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The Hera Saturn entry probe mission

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ABSTRACT

The *Hera* Saturn entry probe mission is proposed as an M-class mission led by ESA with a contribution from NASA. It consists of one atmospheric probe to be sent into the atmosphere of Saturn, and a Carrier-Relay spacecraft. In this concept, the *Hera* probe is composed of ESA and NASA elements, and the Carrier-Relay Spacecraft is delivered by ESA. The probe is powered by batteries, and the Carrier-Relay Spacecraft is powered by solar panels and batteries. We anticipate two major subsystems to be supplied by the United States, either by direct procurement by ESA or by contribution from NASA: the solar electric power system (including solar arrays and the power management and distribution system), and the probe entry system (including the thermal protection shield and aeroshell). *Hera* is designed to perform *in situ* measurements of the chemical and isotopic compositions as well as the dynamics of Saturn's atmosphere using a single probe, with the goal of improving our understanding of the origin, formation,

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In situ measurements
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and evolution of Saturn, the giant planets and their satellite systems, with extrapolation to extrasolar planets. *Hera*'s aim is to probe well into the cloud-forming region of the troposphere, below the region accessible to remote sensing, to the locations where certain cosmogenically abundant species are expected to be well mixed. By leading to an improved understanding of the processes by which giant planets formed, including the composition and properties of the local solar nebula at the time and location of giant planet formation, *Hera* will extend the legacy of the Galileo and Cassini missions by further addressing the creation, formation, and chemical, dynamical, and thermal evolution of the giant planets, the entire solar system including Earth and the other terrestrial planets, and formation of other planetary systems.

1. Introduction

The *Hera* Saturn entry probe mission consists of one atmospheric probe to be sent into the atmosphere of Saturn, and a Carrier-Relay Spacecraft (CRSC). *Hera* will perform *in situ* measurements of the chemical and isotopic compositions as well as the dynamics of Saturn's atmosphere using a single probe, with the goal of improving our understanding of the origin, formation, and evolution of Saturn, the giant planets and the solar system. *Hera* will probe well into the cloud-forming region of the troposphere, below the region accessible to remote sensing, to the locations where certain cosmogenically abundant species are expected to be well mixed.

The formation and evolution of the giant planets hold many keys to understanding the formation and evolution of the solar system as a whole, including the terrestrial planets, as well as exoplanetary systems. Key measurements include the composition and processes within giant planet atmospheres, gravitational fields, magnetospheres, and systems of moons. The *Galileo* probe provided *in situ* measurements of the chemical and isotopic composition of Jupiter's atmosphere. Of particular importance, the Jovian helium abundance was determined with a high accuracy. Moreover, the *Galileo* probe revealed unexpected enrichments of the noble gases Ar, Kr and Xe with respect to the solar abundances. Additionally, the *Galileo* probe mass spectrometer measured the $^{14}N/^{15}N$ ratio, which strongly suggested that the nitrogen in Jupiter's atmosphere was acquired from the protosolar nebula (PSN). The *Galileo* probe and orbiter mission to Jupiter, complemented by the *Juno* mission currently en route to Jupiter and the L-class *JUICE* mission selected by ESA, will provide a solid understanding of the Jupiter system. The *Cassini* orbiter is providing valuable observations of Saturn's upper atmosphere, system of moons, gravitational field, and magnetosphere. However, the *Huygens* probe was destined to enter Titan's atmosphere and did not explore Saturn's atmosphere.

The key missing element towards a similar system understanding of Saturn and an improved context for understanding the *Galileo*, *Juno*, and *JUICE* studies of Jupiter are the measurements of the composition and of the processes within Saturn's deeper atmosphere that only *in situ* exploration can provide. The *Hera* probe will use mass spectrometry to measure the abundances of hydrogen, helium, neon, argon, krypton, xenon, carbon, nitrogen, sulfur, and their compounds at near-equatorial latitude down to at least 10 bars. During its descent, *Hera* will also sample key isotopic ratios D/H, $^{3}He/4He$, $^{20}Ne/^{21}Ne/^{22}Ne$, $^{36}Ar/^{38}Ar$, $^{12}C/^{13}C$, $^{14}N/^{15}N$, $^{16}O/^{17}O/^{18}O$, $^{82}Kr/^{83}Kr/^{84}Kr/^{86}Kr$, and $^{129}Xe/^{130}Xe/^{132}Xe/^{134}Xe/^{136}Xe$. *In situ* measurements of Saturn's well-mixed atmosphere gases will provide a vital comparison to the *Galileo* probe measurements at Jupiter, and a crucial "ground truth" for the remote sensing investigations by the *Cassini* orbiter. *Hera* will investigate Saturn's atmospheric dynamics along its descent trajectory, from (1) the vertical distribution of the pressure, temperature, clouds and wind speeds, and (2) deep wind speeds, differential rotation and convection, by combining *in situ* probe measurements and gravity and radiometric measurements from the carrier. *Hera* is the next logical step in our exploration of the Gas Giants beyond the *Voyager*, *Galileo* and *Cassini* missions.

Hera will lead to an improved understanding of the processes responsible for the formation of giant planets (contribution of the local solar nebula, accretion of icy planetesimals, and nature and formation temperature of the latter). The *Hera* data will shed light on the composition of giant planet precursors and on the dynamical evolution of the early solar system. *Hera* will also address the question as to why Jupiter and Saturn are so different in size, density and core dimension, investigating different pathways to planetary formation, thereby providing new insights on the mechanisms that led to the stunning diversity of giant planets.

The *Hera* probe concept as proposed in response to ESA's Cosmic Vision Medium class size call in 2014 will be composed of ESA and NASA elements, and the CRSC will be delivered by ESA. The probe will be powered by batteries. The CRSC will be powered by solar panels and batteries. We anticipated two subsystems to be supplied by the United States, either by direct procurement by ESA or by contribution from NASA: the solar electric power system (including solar arrays and the power management and distribution system), and the probe entry system (including the thermal protection shield and aeroshell). Following the highly successful example of the *Cassini-Huygens* mission, *Hera* would carry instruments from international partners, with scientists and engineers from both agencies and many affiliates participating in all aspects of mission development and implementation. A Saturn probe is currently one of the five missions on the NASA New Frontier's list, affirming that *Hera* science is a high priority for the European and American Planetary Science communities.

Hera flight could be with a Soyuz-Fregat launch from Kourou on a transfer trajectory to Saturn via several inner solar system flybys, with an arrival at Saturn 7–8 years after launch. The *Hera* CRSC releases the probe on a ballistic trajectory that will take it into Saturn's atmosphere a few weeks after its release. Prior to probe release, the CRSC would image Saturn to provide a global context for the probe science, as well as providing a local context of the probe entry location. Following the release of the *Hera* probe, the CRSC will be deflected to prepare for flight over the probe entry location for the probe data relay.

The science objectives and measurement requirements of such a mission are described in Section 2. The proposed science instruments are detailed in Section 3. Section 4 is dedicated to a description of the current mission configuration and profile. We discuss the management scheme in Section 5. Section 6 is devoted to summary and conclusion.

2. Science objectives and requirements

2.1. Context

The giant planets Jupiter, Saturn, Uranus and Neptune contain most of the mass and angular momentum of the sun's planetary

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