



The CALICO+ Mission – Exploring Ocean World Ceres

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Dwarf planet Ceres is the closest ocean world to Earth. It appears to be rich in water ice and organic material, and its surface shows clear signs of recent, possibly ongoing, geological activity. The presence of such a "wet" body in the asteroid belt is a major surprise. The origin of Ceres is unclear; it might even be a former Kuiper Belt object. A region on Ceres of particular interest is Occator crater with its bright evaporite deposits which signal very recent, if not ongoing, cryovolcanic activity. Our proposed mission CALICO+ (Carbon, Ammonia & Life-Investigations by Ceres Orbiter + lander) will explore Ceres and unravel the secrets of this ocean world. It will investigate Ceres' internal state, origin and evolution and will aim to answer the fundamental question of whether this enigmatic ocean world ever offered the conditions for life.

The CALICO+ spacecraft will be launched on an Ariane 6.4 and will employ solar-electric propulsion to reach Ceres after a cruise phase of four years. CALICO+ will orbit Ceres and unravel the mysteries of its interior. CALICO+ will reveal subsurface brine deposits and ongoing emissions of water from the surface.

The CALICO+ orbiter science payload consists of seven instruments and a lander. The camera system will obtain high-resolution colour images of the surface and provide context for the other instruments. Recent or ongoing surface activity can be identified at unprecedented resolution with the camera, comparing imagery with Dawn's snapshot of Ceres' surface taken some 30 years before the arrival of CALICO+.

An orbit phase of up to two years currently foreseen will provide the impact ionisation mass spectrometer with enough time to sample ejecta from meteoroid bombardment of Ceres' surface, hence enabling an analysis of Ceres' surface material from orbit.

The radar sounder will identify subsurface ice layers as well as the spatial extent of any brine reservoirs and hence will contribute to better understanding the possible cryovolcanic processes hypothesized on Ceres.

The hyperspectral infrared imager will characterise Ceres' surface composition and thermal environment at unprecedented spatial resolution and provide day- and night-time temperatures of Ceres' surface to constrain activity and measure Ceres' surface thermophysical properties.

The particle and fields instruments, a magnetometer and an ion energy spectrometer will investigate the exosphere and constrain the existence and extent of any deep subsurface brine reservoirs from their magnetic signatures.

The radio science experiment will characterise the density distribution of the crust, helping identify any brine pockets in the subsurface.

Towards the end of the mission, a landing site in Ceres' salt deposits in Vinalia Faculae will be

selected and a 80 kg microlander will be deployed with the aim of imaging the surface close-up and determining its chemical and molecular composition in situ, potentially identifying organic building blocks in the brine extrusions that form the faculae. The lander's primary science phase will last three Ceres days (27 h), its primary batteries providing the power to operate its three instruments: a LIBS, a Raman Spectrometer, and a camera. The secondary science phase can be of a similar duration. During the secondary science phase, individual instruments can be operated to perform follow-up investigations based on the outcome of the initial science investigations.

CALICO+ has passed the step-1 down-selection of ESA's M8 mission proposals and is currently awaiting the results of the step-2 down-selection. As ESA's M8 mission, CALICO+ would set the scene for ESA's L4 endeavour to explore another, more distant ocean world – Enceladus.

As a multidisciplinary mission, CALICO+ aims to appeal to as many members of the space and planetary science community as possible. If you are interested in joining the growing CALICO+ consortium, contact one of the authors.

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