DEVELOPING A QCM FOR MEASURING DUST IN THE LUNAR ENVIRONMENT. D. Hooper[1], S. Ximenes[2], A. Palat[1], R. Battaglia[3], M. Mauro[3], E. Patrick[4], M. Necsoiu[4], Hyu-Soung Shin[5], B. Gorin[6], A. Dove[7], [1]WEX Foundation, 110 E. Houston Street, 7th Floor, San Antonio, TX 78205, [2]XArc Exploration Architecture Corporation, San Antonio, TX, [3]Novaetech S.r.l., Naples, Italy, [4]Southwest Research Institute®, San Antonio, TX, [5]Korea Institute of Civil Engineering and Building Technology, Republic of Korea, [6]GoVentures, Inc., Gaithersburg, MD, [7]University of Central Florida, Orlando, FL. (dhooper@wexfoundation.org)

Introduction: Dust is the primary environmental problem on the Moon, an issue that has been recognized since the Apollo era. Dust in the lunar environment is troublesome for both humans and equipment because of its strong adhesion, cohesion, and complex mechanical properties. For instance, it could cause thermal issues, or additional wear and abrasion complications on mechanical components. For humans (or astronauts), repeated dust exposure irritates the eyes, ears, nose, and throat and can damage the lungs. We are developing a Quartz Crystal Microbalance (QCM) as a tool to measure real-time lunar dust accumulation rates and deposition (Fig. 1). A QCM measures a mass variation in grams per second by measuring the change in frequency of a quartz crystal resonator.

Figure 1. QCM brassboard instrument testing in a simple dirty vacuum chamber. Arrow points to round quartz crystal resonator.

Our program objectives include a lunar surface payload intended to address the persistent speculation of lunar surface dust levitation rates and particle size distribution by measuring properties of sub-micron/micron level individual dust grains at near surface elevations that are lofted by surface disturbances. Dust levitation as well as detrimental dispersal may occur naturally or be induced through surface activity of robotics and eventual human presence. We will present on progress in the development of a QCM for lunar studies of dust particle mass accumulation and the potential interpretations for dust lofting, micrometeoroid impacting, and even solar wind deposition.

Background and QCM Testing: Using QCM technology for measuring dust in a space environment is not new. A QCM on the NASA Material Adherence Experiment (MAE) on board the Sojourner rover of the Mars Pathfinder mission was used to measure dust settling on solar panels [1]. More recently, a QCM was used in the GIADA instrument on board the ESA-ROSETTA spacecraft [2] and a configuration of three QCMs (the Opera instrument) is being developed [3].

Modified from a commercial off-the-shelf (COTS) QCM device, our QCM payload has been in development for the last 18 months as a student "payload to the Moon" program. The breadboard instrument configuration has achieved a rating of Technology Readiness Level (TRL) 4 through a stratospheric (120,000 ft.) balloon flight experiment for which we have done sensor calibration and interpretation of measurement data (Fig. 2).

Figure 2. Our high-altitude balloon flight (14 June 2018) included breadboard QCM testing.

Currently scheduled and in preparation are 1) a high-altitude balloon launch for comparison measurements with the breadboard flight data; 2) a low-altitude rocket launch to test stability of the quartz crystal under nominal launch and vibration loads; 3) thermal vacuum testing of the breadboard in a small 1-m diameter Dirty Thermal Vacuum Chamber (DTVC) scheduled for Jan. 2019; and then 4) brassboard vacuum tests scheduled for Spring 2019. The vacuum chamber testing will be conducted in Seoul, South Korea, at our teammate facility of the Korea Institute for Construction and Building Technology (KICT) [4]. As instrument prototype testing continues toward TRL 7, the QCM instrument prototype will be tested at KICT in their larger 4-m diameter chamber (Fig. 3).

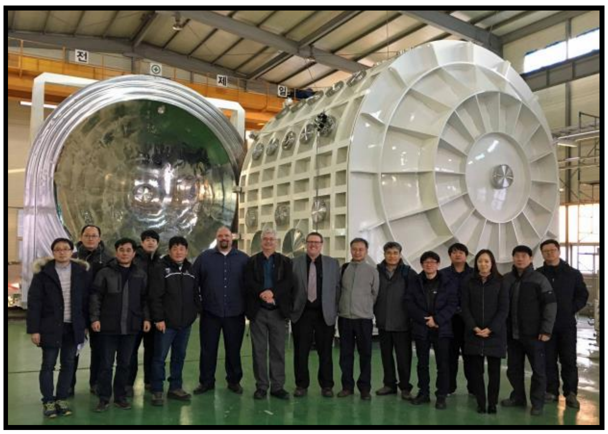

Figure 3. Visiting staff of Southwest Research Institute celebrate the first evacuation of KICT's large DTVC with their staff and contractors.

Conclusions and Path Forward: QCM dust measurements are highly dependent on the environmental conditions, observations of interest, and ability to calibrate and interpret the data (Fig. 4). For example, the electrostatic interactions between particles in the absence of an atmosphere may be a contributing factor to dust lofting, as well as to enhanced adhesion and cohesion. Additionally, micrometeoroid impact velocities expected at the lunar surface and those observed while orbiting a comet are quite different. Our QCM testing goals include development and calibration of this instrument in different environments that help us characterize measurement idiosyncrasies of the sensor that may have bearing on the interpretation of instrument data outputs in a lunar surface environment. Our technology development plan proposes advancing this lunar QCM technology from TRL 4 towards TRL 7, with lunar surface deployment of a QCM lunar dust instrument prototype to demonstrate, calibrate, and validate *in situ* dust counting measurements and our ability to accurately apply our interpretation algorithms. We have been working closely with the Astrobotic lunar lander team for a flight technology demonstration mission. Our QCM development program targets the instrument package for mounting on the payload platform of the commercial Astrobotic Peregrine lunar lander for their 2021 maiden flight.

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References: [1] Landis G. A. and Jenkins P. P. (2000) *JGR*, *105*, 1855–1857. [2] Della Corte V. et al. (2015) *Astronomy & Astrophysics*, *583*, A13. [3] Fries W. D. et al. (2018) *LPSC 49*, Abstract #2276. [4] Yoo Y. et al. (2018) *LPSC 49*, Abstract #2278.

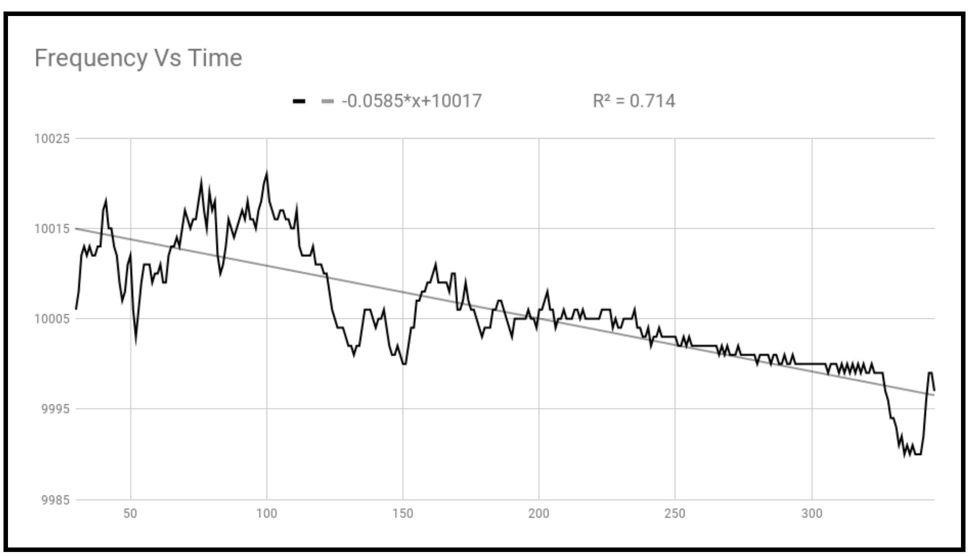

Figure 4. QCM test results from a simple vacuum chamber of agitated dust (see Fig. 1) and plotted as frequency (Hz) versus time (sec).