Candidate Lunar Traverse Gravimetry Investigations Enabled by the VEGA Gravimeter. A. Braun[1], K. A. Carroll[2], A. Ermakov[3]. Queen's University, Dept. of Geological Sciences and Geological Engineering, 36 Union St, Kingston, ON, K7L 3N6, Canada, braun@queensu.ca, [2]Canadensys Aerospace Corporation, kieran.carroll@canadensys.com , [3]University of California Berkeley Space Science Laboratory, eai@berkeley.edu.

Introduction: Surface gravimetry, a standard technique used to investigate the structure and composition of the Earth's subsurface, works equally well on other planetary bodies, e.g., during Apollo 17 the Traverse Gravimeter made measurements across the Taurus Littrow Valley (TLV), from which the thickness of the basalt slab underlying that valley was determined to be 1 km [1], and the details of the North and South Massif interface with that slab were deduced [2].

In order to deduce density estimates of lunar subsurface or surface structures, we require three components, i) a suitable gravimeter with sufficient precision, ii) a capable rover to deploy the gravimeter along a sufficiently long traverse, and iii) a survey design tool for lunar surface gravimetry.

VEGA Gravimeter: Like the Apollo Traverse Gravimeter, the Vector Gravimeter/Accelerometer (VEGA) instrument employs an inertial-navigation grade accelerometer to make gravimetry measurements. Using the measurement principle [3] of gimballing the accelerometer to "chop" the gravity signal followed by synchronous demodulation, VEGA eliminates low-frequency bias drift. Careful thermal control of the accelerometer and analog read-out electronics (to < 0.01 C) reduces mid-band noise. Repeatability of < 2 ppm has been demonstrated in thermal-vacuum tests over a wide temperature range (-30 to + 70 C). Absolute accuracy of 300 microGal is expected on the lunar surface, for 10-minute measurement sequences; longer measurements further reduce this RMS error. VEGA is in the final stages of development (TRL-5/6).

Lunar Rovers: Surface gravimetry investigations require that a gravimeter be transported to multiple stations across the surface, making gravity measurements at each station. The crew of Apollo 17 used their Lunar Roving Vehicle to carry out the traverse of the TLV. In the Artemis era, multiple lunar rover systems are being proposed and/or developed which could be suitable for conducting gravimetry surveys, including the Artemis Lunar Terrain Vehicle as well as the Endurance rover mission concept.

Survey Design: Prior sensitivity studies [2, 4, 7] considering a wide range of geometries, density, instrument precision and noise levels for lunar or planetary geological targets, have explored planetary gravimetry with very promising results. Multiple forward modelling software systems are available including traverse planning to estimate the mission requirements to observe particular target parameters. Here we discuss several types of science investigations using gravimetry traverses on the Moon. While any subsurface or surface density variations could potentially be investigated with the aid of surface gravimetry, we demonstrate what is needed (length of traverse, precision and duration of measurements), what can be achieved (uncertainty of density estimates, geometrical parameters, depth range and resolution), and what science would be enabled or not.

Constraining surface layer density. Nettleton [5] demonstrated a method for estimating the density of near-surface topographical features from the Bouguer gravity along the traverses for varying densities. We have applied an updated version of that method to determining the density of the Moon's Gruithuisen Domes [5]. Future lunar rover missions (e.g., Endurance) could apply this approach to estimate the density of features along their traverse path.

Exploring for potential lava tubes. Some lunar pit craters may be associated with potentially large lava tubes. We have demonstrated in [4, 6] that the surface gravity lows that would result from plausibly-sized lava tubes could be > 1 mGal. Gravimetry surveying in the vicinity of a pit crater would constrain the size, depth and strike of any associated lave tube.

Investigating lunar swirls. Lunar swirl features are typically accompanied by strong magnetic anomalies, the source of the latter being unknown. Conjectures include intrusive dikes bearing high iron content material [8], which could cause enough of a density anomaly to be detected using gravimetry.

In summary, all required components are available to implement surface gravimetry on many lunar and planetary missions. Any density structure/feature can be modelled through our modelling suite to quantify density estimates for particular traverses, eventually de-risking such missions before the flight.

References: [1] Talwani M. (Aug. 2003) *The Leading Edge*, pp.786-789. [2] Urbancic N. R. et al. (2017) JGR Planets, 122, 1181-1194. [3] Carroll K.A. (2019) US Patent No. 10,310,132. [4] Braun A., Carroll K.A. & Jolliff, B. (2022) *LPS LIII*, Abstract #2831. [5] Nettleton L.L. (1939) *Geophysics, 4,* 176-183. [6] Carroll, K. A. et al. (2015) *LPS XLVI,* Abstract #1746. [7] de Veld, F. et al. (2021) *LPS LIV*, abstract #2548. [8] Hemingway, D.J. and Tikoo, S. M. (2018) *JGR Planets 123*.