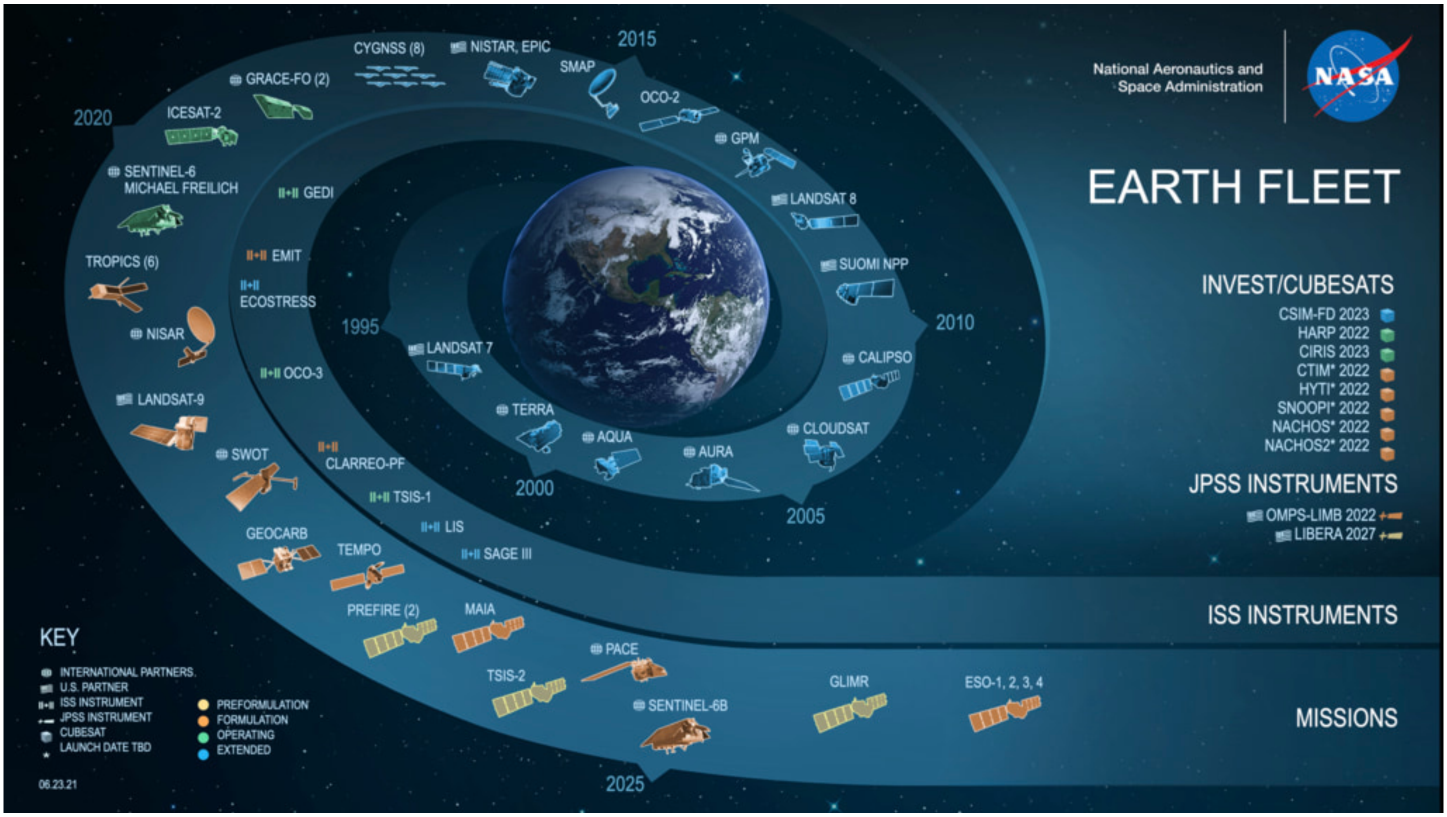
NASA and the French space agency Centre National d'Études Spatiales (CNES), the two agencies leading the development of SWOT, are building upon collaborations that started in the 1980s to monitor Earth's ocean. This partnership, with Thales Alenia Space as a major industry partner, pioneered the use of a space-based instrument called an altimeter to study sea level with the launch of the TOPEX/Poseidon satellite in 1992. The NASA-CNES partnership has continued uninterrupted for three decades, demonstrating a lasting international commitment to studying our home planet. It eventually expanded to encompass several other partners, including the Canadian Space Agency and the UK Space Agency for SWOT, and ESA (the European Space Agency) for the Sentinel-6 Michael Freilich satellite, which launched in November 2020.

SWOT team members from NASA's Jet Propulsion Laboratory, the French space agency Centre National d'Études Spatiales (CNES), and Thales Alenia Space examine the spacecraft during its assembly in Cannes, France. Credit: CNES/Thales Alenia Space

With SWOT, NASA and CNES are taking satellite altimetry to a new level through their collaboration on the Ka-band Radar Interferometer (KaRIn) instrument. KaRIn is a radar instrument that will observe Earth in more detail than any previous altimeter, allowing scientists to see many features on land and in the ocean that are too small for current instruments to measure from space.

6. SWOT is paving the way for future NASA Earth missions.

With its innovative technology and commitment to engaging a diverse community of people who plan to use data from the mission, SWOT is blazing a trail for future Earth-observing missions. Thanks to the ingenuity and dedication of NASA and CNES engineers, the pioneering the KaRIn instrument will provide unprecedented detail on the world's ocean, lakes, rivers, and reservoirs. SWOT's data and the tools to support researchers in analyzing the information will be free and accessible. This will help to foster research and applications activities by a wide range of users, including scientists, resource managers, and others who may not usually have the opportunity to access this knowledge. Lessons learned from SWOT will lead to new questions and improvements for future missions, including NASA's upcoming Earth System Observatory, a constellation of missions focused on studying key aspects of our home planet.



This graphic shows NASA's Earth science missions, including spacecraft currently flying and others in formulation. Credit: NASA

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Products and Events

News Releases, Features, Advisories, Blogs, and Status Reports

Mission news, updates, and feature stories about the SWOT mission will be available at swot.jpl.nasa.gov.

Progress reports on SWOT's road to launch, including the latest updates on launch dates, can be found on the NASA blog for this mission: blogs.nasa.gov/swot.

Interviews with SWOT mission team members may be arranged by calling the JPL newsroom at **818-354-5011** or filling out this form at bit.ly/jpl-media-form.

Video and Images

A SWOT mission media reel is available at the go.nasa.gov/SWOTpresskit.

A playlist of SWOT videos is also available in JPL's YouTube Channel at bit.ly/SWOTYouTubePlaylist.

Additional images related to the SWOT mission are available in the NASA Image and Video Library at go.nasa.gov/SWOTmultimedia, in Planetary Photojournal at go.nasa.gov/3WRPLzB, and the gallery section of this press kit.

Read NASA's image use policy at nasa.gov/multimedia/guidelines/index.html.

Read JPL's image use policy at jpl.nasa.gov/jpl-image-use-policy.

Media Events

A news conference presenting an overview of the mission will take place roughly 30 days ahead of launch.

A pre-launch news conference and a science news conference open to accredited news media will take place at Vandenberg Space Force Base (VSFB) in Central California in the days before launch. Additional briefings and media availabilities at VVSFB are also expected in that time period.

All news briefings will be broadcast and livestreamed.

How to Watch

News briefings and launch commentary will be livestreamed on NASA Television, the agency's website nasa.gov/live, YouTube.com/NASA, Youtube.com/NASAJPL, and the NASA app at nasa.gov/connect/apps.html. (On-demand recordings will also be available after the live events have finished on YouTube.)

NASA TV channels are digital C-band signals carried by 8PSK/DVB-S2 modulation on satellite Galaxy-13, transponder 15, at 127 degrees west longitude, with a downlink frequency of 4009 MHz, vertical polarization, data rate of 36.225 Mbps, symbol rate of 15 Mbps and 5/6 FEC. A digital video broadcast-compliant integrated receiver decoder is needed for reception. For more information about NASA TV's programming schedule, visit nasa.gov/ntv.

Audio Only

Audio only of launch coverage will be carried on the NASA "V" circuits, which may be accessed by dialing 321-867-1220, -1240, -1260 or -7135. On launch day, "mission audio" – the launch conductor's countdown activities without NASA TV launch commentary – will be carried on 321-867-7135.

Live Launch Feed

A live video feed of key launch activities and commentary from mission control at VSFB will be broadcast. The first launch opportunity is targeted for no earlier than Dec. 12, 2022

On-Site Media Logistics

Media accreditation for on-site access closed on Oct 27. Accredited media will have access to VSFB for launch and pre-launch activities related to the SWOT mission. Closer to launch, NASA will release an events-and-briefings advisory with additional information.

Accredited news media can arrange on-site interviews by emailing Jane Lee at jane.j.lee@jpl.nasa.gov or Andrew Wang at andrew.wang@jpl.nasa.gov. Media without credentials can call the JPL newsroom at 818-354-5011 to see if off-site interviews can be arranged.

News briefings and launch commentary will also be streamed on NASA TV, online, and the agency's app. Go to the How to Watch section of the press kit.

Additional Resources on the Web

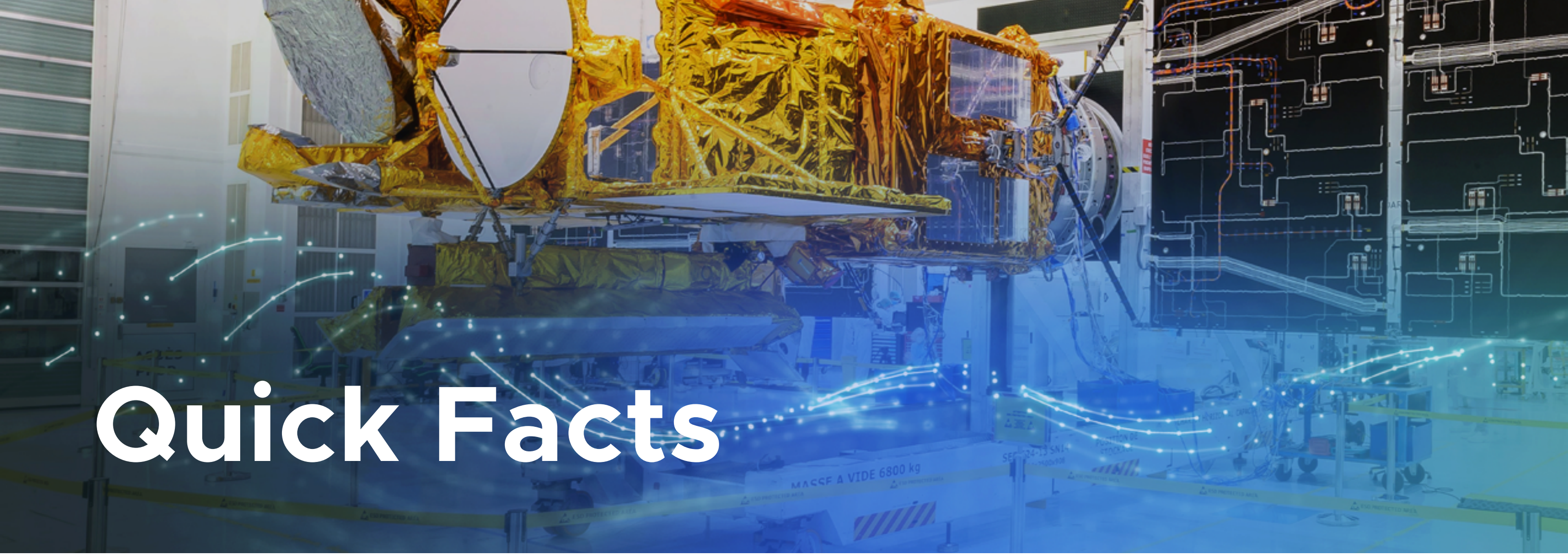
A web version of this press kit is available at jpl.nasa.gov/press-kits/swot/.

Find additional information about the mission at swot.jpl.nasa.gov/

Social Media

Join the conversation! Use the hashtag #TrackingWorldWater to find SWOT content and get updates from these accounts:

- **Twitter:** @NASAEarth, @NASAClimate, @NASAJPL, @NASA_LSP, @NASA
- **Facebook:** NASAEarth, NASA Climate Change, NASAJPL, NASALSP, and NASA
- **Instagram:** @NASAEarth, @NASAClimatechange, @NASAJPL, and @NASA



Quick Facts

Mission Name

Surface Water and Ocean Topography (SWOT)

Spacecraft

Dimensions

- **Height of spacecraft bus and payload:** 16.4 feet (5 meters)
- **Solar panels:** 48.8 feet (14.875 meters) in length, with an area of 335 square feet (31 square meters)
- **Boom length between Ka-band Radar Interferometer (KaRIn) antennas:** 33 feet (10 meters)
- **Spacecraft launch mass, including onboard propellant:** approximately 4,850 pounds (2,200 kilograms)

SWOT team members attach the science payload to the main body of the spacecraft in a clean room at Thales Alenia Space in Cannes, France. Credit: CNES/ Thales Alenia Space

Payload Science Instruments

KaRIn; nadir altimeter; microwave radiometer; X-band system; precise orbit determination package that includes the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) instrument, the laser reflector array (LRA), and the global positioning system (GPS) receiver.

Power

Two deployable motorized solar arrays provide 8 kilowatts; the spacecraft has a 1.5-kilowatt total power demand.

Battery

32-amp-hour battery

Propulsion

Eight 4.95-pound-force (22 newton) hydrazine thrusters

Mission

Launch Date

No earlier than Dec.12, 2022

Launch Site

Space Launch Complex 4E at Vandenberg Space Force Base in Central California

Launch Vehicle

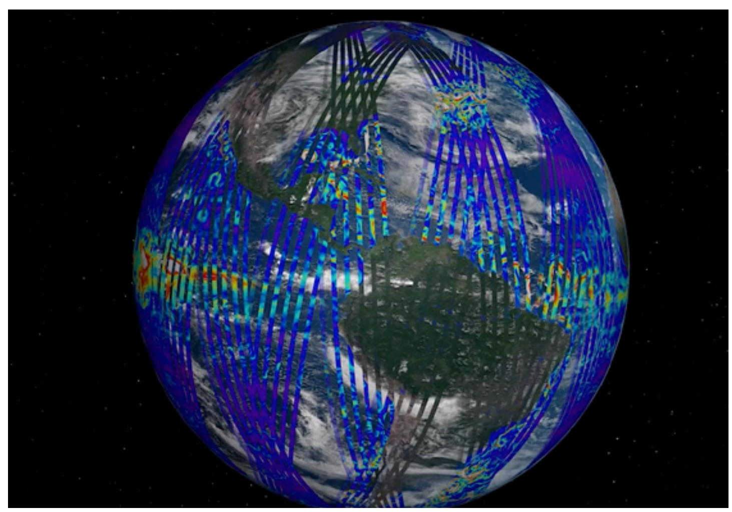
SpaceX Falcon 9 rocket

Prime Mission Duration

Three years

Coverage of Earth

SWOT will cover the entire surface of Earth between 78 degrees south and 78 degrees north latitude in 21 days.



This illustration shows how the SWOT spacecraft will collect data in crisscrossing paths around Earth. Credit: NASA/JPL-Caltech

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Program

International Collaboration

SWOT was jointly developed by NASA and Centre National d'Études Spatiales (CNES), with contributions from the Canadian Space Agency (CSA) and the UK Space Agency. For the flight system payload, NASA is providing the KaRIn instrument, a GPS science receiver, a laser retroreflector, a two-beam microwave radiometer, and NASA instrument operations. CNES is providing the DORIS system, the nadir altimeter, the radio-frequency subsystem that supports KaRIn (together with the UK Space Agency, which contributed a high-power switching subsystem), the satellite platform, and the ground-control segment. The CSA is providing a key part of the KaRIn high-power transmitter assembly. NASA is also providing the launch vehicle and associated launch services.

Budget

- **NASA investment:** $822.4 million
- **CNES investment:** 340 million euros (not including operations after launch)
- **UK Space Agency Investment:** £12.22 million
- **CSA investment:** CA$15.4 million

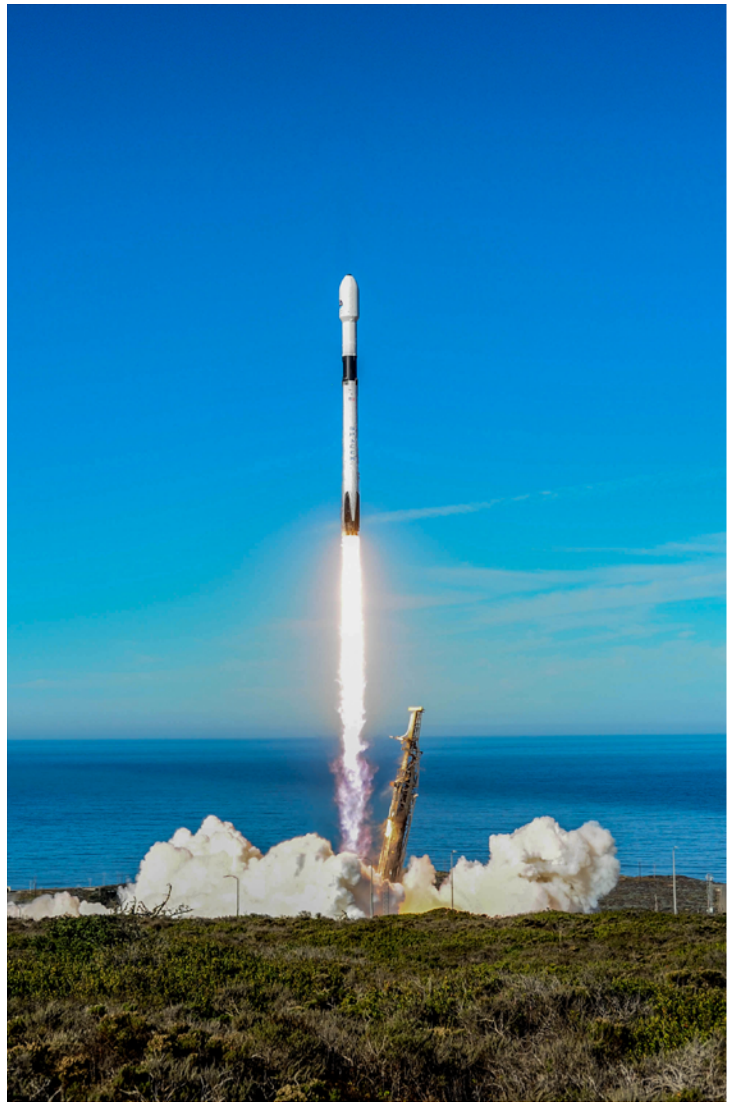
Mission: Overview

The Surface Water and Ocean Topography (SWOT) mission will survey Earth's salt- and freshwater bodies, measuring the height of the water in lakes, rivers, reservoirs, and the ocean. The satellite will cover the planet's surface at least once every 21 days and has a prime mission of three years.

The information on the ocean that SWOT gathers will help researchers better understand how seawater absorbs atmospheric heat and carbon, a process that affects global temperatures and climate change. The satellite's ability to resolve ocean features less than 60 miles (100 kilometers) across – smaller than previous sea level satellites have observed – will also enable it to collect data close to the coast. These measurements will help give researchers a clearer picture of coastal sea level and, ultimately, how sea surface height will interact with a changing climate to affect things like storm surges and coastal flooding.

SWOT will also provide the first comprehensive global survey of freshwater lakes, rivers, and reservoirs from space. The satellite will measure their surface area, or extent, as well as their height. By helping track changes in water volume over time, the data will better equip scientists and water resource managers to monitor how much water flows into and out of the planet's freshwater bodies.

Launch



The U.S.-European Sentinel-6 Michael Freilich spacecraft launched from Vandenberg Space Force Base's Space Launch Complex 4E on a SpaceX Falcon 9 rocket, as will SWOT. Credit: USAF 30th Space Wing/A. Men

Launch Site and Vehicle

The SWOT satellite will launch aboard a SpaceX Falcon 9 rocket, procured by NASA's Launch Services Program. It will lift off from Space Launch Complex 4E (SLC-4E) at Vandenberg Space Force Base (VSFB) in Central California.

Launch Timing

The SWOT spacecraft will be launched no earlier than 6:46 a.m. EST (3:46 a.m. PST) on Dec.12, 2022. The launch date is based on the readiness of the satellite, the Falcon 9 launch vehicle, and the Western Test Range at VSFB. The launch window is instantaneous and will be the same for subsequent days.

Key Events after Launch

These targeted milestones are accurate as of November 2022 but may change if the launch date changes.

- **2 minutes and 15 seconds after launch:** Main engine cutoff (MECO), stage separation, and then second-engine start 1 (SES1) will occur in quick succession. The reusable Falcon 9 first stage will then begin its automated return to the launch site for a powered landing.
- **2 minutes and 59 seconds:** After protecting the satellite as the rocket traveled through the atmosphere, the launch vehicle's nose cone will separate and be jettisoned.
- **8 minutes and 24 seconds:** Stage-II engine cutoff (SECO1) will take place, putting the launch vehicle and spacecraft in a parking orbit.
- **42 minutes and 52 seconds:** Stage-II first restart (SES2) will occur with a 5-second burn, followed by stage-II engine cutoff (SECO2).

- **51 minutes and 59 seconds:** The launch vehicle and spacecraft will separate.
- **About 58 minutes:** The spacecraft may make its first (very short) potential partial contact (no engineering data on spacecraft health) with ground stations in South Africa.
- **1 hour and 18 minutes:** The spacecraft expected to make its first full ground contact, providing first data on spacecraft health, with ground stations in Sweden and Canada.

Orbital Operations

The spacecraft will be launched into a non-Sun synchronous orbit with an inclination of 78 degrees. SWOT will orbit at an altitude of 553 miles (890 kilometers) and make 14 orbits per day. The spacecraft will send back about one terabyte of unprocessed data per day and has a prime mission of three years.

This illustration shows the SWOT spacecraft flying over Earth. Credit: NASA/JPL-Caltech

Mission: Science

Overall Science Goals and Objectives

1. Provide a global inventory of water resources.
2. Understand where the water is, where it's coming from, and where it's going.
3. Observe the fine details of the ocean's surface topography.
4. Improve understanding of the ocean's role in climate change.
5. Measure ocean conditions near coastlines.

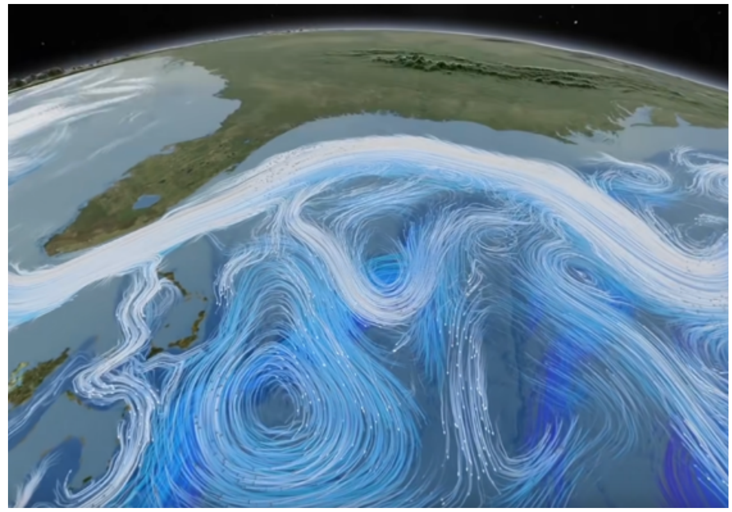
Ocean Measurements

Sunlight reflects off the North Atlantic Ocean in an area to the east of the Bahamas Islands sometimes called the Sargasso Sea in a photograph taken from the Space Shuttle Columbia. Credit: NASA

SWOT will measure sea surface height, or the ocean's surface topography. This will enable scientists to study currents and eddies less than 60 miles (100 kilometers) across – up to 10 times smaller than has been previously detectable with other sea level satellites.

SWOT's ability to "see" smaller areas of Earth's surface will also enable it to fill in observational gaps along coastlines. The spacecraft will collect more precise data than other satellites can along coastlines, where sea level rise can directly impact communities and coastal ecosystems. For example, SWOT will help researchers better understand how rising seas will affect things like storm surges and coastal flooding.

Observing the ocean at these smaller scales will also help researchers assess its role in moderating climate change. Earth's ocean has absorbed more than 90% of the excess heat trapped by human-caused greenhouse gas emissions. Most of the uptake of that heat is thought to occur via currents and eddies less than 60 miles (100 kilometers) across. Gaining greater insight into this process could be key to figuring out whether there's a limit to the ocean's ability to absorb the heat trapped by the carbon and methane emissions from human activities.



This image from an animation visualizes how the ocean absorbs greenhouse gases from the atmosphere. Credit: NASA

Freshwater Measurements

SWOT will produce the world's first comprehensive global survey of Earth's freshwater from space, providing data on more than 95% of the world's lakes larger than 15 acres (62,500 square meters) and rivers wider than 330 feet (100 meters) across. As of now, researchers have reliable measurements of water levels for only a few thousand lakes worldwide and little to no data on some important river systems like that of the Koyukuk River in Alaska. Its network of smaller rivers and tributaries drains an area roughly the size of Kansas.

SWOT will measure the height of water in lakes, rivers, and reservoirs, as well as the surface area, or extent, of that water. Using this information, scientists will be able to calculate how much water moves through those freshwater bodies as climate change accelerates Earth's water cycle. Warmer temperatures mean that the atmosphere can hold more water (in the form of water vapor), which can result in things like volatile precipitation patterns – torrential downpours rather than a steady, gentle rain, for example. Such variability can, in turn, wreak havoc on a community's ability to manage its water resources effectively.

SWOT will also help with tracking changes in water volume over time. Satellites already in orbit can measure the height of water – in the ocean, very large lakes, or very wide rivers, for example – or the surface area of a water body. But to calculate changes in volume over time, scientists need to match up extent and height measurements that may have been collected by different instruments on different days and at

An aerial view of the tundra and Koyukuk River in Alaska, one of the waterways SWOT will be able to measure in greater detail. Credit: U.S. Fish and Wildlife Service/B. Raften

different times. This makes it difficult to know basic information, such as how much water flows through the world's rivers and how much that volume varies. SWOT will eliminate the need to cobble together the extent and height information from different sources and at the same time give researchers a global view of Earth's surface water.

Community Impact

By advancing research into Earth's ocean and freshwater bodies, SWOT will aid communities around the world. Scientists, policymakers, and resource managers will be able to apply SWOT data to challenges, including flood projections, drought monitoring, and assessing how climate change may impact coastal communities and ecosystems.

For example, currently, water levels during a flood are measured after the fact using what are called wrack marks – debris indicating what is often considered the high-water mark during a flood. But wrack marks don't convey how water levels varied during a flood. If SWOT is overhead during such an event, the satellite could capture water levels at particular locations and times, and could contribute to improved flood-forecasting systems in flood-prone river basins.

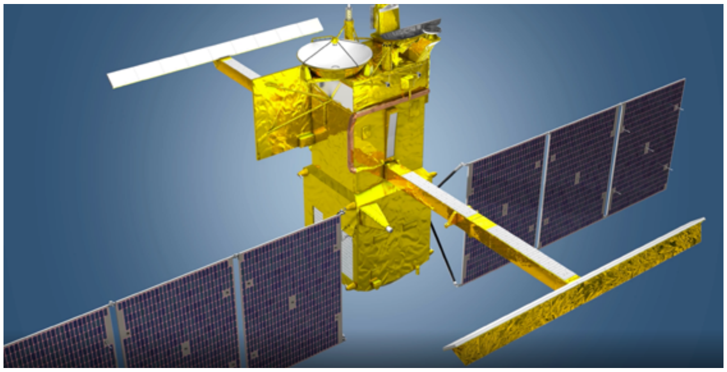
This image video covers how SWOT will help communities plan for a better future by surveying the planet's salt and freshwater bodies. Credit: NASA/JPL-Caltech/CNES/Thales Alenia Space

The satellite will also provide much more detailed information than other satellites about the coastal ocean. Basic data, such as average sea levels near the coast, has gaps, depending on where instruments that measure sea surface height are located. SWOT's improved resolution and global coverage will deliver sea surface height data for many more coastal locations. Knowing where the water is will not only lead to better models of ocean circulation close to the coast, it will help with severe-storm forecasting and storm-surge projections.

SWOT's data and the tools to support researchers in analyzing the information will be free and accessible. For more information on how SWOT data will be applied to local communities, visit the SWOT early adopters website.

Science Instruments

Ka-band Radar Interferometer instrument



SWOT carries an ambitious payload of science instruments to survey nearly all the water on Earth's surface in unprecedented detail. Courtesy: CNES

The scientific heart of the SWOT satellite, the Ka-band Radar Interferometer (KaRIn) instrument, will measure the height of water in Earth's lakes, rivers, reservoirs, and ocean. To do that, KaRIn will transmit radar pulses to Earth's surface and use two antennas to triangulate the return signals that bounce back. Mounted at the ends of a boom 33 feet (10 meters) long, the antennas will collect data over two swaths of Earth's surface at a time, each of them 30 miles (50 kilometers) wide and located on either side of the satellite.

KaRIn will operate in two modes: A lower-resolution mode over the ocean will involve significant onboard processing of the data to reduce the volume of information sent during downlinks to Earth: The higher-resolution mode will be used mainly over land.

This science instrument was provided by NASA's Jet Propulsion Laboratory. The French space agency Centre National d'Études Spatiales (CNES) and Thales Alenia Space built the radio-frequency subsystem, a key part of this instrument. The development of the Duplexer, a high-power switching system that is part of the radio-frequency unit, was funded by the UK Space Agency at Honeywell UK. The Canadian Space Agency contributed the extended interaction klystrons, which are at the heart of the instrument's high-power transmitter assembly.

Nadir altimeter

The nadir (Earth-facing) altimeter instrument measures the height of water on Earth's surface in a narrow strip directly below the satellite, between the swaths the KaRIn instrument observes. Provided by CNES and used on previous ocean-observing satellites, including the Jason series of spacecraft, the altimeter beams radio signals to the water's surface and measures how long the reflected signal takes to return to a receiver. This instrument builds upon the dual-frequency Poseidon family of altimeters that trace their roots to the TOPEX/Poseidon mission launched in 1992. The Poseidon family of altimeters was developed and built by Thales Alenia Space.

Microwave radiometer

Water vapor affects the propagation of radar signals from the KaRIn and nadir altimeter instruments, causing the water level they're measuring to appear higher or lower than it actually is. The microwave radiometer instrument provides water vapor measurements used to correct this effect. It uses heritage technology employed on the Jason-3 mission, pointing two measurement beams in between the two KaRIn swaths. NASA JPL provided this instrument.

Precise orbit determination package

Precisely determining the position of the SWOT spacecraft in orbit is critical when collecting measurements. To do this, SWOT carries a state-of-the-art precise orbit determination instrument package. Each of the package's three science instruments uses a different approach to provide tracking measurements of SWOT's position. The measurements are then used to determine the 3D position and speed of the satellite. The instruments include:

— **Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS):** The DORIS instrument measures the radio signals from 50 to 60 global ground stations that compose the International DORIS Service. Each ground station acts as a beacon to broadcast two stable radio frequencies at 2036.25 megahertz (S-band) and 401.25 megahertz (VHF). SWOT's DORIS instrument measures the Doppler shift of the radio beacons' frequencies to ultimately determine the satellite's position. CNES provided this instrument and it was built by Thales Alenia Space.

— **Laser retroreflector array (LRA):** LRA consists of nine precisely shaped mirrors located on the spacecraft's Earth-facing side. Ground-based laser-ranging stations send laser beams to the satellite's LRA mirrors, which reflect them back to the stations. By measuring how long it takes the laser beams to return to Earth's surface, engineers can determine the distance between the spacecraft and the station. NASA JPL provided this instrument.

— **Global positioning system (GPS) receiver:** The GPS receives tracking signals transmitted by GPS satellites orbiting Earth. The instrument uses these signals to determine the distance between the spacecraft and the GPS satellites. NASA JPL provided this instrument.

Mission: Spacecraft

Spacecraft Bus

The spacecraft bus, mounted below the payload module that carries the science instruments, houses most of the subsystems needed to fly the mission. These include:

Electrical Power

This subsystem generates, stores, and distributes the power needed to operate the spacecraft. The source of power is sunlight collected by SWOT’s two solar arrays, which are 48.8 feet (14.9 meters) in length with an area of 335 square feet (31 square meters). Deployed from opposite sides of the spacecraft bus, the two arrays remain pointed at the Sun via small motors.

Thermal Control

The KaRIn instrument produces about one kilowatt of heat as it operates, and its temperature must remain extremely stable, changing less than 0.09 degrees Fahrenheit (0.05 Celsius) per minute. To maintain allowable flight temperatures, the thermal subsystem uses multiple tools, including mechanical-thermostat and flight-software-controlled heating elements, multilayer insulation blankets, thermal-control surface finishes, high-conductivity interface materials, and materials for heat spreading.

Attitude Control

To determine SWOT’s precise orientation in space, or attitude, SWOT will use star trackers. These navigation devices collect images of stars around the spacecraft and compare them to patterns formed by stars with well-documented locations and brightness. By comparing the observed star locations with the known patterns, the trackers can calculate exactly where the spacecraft is. Adjustments in the spacecraft’s orientation will be carried out as needed using electromagnets (magnetic torquers) and reaction wheels (spinning wheels used on many missions that help a spacecraft adjust and maintain its orientation) mounted on the bus.

Propulsion

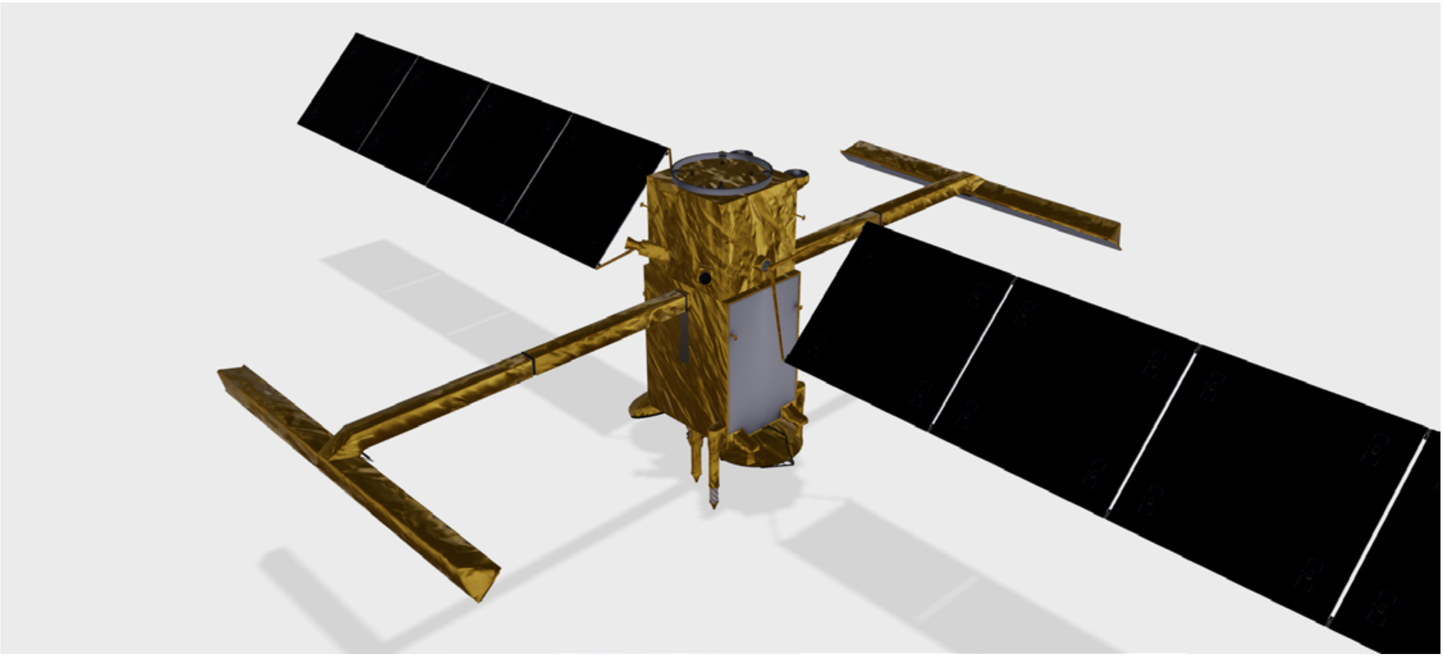
SWOT will adjust its orbit when necessary by firing its thrusters – small rocket engines used only for in-flight corrections. This subsystem also includes a propellant tank.

Telecommunications

Operational communications between SWOT and Earth will take place four times a day on S-band microwave wavelengths (2-4 GHz), which are commonly used for satellite communications. Science data will be transmitted to the ground 21 times a day by an antenna using X-band microwave wavelengths (8-12 GHz).

Command and Data Handling

A centralized processor will manage the observatory's communication links and perform "housekeeping" tasks such as sending and receiving commands and storing data.



An Image from 3D model of the SWOT spacecraft. Image Credit: NASA/JPL-Caltech

Ground Systems

Satellite control and operations

CNES' Satellite Control Center in Toulouse, France, will oversee satellite operations. Four times a day, CNES' S-band telemetry network will uplink commands and other communications to some of its ground stations in Canada, Sweden, South Africa, French Guiana, and Aussaguel (near Toulouse) in France. NASA instruments will be monitored from the instrument control center at JPL.

Science Data and Processing

The SWOT payload module will downlink science data about 21 times a day using X-band radar wavelengths. About 1 terabyte of data will be downlinked from SWOT every day, with KaRIn data representing about 99% of the total. The spacecraft will process some ocean data onboard to reduce the volume that must be downlinked, but higher-resolution data on areas on freshwater bodies will be downlinked directly and processed on the ground.

CNES' mission operations area for SWOT in Toulouse, France. Credit: Courtesy: CNES/F. Lancelot

CNES will process the entire set of daily operational data to create various science and research products. Routine products will be generated within a few days of data acquisition. JPL reprocesses all needed ocean and hydrology science data products during the prime mission. Data products will be distributed via both NASA's Physical Oceanography Distributed Active Archive Center and CNES distribution portals.

Management

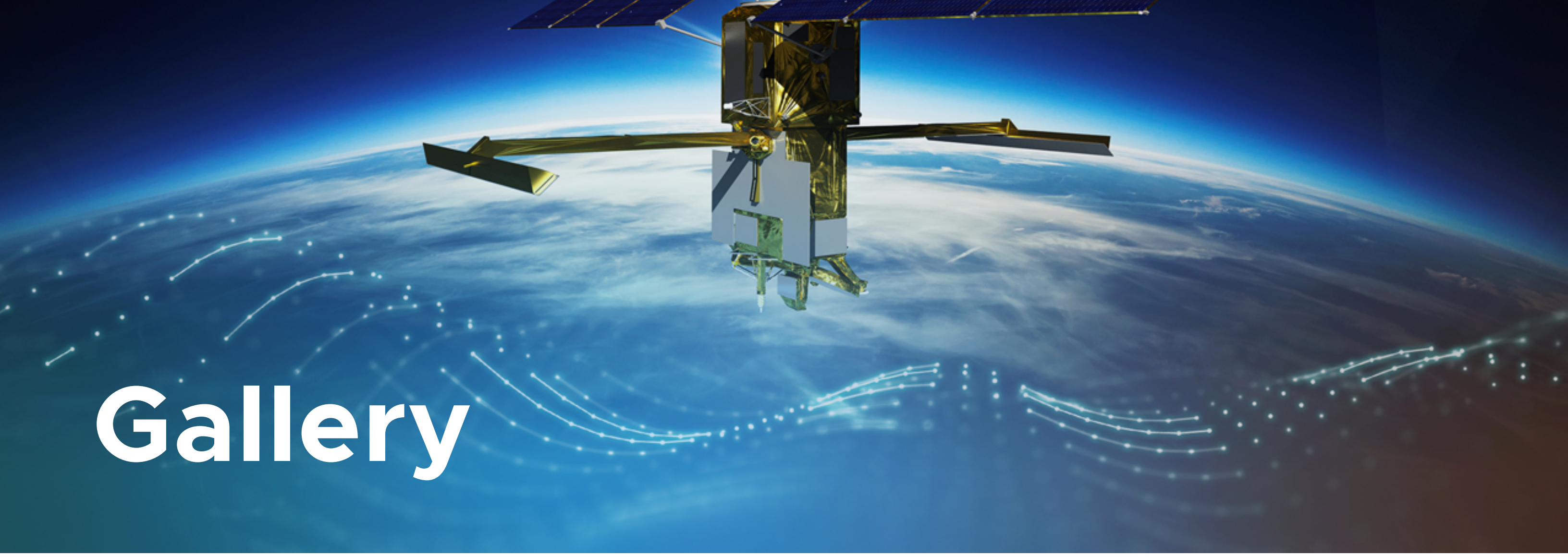
SWOT is a joint mission developed by NASA and the French space agency Centre National d'Études Spatiales (CNES), with contributions from the Canadian Space Agency and the UK Space Agency. NASA's Jet Propulsion Laboratory, a division of Caltech in Pasadena, California, manages the mission for the Earth Science Division in the Science Mission Directorate at NASA Headquarters in Washington. JPL constructed the satellite's science payload, while CNES' prime contractor Thales Alenia Space completed assembly, integration and test of the payload and of the spacecraft bus at its headquarters in Cannes, France.

At NASA Headquarters, **Thomas Zurbuchen** is the associate administrator for the Science Mission Directorate. **Karen St. Germain** is the director of the Earth Science Division. **Tahani Amer** is program executive for SWOT, and **Nadya Vinogradova Shiffer** is program scientist for the mission.

At NASA JPL, **Parag Vaze** is the project manager, and **Lee-Lueng Fu** is the project scientist.

At CNES, **Thierry Lafon** is the program manager for SWOT; **Annick Sylvestre-Baron** is the oceanography science expert; **Philippe Maisongrande** is the hydrology science expert; and **Anne Lifermann** is the coastal science expert.

At Thales Alenia Space, **Christophe Duplay** is the project manager for the SWOT satellite. **Frédéric Robert** is the project manager for the KaRIn radio-frequency subsystem and **Cédric Biegel** is the project manager for the Poseidon altimeter.



Gallery

Images

NASA Image and Video Library

go.nasa.gov/SWOTmultimedia

SWOT images and videos from a NASA-wide library

Planetary Photojournal

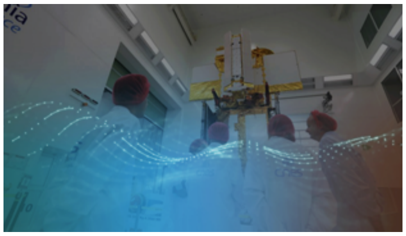
go.nasa.gov/3WRPLzB

SWOT images from the NASA/JPL image library

Launch Images from NASA Kennedy

flickr.com/photos/nasakennedy

Launch-related images from Kennedy Space Center's photographers



CNES Images

bit.ly/CNESSWOTimages

SWOT images from the French space agency

Web Videos

SWOT Mission Overview

bit.ly/SWOTMissionVideo

Short video explainer about what SWOT will study and features of the spacecraft

SWOT Video Playlist

bit.ly/SWOTYouTubePlaylist

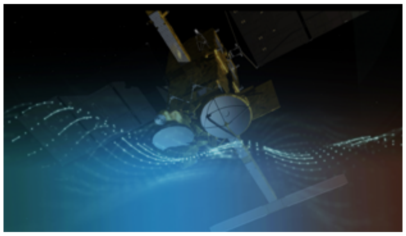
A collection of web videos about the mission from NASA/JPL

CNES Videos

bit.ly/CNESSWOTvideos

SWOT videos from the French space agency

Animations and Raw Videos



SWOT Mission Media Reel

go.nasa.gov/SWOTmediareel

Raw video of the spacecraft being built, interviews with team members, spacecraft animations