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The Europa Clipper Mission: Exploring The Habitability Of A Unique Icy World

R. T. Pappalardo (1), D. A. Senske (1), **H. Korth** (2), R. Klima (2), S. D. Vance (1), K. Craft (2), and the Europa Science Team. (1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, (2) The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA.

1. Introduction

A key driver of planetary exploration is to understand the processes that lead to potential habitability across the solar system. In the forefront of this objective is evaluating the astrobiological potential of the icy outer planet satellites. It is in this context that a mission to Europa is currently being formulated.

2. Mission Goal, Objectives, and Investigations

The overarching science goal of the Europa mission is to explore Europa to investigate its habitability. Following from this goal are three Mission Objectives (bold roman numerals), from each of which flow several Mission Investigations (numbered items), as listed below. Also listed (abbreviations) are each of the instruments, plus Gravity and Radiation science, that synergistically address these Investigations and Objectives, which are defined and discussed in more detail in the next section. Folded into these three objectives is the desire to search for and characterize any current activity, notably plumes and thermal anomalies.

I. Ice Shell & Ocean – Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange.

1. Characterize the distribution of any shallow subsurface water and the structure of the icy shell *(EIS, REASON)*;
2. Determine ocean salinity and thickness *(ICEMAG, MISE, PIMS, SUDA)*;
3. Constrain the regional and global thickness, heat-flow, and dynamics of the ice shell *(E-THEMIS, EIS, Gravity, ICEMAG, PIMS, REASON)*;
4. Investigate processes governing material exchange among the ocean, ice shell, surface, and atmosphere *(EIS, ICEMAG, MASPEX, MISE, REASON, SUDA)*.

II. Composition – Understand the habitability of Europa's ocean through composition and chemistry.

1. Characterize the composition and chemistry of endogenic materials on the surface and in the atmosphere, including potential plumes *(EIS, Europa-UVS, ICEMAG, MASPEX, MISE, PIMS, REASON, SUDA)*;
2. Determine the role of the radiation and plasma environment in creating and processing the atmosphere and surface materials *(EIS, Europa-UVS, MASPEX, MISE, PIMS, Radiation, REASON, SUDA)*;
3. Characterize the chemical and compositional pathways in the ocean *(EIS, ICEMAG, MASPEX, MISE, SUDA)*.

III. Geology – Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.

1. Determine sites of most recent geological activity, including potential plumes, and characterize localities of high science interest and potential future landing sites *(E-THEMIS, EIS, Europa-UVS, MASPEX, MISE, PIMS, Radiation, REASON, SUDA)*;
2. Determine the formation and three-dimensional characteristics of magmatic, tectonic, and impact landforms *(EIS, REASON)*;
3. Investigate processes of erosion and deposition and their effects on the physical properties of the surface *(E-THEMIS, EIS, Europa-UVS, PIMS, Radiation, REASON, SUDA)*.

3. Exploring Europa Through Synergistic Investigation

To address the science questions of the Europa mission, NASA selected a scientific payload comprised of nine instruments. This payload includes five remote-sensing instruments that observe the

wavelength range from ultraviolet through radar, and four *in situ* instruments that measure fields and particles.

Europa Ultraviolet Spectrograph (Europa-UVS). Operating at ultraviolet wavelengths, Europa-UVS will measure the composition and chemistry and the structure and variability of Europa's tenuous atmosphere. In addition, Europa-UVS will enable characterization of the plasma environment and the search for and characterization of the distribution, structure, composition, and variability of any active plumes. Europa-UVS data can constrain surface composition and microphysics and relationships to endogenic and exogenic processes.

Europa Imaging System (EIS). Composed of a narrow- and wide-angle camera with stereo and color imaging capability, EIS can map Europa globally at 100 m resolution and image almost any point on the surface at better than 20 m resolution, providing constraints on the formation of surface features. Very high-resolution imaging addresses small-scale regolith processes and can characterize sites amenable for a future lander. Distant imaging would search for active plumes and provide a means to characterize the ice shell through modeling of the limb shape.

Mapping Imaging Spectrometer for Europa (MISE). Operating in the 0.8–5.0 μm wavelength range, MISE data can be used to assess the habitability of Europa's ocean through examination of the inventory and distribution of surface compounds, including any biologically relevant deposits. MISE data can be used to identify and map the distributions of organics, salts, acid hydrates, water ice phases, altered silicates, radiolytic compounds, and warm thermal anomalies at global, regional, and local scales on Europa.

Europa Thermal Imaging System (E-THEMIS). The E-THEMIS investigation permits detection and characterization of thermal anomalies that may indicate recent activity. Thermal inertia information derived from E-THEMIS measurements can be used to characterize regolith particle size, block abundance, and subsurface layering. This investigation can also aid characterization of any active plumes.

Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON). REASON data will permit mapping of Europa's vertical crustal structure and the search for subsurface water. They can also be used to study the distribution of shallow subsurface water and to search for the deeper ice-ocean interface and to provide insight into material exchange among the ocean, ice shell, surface, and atmosphere. Solid body geophysical measurements can constrain the amplitude and phase of the tides. Derived dielectric and other physical properties support characterization of the scientific value and hazards of sites for a potential future lander.

Interior Characterization of Europa using Magnetometry (ICEMAG). ICEMAG can measure magnetic fields to infer magnetic induction at multiple frequencies. This, in turn, would permit the location, thickness, and salinity of Europa's ocean to be estimated. In addition, the data can be used to identify sources and losses of Europa's atmosphere, coupling of Europa to Jupiter's ionosphere, and coupling of any plumes to flowing plasma.

Plasma Instrument for Magnetic Sounding (PIMS). PIMS data can be used to identify plasma contributions to Europa's magnetic field and to understand mechanisms of weathering and release of material from Europa's surface into the atmosphere. PIMS data can facilitate an understanding of how Europa influences its local space environment and Jupiter's magnetosphere.

MAss Spectrometer for Planetary Exploration /Europa (MASPEX). MASPEX can perform *in situ* analysis of neutral gases to identify major volatiles and key organic compounds in Europa's exosphere and possible plumes, and their association with geological features. MASPEX data can be used to derive the relative abundances of key compounds, to constrain the chemical conditions and biological suitability of Europa's ocean including isotopologues, radiolysis products, and organic molecules.

SUrface Dust Analyzer (SUDA). The SUDA investigation can map surface composition by direct analysis of particles ejected by micrometeoroid impacts. SUDA data can be used to characterize the alteration of Europa's surface via exogenous dust and to determine the composition of particles in active plumes to determine ocean properties.

In addition, gravity science can be achieved via the spacecraft's telecommunication system in combination with radar altimetry. Moreover, the spacecraft's planned radiation monitoring system could provide valuable scientific data. Working together, the Europa mission's robust investigation suite can be used to test hypotheses and enable discoveries relevant to the interior, composition, and geology of Europa, thereby addressing the potential habitability of this intriguing ocean world.