THE MAPPING IMAGING SPECTROMETER FOR EUROPA (MISE) INVESTIGATION: EXPLORING EUROPA’S HABITABILITY USING COMPOSITIONAL MAPPING. D. L. Blaney¹, R. N. Clark², J. B. Dalton¹, A. G. Davies¹, R. O. Green¹, M. M. Hedman³, C. A. Hibbits¹, Y. Langevin⁵, J. I. Lunine⁶, T. B. McCord⁷, C. Parancas¹, S. L. Murchie⁶, F. P. Seelos⁸, and J. M. Soderblom⁹. ¹NASA Jet Propulsiton Laboratory, California Institute of Technology, Pasadena CA, Diana.L.Blaney@jpl.nasa.gov. ²Planetary Science Institute, Tucson AZ. ³University of Idaho, Moscow ID. ⁴Applied Physics Laboratory, John Hopkins University, Laurel, MD. ⁵Institut d’Astrophysique Spatiale, Orsay, France. ⁶Cornell University, Ithaca, NY. ⁷Bear Fight Institute, Winthrop, WA. ⁸Massachusetts Institute of Technology, Cambridge, MA.

Introduction: The Mapping Imaging Spectrometer for Europa (MISE) is being designed as a high-optical throughput pushbroom spectrometer that can collect measurements within Europa’s challenging radiation environment. MISE is planned to cover a spectral range from 0.8–5 µm. With an instantaneous field of view of 250 µrad/pixel and a swath width of 300 pixels, this design yields 25 m/pixel spatial sampling in a swath 7.5 km wide at 100 km altitude, and 10 km/pixel scale full disk images at 40,000 km. MISE would return composition information for each pixel in the image measured.

MISE could 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 (Figure 1). Mapping the composition of specific landforms is critical to understand surface and subsurface geologic processes, including recent or current activity. High spatial resolution compositional mapping is also essential for detecting small outcrops of potentially recent endogenic organics and salts.

Assessing Habitability: A potentially habitable environment is one that is capable of supporting life, though it may not be inhabited. The generally accepted ingredients for an environment capable of hosting life as we know it include a source of “free energy” (available to do work of some sort), organics, and liquid water [1]. In addition, contact of liquid water with rock, providing a source of the elements needed for biological processes, is also assumed to be essential. Given the determination of a global layer of liquid water exists below the crust, three lines of evidence will be investigated to assess habitability: 1) presence and distribution of organics including complex organics such as amino acids; 2) salt chemistry of the ocean; and 3) evidence of current and recent surface change as a proxy for internal activity.

Why Reflectance Spectroscopy? The 0.8–2.5 µm region is essential for quantifying ice, hydrates and bulk surface composition, while the 3–5 µm region is required for detecting low abundances of organics, most radiolytic products, and discriminating salts from acid hydrates (Figure 2). These longer wavelengths can also be used to measure thermal emissions from currently active regions.

Organics: The 3–5 µm spectral range is critical to detecting organics because weak C=C bonds (e.g., octane) in some aliphatic hydrocarbons contrast sharply with the stronger C=C bonds (e.g., benzene) and C≡C bonds found in other hydrocarbons. These differences provide an approach to distinguish classes of hydrocarbons, as well as from other dissimilar materials that might exist on the surface of Europa (Figure 2).

Salts: One of the major debates regarding Europa surface composition from Galileo NIMS data is the relative abundances of acid hydrates produced by the irradiation of surface ice with Iogenic ions [2] and hydrated sulfates produced from brines in Europa’s ocean [3-5]. NIMS’s spatial sampling, spectral resolution, and signal-to-noise ratio (especially at wavelengths >2.6 µm), are insufficient to distinguish between these models. However, these materials are distinct at 3.5 µm (Figure 2). Salts can also be discriminated from

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*Figure 1.* Galileo Solid State Imager (SSI) images of Europa at (a) 25 m/pixel, (b) 300 m/pixel, and (c) 7 km/pixel, which correspond roughly to expected MISE local, regional, and global spatial sampling.
each other and water ice based on the differences in fine-scale spectral structure and band centers (Figure 2). Variations in sulfate cations and salt hydration also produce identifiable spectral features so that mineralogy can be determined, especially at European temperatures [6].

Current activity/Ice/Radiolytic Products: Thermal emission from active eruptions (including plumes) would yield strong thermal emission at 5 μm [7,8]. Newly erupted liquids (at ≈273K) would cool quickly. A localized thermal anomaly could be indicative of recent or current geologic activity. Multispectral imaging from ~4–5 μm at high spatial scale would thus enable mapping of the surface temperature of such thermal anomalies, providing key diagnostics regarding the genesis of such material.

Water ice spectral features could be used to estimate surface ages and thermal history of the surface. Hexagonal crystal water ice forms when condensing above 150 K; at colder temperatures either metastable cubic ice or amorphous water ice forms [9,10]. Amorphous water ice irreversibly transforms into crystalline ice on a timescale of 10–20 years at European temperatures (~100 K) [9, 11]. Transient thermal events can also induce a crystalline phase change more quickly. The physical state of the water ice can, therefore, act as both a chronometer and a recorder of past thermal events.

Thermally driven timescales, however, may not be determinative of the phase of the water ice, given that charged particles from co-rotating Jovian plasma continually impact the surface. These disrupt the water ice crystal structure so that it spectrally appears identical to amorphous solid water [12-17]. Charged particles that change the structure of ice can also produce chemical changes in water ice and other materials on the surface (e.g., create peroxide). These processes are happening continuously on Europa so the state of crystallinity and abundance of compounds like acid hydrates can constrain the radiation/impactor flux and surface age. Species of interest that MISE could measure include SO₂, H₂O₂, CO₃, clays, and organics.

Data from MISE could be used to produce compositional maps (Figure 3) to assess habitability and the potential for sending future landers for life detection experiments.

**Figure 3.** Synthetic Europa image cube illustrates how MISE can assess habitability. (a) 1 μm albedo map with full spectrum and compositional information at each pixel. (b) Ice phases: red=acid hydrate, green=crystalline ice, blue=amorphous ice. (c) Distribution of salts, (d) Thermal emission, and (e) Compilation of salts (red), C-C materials (green), and C=C materials (blue). Yellow areas have both salts and organics. MISE would assess this area as habitable due to the presence of all three indicators (salts, current activity, organics associated with bands).

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