Development of MEMS-Based Inertial Gravimetry for Planetary Exploration. C. S. Lawson[1], M. E. Evans[2], P. B. Niles[3], [1]Jacobs Technology-NASA Johnson Space Center (JSC), Houston, Tx.; [2]Texas A&M University at Galveston, Galveston, Tx. (chandler.s.lawson@nasa.gov; clawson41@tamu.edu); [3]NASA Johnson Space Center (JSC) Astromaterials Research and Exploration Science (ARES) (michael.e.evans@nasa.gov).

Introduction: Gravimetry, the measurement of slight variations in gravitational acceleration, can be used to infer density distributions in a planet's subsurface. While surface-based surveys are common on Earth, extraterrestrial surveys are typically confined to orbital platforms. This restricts the resolution of the data and inhibits the study of crustal structure at a finer scale, representing a need for data collected at the surface or near surface. Recently, the first surface gravity traverse on Mars was performed using the microelectromechanical systems (MEMS) engineering accelerometers on the Curiosity rover [1]. This study highlighted the potential of MEMS devices for planetary exploration. Additionally, such devices are more robust and have lower masses, costs, and power requirements than traditional gravimeters, adding to their suitability for planetary applications. NASA has developed an instrument that utilizes tri-axial MEMS accelerometers contained within an inertial measurement unit to conduct gravity measurements. Here, we discuss a project that aims to support wider efforts to develop MEMS gravimeters for planetary exploration [2,3].

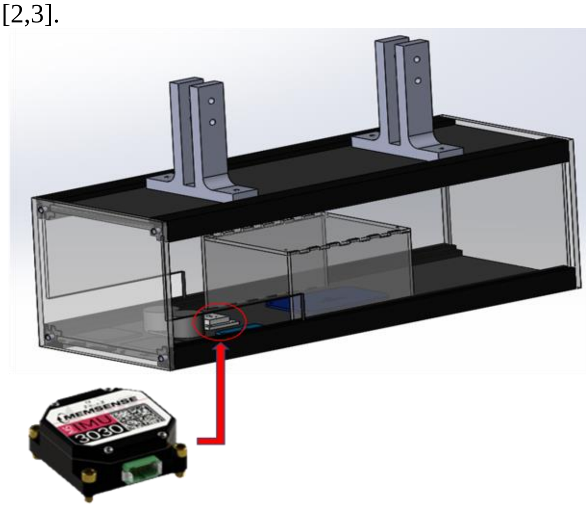

Figure 1 - Instrument suite enclosure containing the inertial measurement unit.

Method: NASA has developed an instrument suite that utilizes tri-axial MEMS accelerometers contained within a navigation-grade inertial measurement unit (IMU) to conduct gravity measurements [4] (Figure 1). By using the instrument to measure changes in the relative magnitude of gravity with changes in position and elevation; changes in subsurface density could be inferred. Laboratory data indicates that the measurements performed by the accelerometers are insufficiently precise for this application. Thus, we have developed a data processing method that accounts for tilt-related bias and scale errors, variations in temperature and atmospheric pressure, and noise.

For static point observations, a linear estimation algorithm is used to solve for the bias and scale errors along each accelerometer axis [5]. The accelerometers are subject to drifts induced by variations in environmental temperature and internal IMU temperature. Additionally, the accelerometers seem to be sensitive to changes in atmospheric pressure and a time-dependent unidirectional drift is present in all datasets. We use non-linear least squares regression to model these effects. Any remaining noise in the data is reduced via wavelet shrinkage denoising, which excel at modeling the transient effects associated with high-frequency noise.

Applying these methods to static datasets yields precisions of approximately 10 mGal, equivalent to the precision of the Martian survey. These methods will be applied to a survey of the High Island salt diapir. The survey will consist of both static-point and moving-base surveys along an 8.5km traverse (Figure 2). The moving-base surveys will require additional corrections to remove kinematic accelerations detected by the accelerometers. The development of more complex methods for moving-base surveys will be informed by the data collected during the traverse.

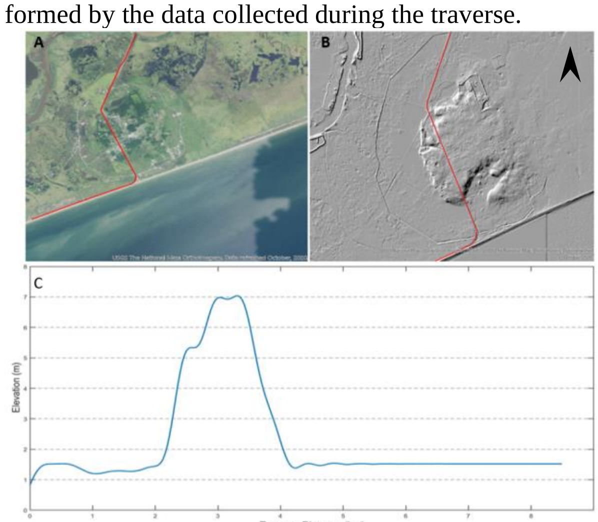

Figure 2 - High Island salt diapir on the Texas Gulf Coast. A) Planned traverse over the salt diapir. B) DEM with the traverse overlain. C) Elevation change over the traverse.

Summary: The successful application of MEMS accelerometers to the measurement of gravity variations resulting from subsurface density contrasts would further demonstrate the potential of such devices for planetary exploration. The development of moving-base survey methods could allow for airborne gravimetry to be conducted on bodies such as Mars to bridge the spatial gap between surface and orbital surveys. The low mass and power requirements make MEMS gravimeters well-suited for such applications. Given that orbital surveys are limited in spatial resolution, airborne and moving-base surveys would yield higher resolution data in a rapid and efficient manner.

References:

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