

# Lunar Surface Gravimetry Science Opportunities

Kieran A. Carroll<sup>1</sup>, David Hatch<sup>2</sup>, Rebecca Ghent<sup>3</sup>, Sabine Stanley<sup>4</sup>, Natasha Urbancic<sup>5</sup>, Marie-Claude Williamson<sup>6</sup>, W. Brent Garry<sup>7</sup>, Manik Talwani<sup>8</sup>, Harrison H. Schmitt<sup>9</sup>, Jennifer Elliott<sup>2</sup>

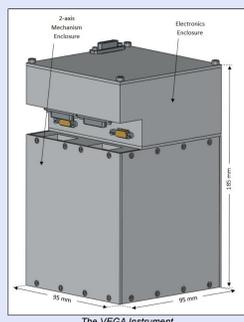
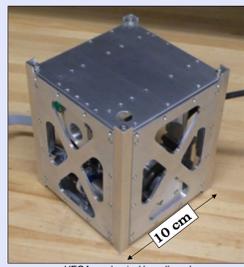
1: Gedex Systems Inc., kieran.carroll@gedex.com, 2: Gedex Systems Inc., 3: University of Toronto, 4: Johns Hopkins University, 5: University of British Columbia, 6: Geological Survey of Canada, 7: NASA GSFC, 8: Rice University, 9: University of Wisconsin-Madison

## Introduction VEGA Instrument

- Gedex has developed a low cost compact space gravimeter instrument, **VEGA** (Vector Gravimeter/Accelerometer)
- This instrument could be used in various lunar surface science investigations

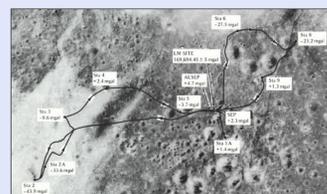
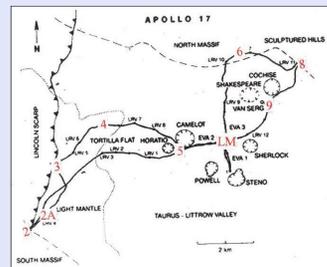
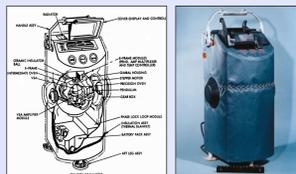
### VEGA Space Gravimeter Information

- Measures **absolute gravity vector**, with no bias
- Accuracy:** 0.1-1 microG on the Moon
- Bandwidth:** 1-10 mHz
- Size:** 9.5 x 9.5 x 18.5 cm
- Power consumption:** 4-12.5 W (depending on spacecraft temperature)
- Current Technology Status:** TRL 4



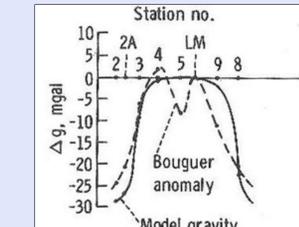
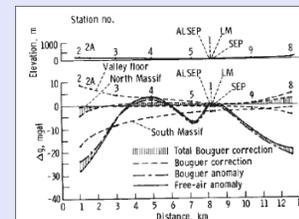
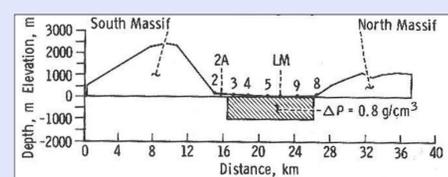
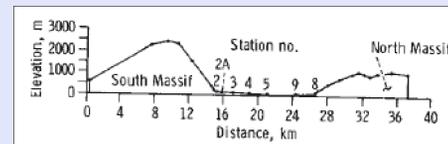
## Past Lunar Surface Gravimetry

### December 1972: Lunar Traverse Gravimeter Experiment on Apollo 17



- Gravimeter sensor is a Bosch ARMA D4E Vibrating String Accelerometer (VSA)
- Adapted [following Wing] by MIT's CSDL
- Scalar gravimeter
- Target performance: 1 mGal (1 microG)
- Achieved performance: 1.8 mGal RMS noise, 5 mGal accuracy

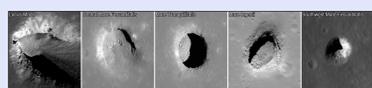
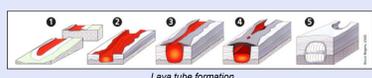
- This was the first surface gravimetry survey ever done off-Earth, and the only one done to date.
- Site: Taurus-Littrow Valley, Mare Serenitatis



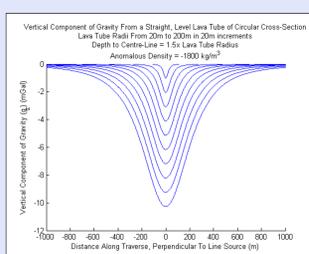
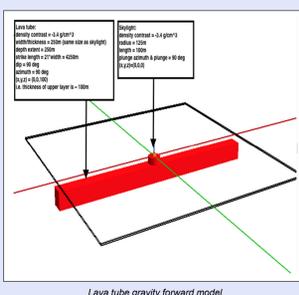
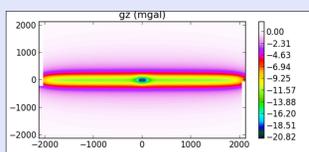
- Survey conducted by Harrison Schmitt and Eugene Cernan, funded by NASA
- An intriguing gravity low was found at Station 5...
- Science team: Manik Talwani (P.I.), George Thomson, Brian Dent, Hans-Gert Kahle, Sheldon Buck
- The survey "did geophysics," with the P.I. inferring subsurface structure from gravity results.

## Potential Near-Term Lunar Surface Gravimetry Science Investigations

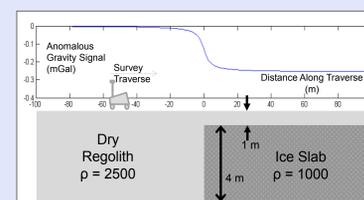
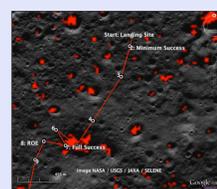
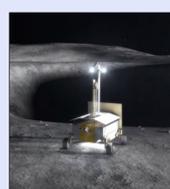
### Explore Lava Tubes



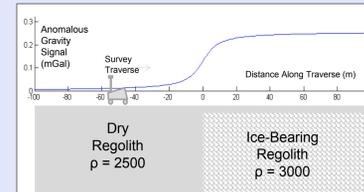
- Astrobotic Google Lunar X-Prize lander/rover mission to a pit crater in Lacus Mortis
- Gravimetry could "see" subsurface voids from the surface
- Forward modelling of a lava tube was performed to define range of parameters for detectable lava tubes



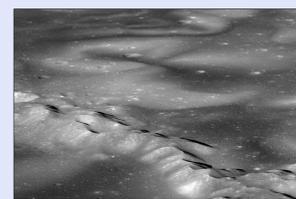
### Detect Lunar Ice



- 2020: NASA Lunar Resource Prospector
- Exploring Permanently-Shadowed Regions near a Lunar pole, looking for signs of ice
- Certain types of plausible ice deposits would produce measurable gravimetry signals



### Explore Lunar Swirls



Mare Ingenii Lunar Swirl



Reiner Gamma Lunar Swirl



Lunar Compass rover engineering model

- High-albedo, optically immature, sinuous features on the Lunar surface
- E.g., Reiner Gamma, Mare Ingenii
- These are coincident with relatively strong magnetic anomalies.
- Possible cause: an intrusion of iron-rich material near the surface
- This could cause a mass anomaly large enough to detect with a surface gravimetry survey
- Blewett et al. of JHU/APL have proposed a Lunar rover mission (Lunar Compass) to study lunar swirls. A VEGA instrument could help investigate the source of the Reiner Gamma magnetic field

### Taurus-Littrow Follow-up Gravimetry Survey



- PT Scientists is planning a lander/rover mission to Apollo 17 landing site in Taurus-Littrow Valley
- A rover equipped with a VEGA gravimeter could do a follow-up to the TGE gravity survey
- Survey with increased spatial resolution
- E.g., try to resolve details of the Station 5 gravity anomaly