IMAGING SPECTROMETERS ON SMALLSATS TO MARS: SCIENCE DRIVERS AND NEEDED TECHNOLOGIES

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Introduction: Recent technology advances have led to the development of highly capable imaging spectrometers [13] that are low enough mass and power that they could be compatible with small sat missions to Mars. However, to support these instruments on future small sat missions to Mars, technology development and maturation are needed. Key areas for advancement include developing highly capable small sat buses that have the pointing stability and comm capabilities demanded by data-heavy imaging spectrometers.

Background: Numerous reports have cited the need to better understand both the vertical structure of Mars' polar deposits (PLD) [1-6] as well as the nature and timing of major environmental transitions recorded in the myriad sites where alteration minerals have been identified [1-3, 7- 9]. The recent Mars Architecture Strategy Working Group (MASWG) report linked these questions to two mission Arcs (#1 Diverse Ancient Environments and Habitability, and #3 Ice and Geologically Recent Climate Change) [10], and suggested they could be addressed by next generation visible short-wave infrared (VSWIR) and thermal (IR) imaging spectrometers.

Example mission concept overview: Both NEX-SAG and ICE-SAG strawman payloads [1, 4] included a CRISM-like instrument and a THEMIS-like thermal mapper at improved spatial resolution over current measurements. The inclusion of one or both of these instruments on a future mission can address several major open questions. How are the current surface ice deposits linked to current and recent climate? How are dust and volatiles cycled between the surface and atmosphere and how does dust contribute to the formation of layers? How do known deposits of aqueous alteration minerals relate to and record ancient environmental transitions? Which environments are conducive to the origin and possible evolution of life? Fundamental to these questions is the need to characterize the compositional diversity linked to water at spatial scales significantly better than current orbital data.

Advances from CRISM imaging spectroscopy have demonstrated that high resolution compositional information is required to resolve the details of transitions in mineral assemblages that signal changes in environmental conditions. For example, Fig. 1 illustrates the detail available at 5m/pix with the CaSSIS camera on TGO. The current best SWIR data are from CRISM at 18 m/pix, which has illuminated thousands of sites where alteration minerals are exposed [8, 9].

THEMIS, a multi-channel LWIR imager at 100 m/pixel, has provided global maps, but cannot provide detailed mineralogy and is usually supplemented with data from TES. However, TES had a very coarse spatial resolution (>3km) that was insufficient for detecting outcrop scale mineralogy.

The Mars Orbiter for resources, ices, and environment (MORIE) mission concept study [11, 12], included dual range spectral system with a single shared telescope. The SWIR and LWIR spectrometers have similar telescope requirements in terms of diffraction and signal-to-noise ratio. Using a beam splitter allows the instruments to share a telescope and reduce overall mass while still achieving the desired spatial resolution in both SWIR and LWIR.

Instruments: *The Mars Aqueous Environment Spectral Imager (MAESI).* Taking advantage of significant instrument development at JPL [13], including systems created for both earth and planetary applications (EMIT, MISE, M3, UCIS-Moon, HVM3 on Lunar Trailblazer) a compact, high TRL instrument (Fig. 1) can be created that covers wavelengths from 600 to 3600 nm at SNR values similar or better than CRISM with 10nm spectral sampling, a spatial footprint of ~6m and a swath of 5km. Higher spatial resolution compositional data will identify both primary minerals and their alteration products across environments and ages and provide a comprehensive record for many sites beyond the 4 surface locations visited by rovers. Additionally, this wavelength range can provide detailed compositional measurements of ice and non-ice components of the PLD [e.g., 14, 15].

Mars Far Infrared Emission imager (Mars-FIRE). The MORIE mission included a LWIR imager that has heritage from PREFIRE using a grating for dispersion and uncooled micro-thermopile arrays. The design achieved a spectral range from 6–25 μm, in at least 20 channels with < 1 μm bandpass, and < 100 m spatial resolution. This instrument can provide quantitative mineral abundance estimates with spectral fidelity and mineral discrimination similar to TES, but with a significantly improved footprint (equivalent to THEMIS), revolutionizing our understanding of both primary and alteration mineralogy. This wavelength range is also important for mapping polar ices and atmospheric conditions [16, 17]. The Mars Atmosphere and Volatile Resource Investigation Camera

(MAVRIC). Also included in MORIE was a small, lightweight wide-angle camera to continue the decades long record of weather and seasonal frost monitoring from MOC and MARCI at better spatial resolution. This updated camera images limb-to-limb on the dayside in one dozen visible and SWIR bands acquiring daily global coverage to characterize seasonal frost, clouds and dust-storm evolution. SWIR channels can discriminate v

Needed Technologies: MAESI alone could be a compelling SIMPLEx concept (similar to Lunar Trailblazer) focused solely on alteration environments and minerals. The addition of LWIR and concurrent observation of locations in both wavelength ranges provides an unprecedented and unique view under similar atmospheric conditions. Detailed study needs to explore whether a tandem spectroscopic system is achievable within the cost and mass bounds envisioned for low-cost missions.

Technology development is required for a small sat mission concept that supports either a standalone SWIR instrument (like MAESI), or a combination LWIR and SWIR instrument (MAESI + Mars-FIRE). Key areas for future work include maturation of capable small spacecraft bus that can operate in Mars orbit (preferable for >1 Mars year, or 2 Earth years), with sufficient pointing stability for imaging spectrometers to collect data. Comms for such a mission will additionally need to support the ability to transmit large data volumes associated with data-heavy imaging spectrometer observations from Mars.

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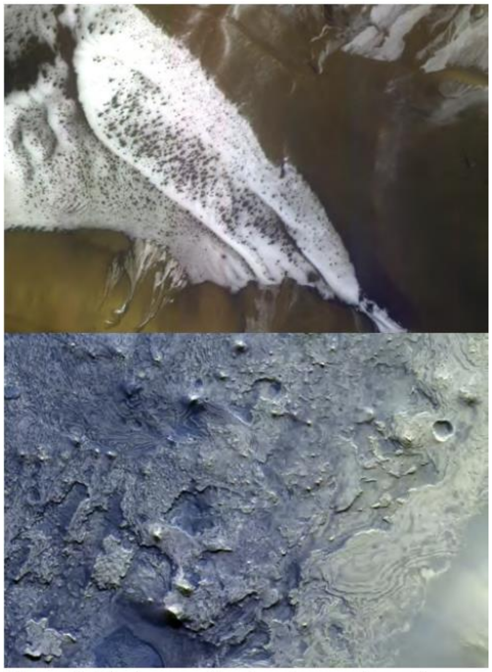

Figure 1: Next generation imaging spectrometers can capture compositional information at 5m/pixel spatial scales, equivalent to CaSSIS. The upper image shows seasonal ice covering a crater wall at 68°S, near Sisyphi Planum. The lower image illustrates layered erosional morphology at the SE rim of Izamal crater in Meridiani Planum. Image credit ESA/ROSCOSMOS/CASSIS.

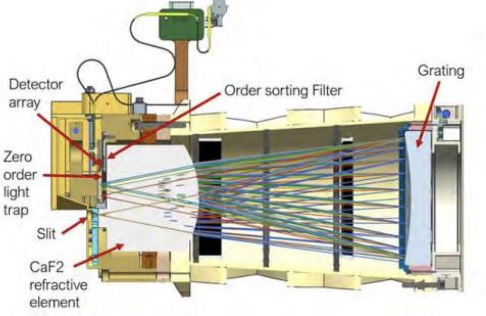

Figure 2: JPL prototype for the MAESI instrument based on a Dyson spectrometer operating in a push-broom mode. See also [13].