Europa Clipper as it might look orbiting Jupiter
Credit: NASA

JOURNEY TO AN ICE WORLD

NASA'S EUROPA CLIPPER

BY JORDAN STRICKLER

Launched on October 14, NASA's Europa Clipper has begun an ambitious mission to study Jupiter's second Galilean moon, a location long believed to have conditions possibly fit for life. Throughout its quest, Europa Clipper will orbit Jupiter and pass Europa almost 50 times, enabling researchers to gather data on the moon's icy surface, its subsurface ocean, and its geological activity.

From its discovery by Galileo Galilei in 1610, Europa has captivated researchers. Though its size is roughly similar to that of the Moon, its smooth, icy surface is what really sets it apart from other celestial objects. Underneath this frozen surface, scientists believe there's a worldwide ocean of liquid water, which makes Europa among the main research targets. Europa Clipper aims to ascertain whether Europa's environment might sustain life, not to search for life directly.

"Europa has always been one of the most compelling places in our solar system regarding the search for life. With Europa Clipper, we can finally investigate this moon with the tools and precision we've only dreamed of for decades," said Al Cangahuala, Europa Clipper deputy mission systems manager. "It's a mission that's not just about exploration—it's about answering questions that could redefine our understanding of where life might exist beyond Earth."

Launched from the Kennedy Space Center aboard a SpaceX Falcon Heavy rocket after waiting out a number of hurricane-related delays, the spacecraft marks another significant turning point in NASA's study of the outer planets and their moons.

Designed to conduct the first thorough exploration of Europa, the solar-powered spacecraft spans over 100 feet (25.7 meters), roughly the length of a basketball court, with its solar arrays fully deployed. The large panels are required to gather the meager sunlight accessible at Jupiter's distance, about five times farther from the sun than Earth.

The trip to Jupiter's moon will take five and a half years. Europa Clipper will fly past Mars and then sling by Earth in a pair of gravity assists to build the momentum required to reach its destination. Known as the Mars-Earth gravity assist (MEGA) trajectory, this approach optimizes launch vehicle capability, propellant mass, and payload mass.

The spacecraft will spend roughly a year modifying its path once it reaches Jupiter, before starting its series of close passes of Europa. The three-year mission will see the spacecraft gather data from a planned 49 flybys of Europa, passing as close as 16 miles (25.7 kilometers) from the moon's surface.

"This isn't just a single-pass mission," Cangahuala said. "We're talking about numerous flybys over three years. Each one of those flybys will give us new coverage and insights into Europa's surface, its ice shell, its ocean, and the way these elements interact.


Europa Clipper integrated into a Falcon Heavy's payload fairing
Credit: SpaceX

We've designed Europa Clipper to be a data-gathering machine, capable of collecting detailed measurements that will fuel scientific discovery for decades."

Europa Clipper's science goal is to explore Europa and investigate its habitability. In turn, this leads to three science objectives: characterizing the moon's ice shell and sub-surface ocean, understanding its composition and chemistry, and understanding its geology. Nine scientific instruments—each meant to offer comprehensive and complementary knowledge about Europa's surface, subsurface, and interactions with Jupiter's magnetosphere—will help to meet these goals.

Europa Clipper contains among the most advanced instruments ever sent to the outer solar system. The Europa Imaging System (EIS) will record high-resolution pictures of Europa's surface that expose features as tiny as 1.5 feet (0.5 meters). These images will allow researchers to better grasp the geological processes of the moon, including the chaotic terrain implying active tectonic or cryovolcanic activity under the surface.

The Mapping Imaging Spectrometer for Europa (MISE) will measure the spectra of light reflected from Europa's surface, analyzing Europa's surface composition. This will enable researchers to recognize organic molecules and salts that might offer hints regarding the ocean's chemistry and whether it contains the elements of life.

The Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) instrument will locate any subsurface lakes or pockets of liquid water using ice-penetrating radar to determine the thickness of Europa's ice shell. Understanding the interactions between the ice and the ocean and whether the ice shell is thin enough to let material from the ocean reach the surface depends on this radar.

"REASON is one of numerous essential tools on Europa Clipper," Cangahuala said. "It's designed to send radio waves deep into Europa's ice shell, allowing us to measure its thickness and detect whether liquid water exists beneath. Without a tool like REASON, we'd only be able to make educated inferences about what's beneath that ice. With this instrument, one can determine whether the ice is thin enough so that possible organic compounds and salts on the surface can likely reach the ocean, improving the odds that Europa could sustain life. That's crucial for understanding Europa's potential habitability."

Europa Clipper is also suited for investigating the moon's tenuous atmosphere. In addition to providing data about Europa's surface composition, the Europa Ultraviolet Spectrograph (Europa-UVS) will search for plumes of water vapor venting from the subsurface ocean of the moon through ice cracks. Examining these plumes would offer a chance to investigate oceanic composition without having to drill through the ice, estimated to be 10 to 15 miles (16 to 24 kilometers) thick.

One of Europa Clipper's many challenges will be Jupiter's strong radiation environment. Europa's orbit resides within a harsh, charged particle-filled region capable of destroying spacecraft electronics. Europa Clipper's electronics are mostly kept in a specifically built radiation vault to guard against this. With its thick aluminum-zinc walls, this vault will help to protect the vital systems of the spacecraft from the strongest radiation it will encounter.

Europa Clipper's instruments and systems must be carefully maintained, even with this protection, to guarantee they can survive the hostile environment of deep space. Engineers have built the spacecraft to operate in ways that minimize radiation damage, including annealing—allowing some components warm up to "heal" radiation-induced damage—in the intervals between Europa encounters.

"Radiation slowly damages our electronics over time, even with the shielding we've built into the spacecraft," Cangahuala explains. "That's where annealing comes in. It's a process where we warm up the electronics to help them recover from radiation exposure, almost like giving the systems a chance to heal themselves. We can't avoid radiation while investigating Europa, but with annealing, we can prolong the spacecraft's health and keep the mission on track to complete its objectives."

Temperature control of the spacecraft will be among the most delicate tasks of the mission. Europa Clipper operates far from the sun and must carefully save heat, but it runs the danger of overheating if all its instruments are active during flybys. The spacecraft can use radiators to shed extra heat as needed and has a sophisticated thermal control system that moves fluids from warmer areas to cooler sections.

Europa Clipper also aims to investigate whether Europa's ocean has the right conditions to sustain life. Water, one of the fundamental components of life as we know it, has been observed venting from the moon's surface. The main question is whether the subsurface ocean also has the chemically required nutrients and energy sources needed to support life.

"Europa is a fascinating water world," Cangahuala said. "Beneath that frozen surface is a vast ocean—with potentially twice the amount of water of all of Earth's oceans combined. What's fascinating is the possibility that this ocean interacts with the ice shell above and rocky seafloor below, creating conditions that might be right for life."

One of the most fascinating prospects is that Europa's ocean floor might have hydrothermal vents, like those discovered on Earth's ocean floor. On our planet, these vents supply heat and nutrients to deep ocean ecosystems where sunlight can't penetrate. Similar vents on Europa might supply an energy source for the moon's subsurface ocean.


Out at Jupiter, Europa Clipper needs huge solar panels to operate
Credit: NASA/JPL-Caltech

The Europa Clipper Magnetometer (ECM) will measure the strength and direction of the moon's magnetic field. Europa doesn't independently generate its own magnetic field, but time-variations of Jupiter's magnetic field appear to induce a magnetic field within Europa, presumably via electric currents flowing in a salty ocean beneath Europa's ice. The ECM measurements should offer hints on the ocean's depth, salinity, and temperature.

The mission's plasma instrument (PIMS) will study plasma's density, temperature, and flow near Europa. PIMS is designed to catch charged particles in space, revealing the plasma's speed and density. While interesting on its own, understanding the density, temperature, and flow of plasma will also help calibrate data from the ECM. The powerful combination of these two instruments is key to precisely determining Europa's ice shell thickness, and the depth and conductivity of its ocean.

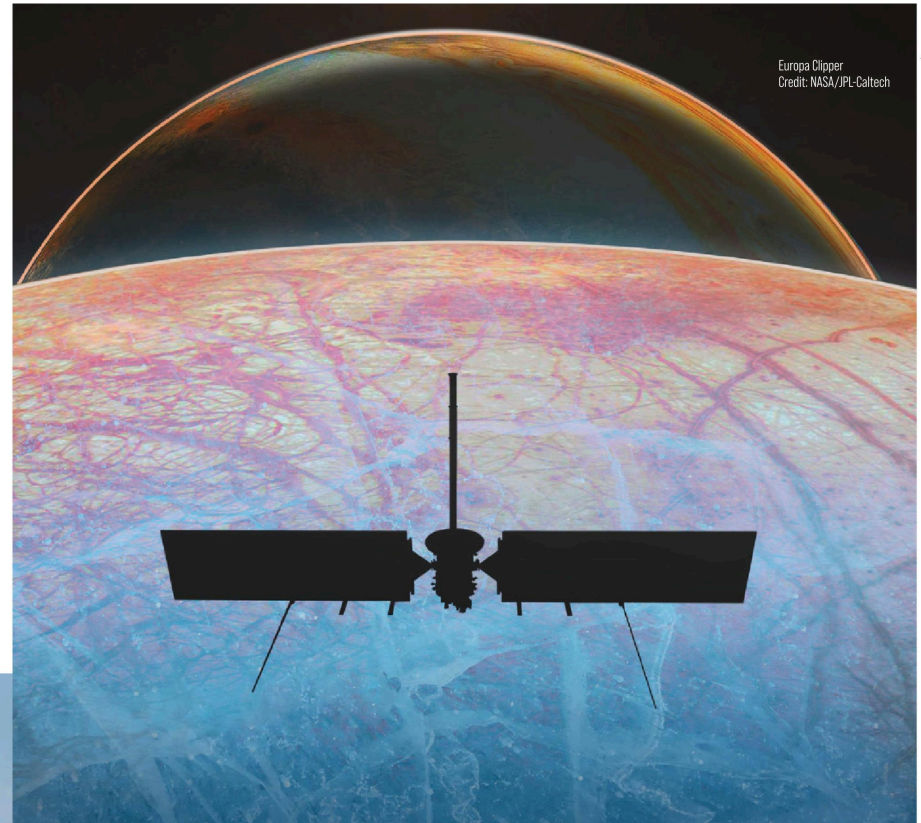
The Surface Dust Mass Analyzer (SUDA) will also study material from Europa—in this case, molecules blasted off the surface by the perpetual bombardment of micrometeorites. The tiny impacts pepper away at the icy surface so much that at any time, there are about 1,100 pounds (499 kg) of surface material floating above Europa in its tenuous atmosphere, called an exosphere. Studying these tiny ice and dust particles gives Europa Clipper a way of assessing surface materials directly without having to land.

Looking for molecules that might form the building blocks of life, the Mass Spectrometer for Planetary Exploration/Europa (MASPEX) will examine gases from Europa's exosphere, as well as any water plumes Europa Clipper passes through. MASPEX will analyze these gases, enabling the study of the chemistry of the moon's suspected subsurface ocean, if and how the ocean and surface exchange material, and how radiation alters compounds on the moon's surface.

The Europa Clipper mission concept is the result of decades of scientific and technical effort. Originally proposed in the late 1990s, the plan for a Europa mission has changed dramatically over time. Early ideas called for a small spacecraft orbiting Europa. However, the difficulties of working in Jupiter's radiation environment resulted in the present mission design—many looping flybys instead of a protracted orbit.

"Galileo was the first mission to give us a real sense of the fascinating conditions at Europa," Cangahuala said. "Its images showed those incredible cracks and ridges on the surface, evidence of interesting mechanical dynamics on many scales at and beneath the ice. Radio science measurements further established the possibility of a large sub-surface ocean. With the ongoing Juno mission, our understanding of Jupiter's magnetic field and Europa's environment was refined. Now, Europa Clipper will take us to the next level."


Europa Clipper launched on a Falcon Heavy rocket on October 14
Credit: SpaceX


Europa Clipper
Credit: NASA/JPL-Caltech

The mission's success will depend on the spacecraft's capacity to negotiate the intricate gravitational dynamics of the Jupiter system and resist the radiation environment around Europa. From its propulsion system to its thermal controls, NASA has tested every facet of Europa Clipper's design to guarantee the spacecraft can fulfill its mission. These tests have pointed out possible challenges, including the spacecraft's radiation damage sensitivity, and engineers have created mitigations to lower these hazards.

Once Europa Clipper finishes its mission, it will be guided to collide with another of Jupiter's Galilean moons, Ganymede, to avoid contaminating Europa. Though it isn't thought to be as likely to sustain life, Ganymede, like Europa, is also thought to have a subsurface ocean. This controlled crash will also give the European Space Agency's JUICE mission—scheduled to reach Jupiter in 2031—an opportunity to witness the event.

"The Europa Clipper mission is more than just a short-term investigation," Cangahuala explains. "The data we gather will be studied for decades. Just like scientists are still analyzing data from the Voyager spacecraft, we expect that the information we collect from Europa will fuel research for future generations of scientists. We're providing the foundation for a much deeper understanding of Europa, and that will likely lead to future surface missions that build on what we find. It will also set a standard for the investigation of other water worlds. It's a watershed moment, pun intended, to contribute to something with such a long-lasting impact." ■