THE LUNAR THERMAL MAPPER INSTRUMENT FOR THE LUNAR TRAILBLAZER MISSION.

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Introduction: Lunar Trailblazer is a pioneering NASA SIMPLEx mission to investigate the presence and form of water on the Moon, selected for Phase A/B development with Preliminary Design Review in September 2020 to be ready for launch as an ESPA Grande class ride-along as early as late-2022 [1]. During the Phase A/B study a "ride-share" launch opportunity with NASA's Interstellar Mapping and Acceleration Probe (IMAP) has been baselined for a late 2024 launch. This presentation will detail one of the two science instruments, the Lunar Thermal Mapper (LTM), in the context of Lunar Trailblazer's science mission.

The detection of possible surficial water in both sunlit and shadowed regions via remote sensing of the Moon was one of the most unexpected discoveries of the 2000's. Observations by visible and near infrared (VNIR) imaging spectrometers, in particular the Moon Mineralogy Mapper (M^3) on Chandrayaan-1 [2] and confirmed by lunar flybys (e.g., Visible and Infrared Mapping Spectrometer (VIMS) on Cassini [3] and the Deep Impact spacecraft [4]) have shown possible water/hydroxyl features near 3 µm, with hints of spatial and temporal variation. At the lunar poles, observations of permanently shadowed regions with temperatures <100 K [5] from the Diviner Lunar Radiometer (Diviner) on NASA's Lunar Reconnaissance Orbiter (LRO), and measurements made by the LCROSS impactor [6] suggest water ice.

However, although measurements by M^3 were capable of detecting water, the instrument was not optimized to characterize it fully (e.g., form, abundance, and temporal variation). The Lunar Trailblazer mission is specifically designed to resolve these questions.

The Lunar Trailblazer Mission: Lunar Trailblazer focuses on understanding the Moon's water: its form (ice, H_2O, or OH), abundance, and distribution as well as the Moon's potential time-varying water cycle. A Ball Aerospace-integrated smallsat will carry the JPL High-resolution Volatiles and Minerals Moon Mapper (HVM^3) shortwave infrared (SWIR) imaging spectrometer [7] and the UK-contributed, University of Oxford/STFC RAL Space-built Lunar Thermal Mapper (LTM) thermal infrared (TIR) multispectral imager, which simultaneously measures composition, temperature, and thermophysical properties. Through coaligned measurements of HVM^3 and LTM at selected targets, Lunar Trailblazer has four primary science objectives: (1) determine water's form (OH, H_2O or ice), abundance, and local distribution as a function of latitude, soil maturity, and lithology; (2) assess possible time-variation in lunar water on sunlit surfaces; (3) use terrain-scattered light to determine the form and abundance of exposed water in permanently shadowed regions; and (4) understand how local gradients in albedo and surface temperature affect ice and OH/H_2O concentration, including potential identification of new, small cold traps.

Trailblazer provides unprecedented sensitivity for direct detection of lunar water at key targets. HVM^3 builds upon the demonstrated ability of M^3 to detect lunar water even in permanently shadowed regions [13] with enhanced spatial and spectral resolution, SNR, and spectral range. LTM brings enhanced spectral and spatial resolution relative to Diviner. Understanding the lunar water cycle, and determining the abundance, local distribution and form of water will support future human and robotic exploration and utilization of the Moon and its resources. Reconnaissance and characterization of potential landing sites will also be possible.

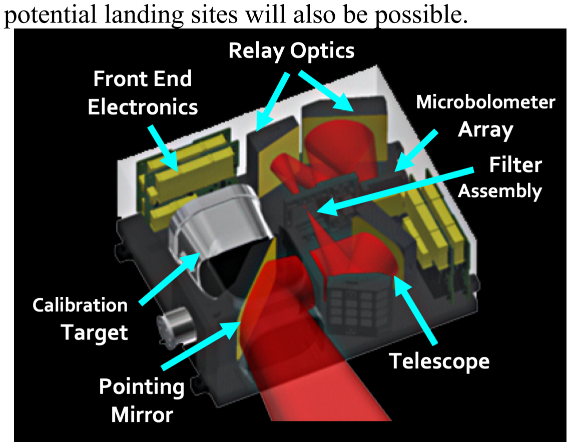

Figure 1. LTM, multispectral TIR mapper.

Lunar Thermal Mapper (Oxford University /RAL Space, Figure 1) is a push broom multispectral thermal mapper with eleven compositional and four temperature mapping channels. From an orbital altitude of 70 - 130 km LTM has an instantaneous field of view (IFoV) of ~18 -34 m/pixel and an average swath width (depending on detector layout) of ~12 km. LTM is co-aligned with HVM^3 to capture the temperature of the surface in the central section of the HVM^3 field of view [1].

Table 1. Baseline filter set for the Lunar Trailblazer Lunar Thermal Mapper. The current design includes eleven channels for compositional mapping (green) and four channels for surface temperature mapping.

Filter (µm)	Thermal	Composition	Inerference Filter	Mesh Filter	$\Delta \nu \approx 40cm^{-}$
7		x	x		x
7.25		x	x		x
7.5		x	x		x
7.8		x	x		x
8		x	x		x
8.28		x	x		x
8.55		x	x		x
8.75		x	x		x
9		x	x		x
9.5		x	x		x
10		x	x		x
6.25 - 12.5	x		x		
12.5 - 25	x		x		
25 -50	x			x	
50-100	x			x	

LTM uses a five mirror optical system and uncooled microbolometer detector array to map the lunar surface (Figure 1). The infrared filters for compositional and temperature mapping are mounted at an intermediate focus. Radiometric accuracy of the instrument is maintained by viewing an onboard blackbody calibration target and space with a motorized pointing mirror.

LTM's baseline set of infrared channels (Table 1) includes the three compositional channels that are currently in orbit around the Moon as part of the Diviner experiment [6]. This will allow cross-calibration and improved spatial resolution from Trailblazer's nominal 70 - 130 km operational orbit (~18 -34 m for LTM c.f. ~200 m for Diviner [8]).

Lunar Surface Temperature Investigation: LTM's main function as part of the Trailblazer volatiles investigation is to provide an independent estimate of surface temperature to augment the thermal correction procedure for the HVM^3 instrument in the ~3 µm region. This is achieved using a combination of four relatively broadband infrared channels that span 6.25 to 100 µm (Table 1) with roughly equal logarithmic wavelength spacings. A detector trade study is currently underway as part of the mission's Phase A activities, but a Noise Equivalent Temperature Difference (NEDT) of at least 5 K at 100 K is expected.

Compositional Investigation: LTM expands on the highly successful Diviner compositional investigation [e.g., 9] by including eleven narrow (~40 cm^{-1}) channels from 7 – 10 µm (Table 1). These eleven channels interrogate the position and shape of the Christiansen Feature (CF). Science targets for LTM's compositional investigation include: (a) the highly silicic constructs that were identified by their short (<7.8 µm) CF positions [10]; (b) Mg-spinel lithologies that occur in small (~ <5 km) exposures in multiple geological settings [e.g., 11]; (c) Possible mantle exposures near impact basins by examining the ratio of olivine to plagioclase (dunite vs. troctolite); (d) Irregular Mare Patches (IMPS, e.g [12]) with scales of 100 – 5000 m where Trailblazer's higher spatial resolution will provide fully spatially resolved multi-spectral maps for the first time.

Current status of the LTM instrument: As part Phase A activities a breadboard of the LTM instrument is currently under assembly and test at the University of Oxford, Department of Physics. In addition, the long-wave (>20 µm) performance of current generation commercial microbolometer detector arrays is under evaluation for selecting the flight detector.

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