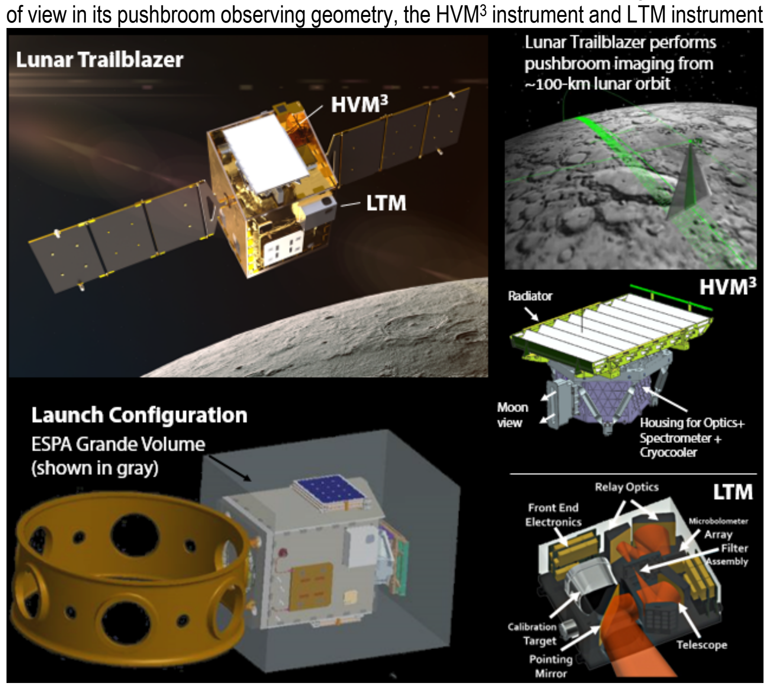
LUNAR TRAILBLAZER: A PIONEERING SMALLSAT FOR LUNAR WATER AND LUNAR GEOLOGY.

B.L. Ehlmann[1], R.L. Klima[3], C. L. Bennett[4], D. Blaney[2], N. Bowles[5], S. Calcutt[5], J. Dickson[1], K. Donaldson Hanna[6], C.S. Edwards[7], R. Green[2], M.A. House[8], A. Klesh[2], C. McCaa[9], J. Miura[1], C. Pieters[10], C. Seybold[2], D. Thompson[2], W. Williamson[2], J. Wood[9]. [1]Div. Geol. & Planetary Sciences, Caltech, Pasadena, CA, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [3]JHU Applied Physics Lab, Laurel, MD, [4]IPAC, Caltech, Pasadena, CA [5]Univ. of Oxford, United Kingdom, [6]Univ. of Central Florida, Orlando, FL [7]Northern Arizona Univ., Flagstaff, AZ [8]Pasadena City College, Pasadena, CA, [9]Lockheed Martin Space, Littleton, CO, [10]Brown Univ., Providence, RI,

Mission Objectives: Lunar Trailblazer is a NASA SIMPLEx smallsat mission for understanding the Moon's water and water cycle. Confirmed in November 2020, the ESPA Grande Lunar Trailblazer is in build (Fig. 1, 2). The spacecraft will be delivered in late 2022. Lunar Trailblazer's goal is to understand the lunar water cycle. Trailblazer is optimized to make targeted measurements of the infrared properties of the lunar surface to (1) detect and map water on the lunar surface at key locations to determine its form (OH, H_2O, ice), abundance, and distribution as a function of latitude, soil maturity, and lithology; (2) assess possible time-variation in lunar water on sunlit surfaces; (3) map the form, abundance, and distribution of water ice in the PSRs; and (4) measure surface temperature to quantify local gradients and search for small cold traps.

Figure 1. Schematics of the Lunar Trailblazer spacecraft, its launch configuration, fields of view in its pushbroom observing geometry, the HVM³ instrument and LTM instrument



Mission Profile and Spacecraft: Lunar Trailblazer is among the first generation of rideshare planetary smallsats, selected under the SIMPLEx-2 program. Implemented as a Class-D 7120.5e mission, Lunar Trailblazer is a PI-led mission at Caltech, managed by JPL with industry partner Lockheed Martin Space providing the spacecraft and integrated flight system. Science and mission operations will be led from Caltech. A student collaboration at Caltech and Pasadena City College involves undergraduate students—as well as graduate students and postdocs of the Co-I institutions—in all aspects of mission design and operations.

Table 1. Lunar Trailblazer mission and flight system characteristics

Mission Parameters	
Volume, Mass	ESPA Grande, MEV 210 kg
Lifetime	2 years (Launch – End of Primary Science Mission)
Lunar Orbit	100±30km polar
Comm.	DSN compatibility, X-band
Subsystem	**Manufacturer/ Model**
CDH	Cobham Sphinx w/ custom mezzanine board
FSW	ASI MAX + LM DSE FSW
GNC	Blue Canyon Flexcore System
EPS	GomSpace Power Distribution, LM Arrays
Propulsion	Monoprop Hydrazine System
Telecom	SDL Iris radio / LGAs
Mechanisms	Honeybee SADA + SADE
Instruments	HVM³ (JPL), LTM (Oxford)

Lunar Trailblazer has an MEV mass of 210-kg and fits within an ESPA Grande volume (Fig. 1, 3; Table 1). Its hydrazine chemical propulsion system provides ~1000 m/s of delta-v. From its separation from the primary, cruise to the Moon takes 4-7 mo., depending on the lunar phase at

Figure 2. Lunar Trailblazer is in build; select instrument components as of Nov. 2020

launch. Trailblazer uses its propulsion system to enter into a ~100-km polar orbit around the Moon. Lunar Trailblazer maintains its science orbit via periodic orbital maintenance, approximately every 3 months.

Data are acquired simultaneously in pushbroom mode with two science instruments: the High-resolution Volatiles and Minerals Moon Mapper (HVM^3) and the Lunar Thermal Mapper (LTM) to determine volatile content, lithology, and surface temperature (Figs. 1, 3; Table 2). The most sensitive measurement uses terrain-scattered light to map water ice content in permanently shadowed regions (PSRs). Over Trailblazer's ≥1-year primary science mission, each instrument will acquire ≥1000 targeted images of the Moon and additional data for calibration. Targets include sites of distinctive lithologic composition, sites viewed at multiple (≥3) times of day, targets along latitudinal gradients in areas of homogeneous composition, and PSRs.

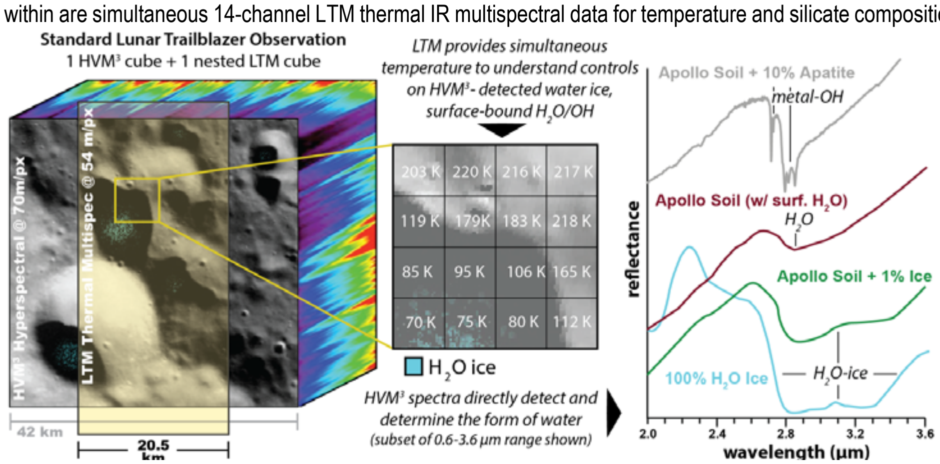
Instruments: HVM^3 is a MatISSE-developed, JPL-built, modernized version of the successful M^3 imaging spectrometer and has been optimized to identify and quantify water [1]. Active cooling of the focal plane and spectral range out to 3.6 µm with spectral sampling of 10 nm enable sensitive discrimination of the form and abundance of even small amounts of water by discrimination of the absorption band centers of bound OH/H2O versus H_2O ice. Longer integration times (5x) enable this capability within PSRs.

Table 2. Current best estimate observing parameters from 100±30 km orbit

HVM^3	
Spatial Sampl.	50-90 m/pixel
Swath Width	30-55 km
Spectral Range	0.6 – 3.6 µm
Spectral Sampl.	10 nm
SNR	>100 at reference
Uniformity	>90% cross track
# Data Cubes*	≥1000
LTM	
Spatial Sampl.	40-70 m/pixel
Spatial Width	14-27 km
Thermal	4 broad bands, 6-100 µm, for 110-400K (±<2 K)
Composition	11 channels, 7-10 µm w/ <0.5 µm resolution
# Data Cubes*	≥1000

LTM is a UK-contributed, University of Oxford-built miniaturized thermal infrared multispectral imager, optimized to simultaneously measure temperature, composition, and thermophysical properties [2]. LTM carries four temperature channels for identification of cold traps and 5 K discrimination of temperature on the lunar surface. LTM additionally has 11 compositional channels to measure the Si-O Christiansen feature, extending prior 3-channel maps at the Moon by the Diviner instrument to better discriminate silicate lithologies, particularly silicic and mafic endmembers.

Figure 3. Graphic of the simultaneous composition and temperature data that will be acquired by Lunar Trailblazer. The HVM^3 imaging spectrometer acquires data in 100's of infrared channels (0.6-3.6 µm) and nested within are simultaneous 14-channel LTM thermal IR multispectral data for temperature and silicate composition.



Trailblazer's dataset will comprise the highest spatial and spectral resolution shortwave infrared and mid-infrared maps to determine lunar volatile distribution and abundance, surface composition for geology, and surface thermophysical properties. If mission data return and mission duration permit, after satisfying its science objectives, Lunar Trailblazer will acquire additional data of high priority to the lunar science and exploration community, including geologic investigations of lunar lithologies (e.g., irregular mare patches, silicic domes, Mg-spinel-rich locations, dunite/troctolite regions, pyroclastic deposits) and reconnaissance for candidate landing sites. We are accepting suggested targets from community targeters (https://forms.gle/AwWsFWLzQPhycXmr7)

Acknowledgements: Thanks to the NASA HQ and PMPO offices and the entire team and staff contributing to the success of Lunar Trailblazer at Caltech, JPL, Lockheed, Oxford, RAL Space, UKSA, NASA, and other partners. For more information, see trailblazer.caltech.edu. Lunar Trailblazer is funded under NASA contract #80MSFC19C0042. References: [1] Thompson et al., LPSC 2020, abs. #2052 [2] Bowles et al., LPSC 2020, abs. #1380 [3] http://murray-lab.caltech.edu/LunarTrailblazer/webmap/