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Optimising Thermal Mapping Instrument Filters to Unveil Enceladus' Subsurface Secrets

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Introduction: Enceladus is a key target for astrobiological study, with its subsurface ocean and cryovolcanism focused at the South Pole's 'tiger stripe' fractures; understanding temperature variations is essential to decipher the moon's geological activity and potential for life. Blending heritage from TechDemoSat-1, Mars Climate Sounder, and Lunar Trailblazer, the University of Oxford's Enceladus Thermal Mapper (ETM) faces new opportunities and challenges in observing this active icy moon of Saturn. This high heritage thermal instrument will characterise Enceladus' activity and surface properties by measuring its day, night, and polar-night temperatures, with particular focus on the tiger stripes. The winter temperatures are the most challenging, as they plunge as low as 45 K. This cold temperature regime is driving adaptations to sensor design and operations, for example requiring long exposure times and meticulous noise control.

High-Resolution Multi-Band Radiometric Thermal Mapping vs Spectroscopy: Cassini's Composite Infrared Spectrometer (CIRS) achieved high spectral and spatial resolution, with its highest spatial-resolution detectors (focal planes 3 and 4) having 10 pixels, each with an instantaneous field of view (iFOV) of 0.273 mrad [1]. However, due to the limited flyby nature of Cassini much of Enceladus was left without high-resolution thermal mapping. In contrast, the University of Oxford's multi-band radiometric instrument operates 384 cross-track line scanning pixels, each with an iFOV of 0.540 mrad. The instrument has space for 15 wavelength bands and operates as a 384 x 288 pixel push-broom sensor. Preliminary mission concepts anticipate flying this instrument in orbit around Enceladus at an altitude of 150 km. This would mean ETM could globally map Enceladus at 80 m/pixel resolution, with a track 31 km wide (Fig. 1).

Digital Twin Instrument for Optimised Filter Selection: We will discuss the newly developed digital model of the instrument, which creates a framework for comparing and selecting various bandpass filters and sensor geometries. Strategically chosen filter profiles will facilitate the determination of black body emission curves, allowing for precise temperature measurements with a goal of improving constraints on global thermal emission due to tidal heating. The suitability of different filter profiles for NASA's science goals will be discussed.

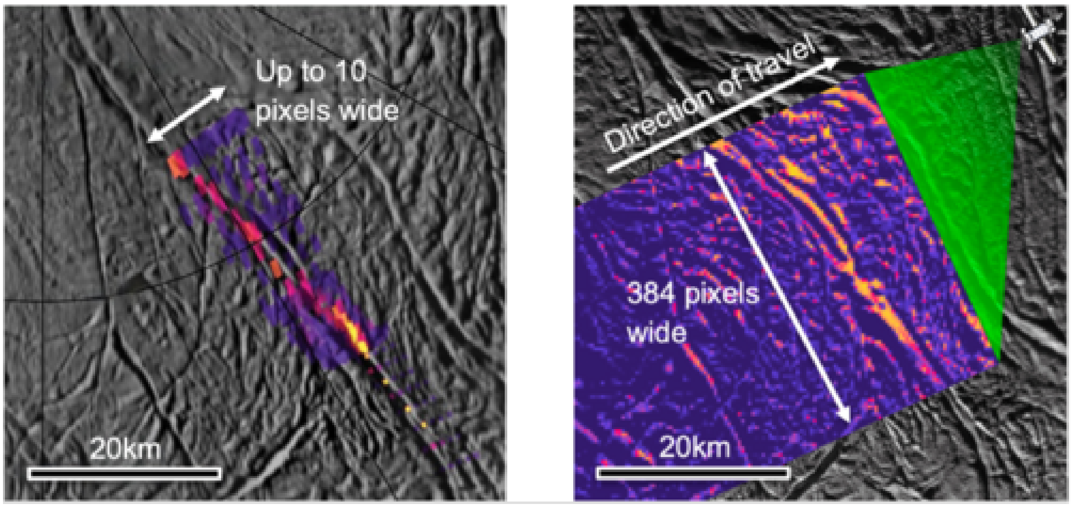

Figure 1: Fractures at Enceladus' South Pole – Cassini's CIRS compared to Enceladus Thermal Mapper Warm fractures at Enceladus' South Pole vary in temperature along their length. (Left) One of the highest resolution thermal maps captured by Cassini. [2] (Right) Artistic impression: Orbiting at 150 km, ETM's ground track would be 31 km, and it would be capable of resolving 80 m features at nadir.

References: [1] Howett, C. J. A., Spencer, J. R., Pearl, J., and Segura, M. (2011) J. Geophys. Res., 116, E03003. [2] NASA/JPL/GSFC/SWRI/SSI (2010) "Zooming in on heat at Baghdad Sulcus", Cassini-Huygens, https://saturn.jpl.nasa.gov/