DEVELOPING A QCM FOR MEASURING DUST IN THE LUNAR ENVIRONMENT

WEX FOUNDATION — ADVANCING CAREERS IN SPACE

LCATS — Lunar Caves Analog Test Sites

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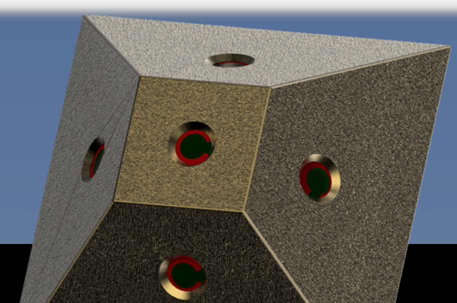

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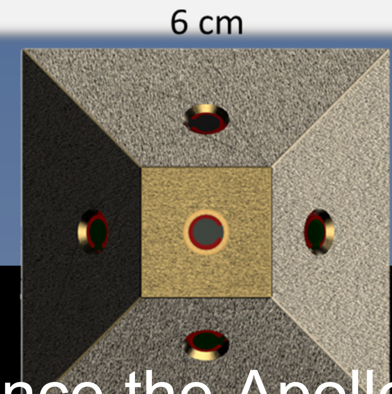


INTRODUCTION

Lunar dust is believed to be the number one environmental problem for lunar exploration. Its significance has been documented since the Apollo era but the last dust measurement instruments deployed on the lunar surface were the Apollo Dust Detector Experiment (DDE), which measured low-energy dust particles' collective movement and the changes in temperature it causes, and the Apollo 17 LEAM experiments which measure high-velocity ejecta dust particle impacts and the low-velocity lofted dust population. There has been persistent speculation about lunar surface dust levitation rates and particle sizes. Our lunar surface payload uses Quartz Crystal Microbalance (QCM) technology to address these open issues by measuring sub-micron and micron scale individual lunar dust grain properties at near surface elevations in real-time as the particles are lofted by natural or induced surface disturbances. Applications include monitoring dust lofting, micrometeoroid impacts, and solar wind deposition.

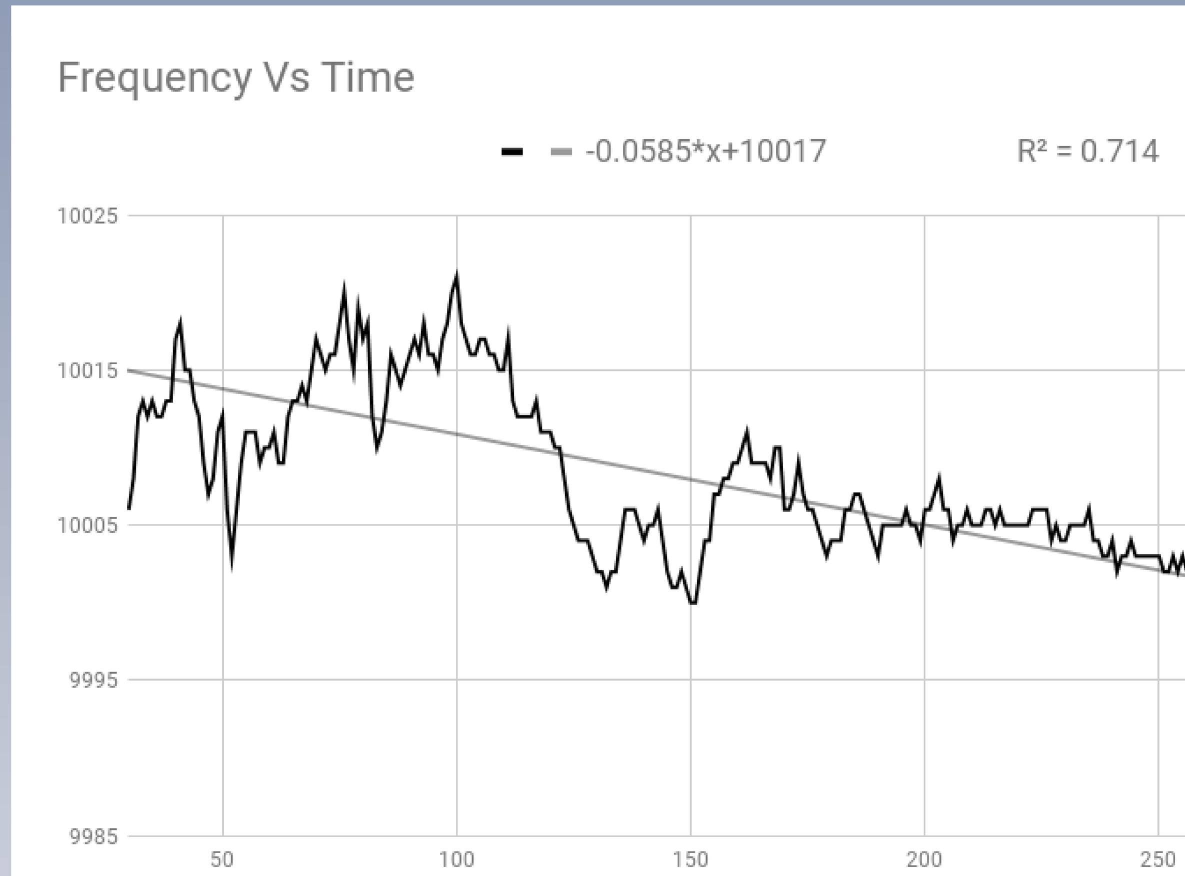
BACKGROUND AND QCM TESTING

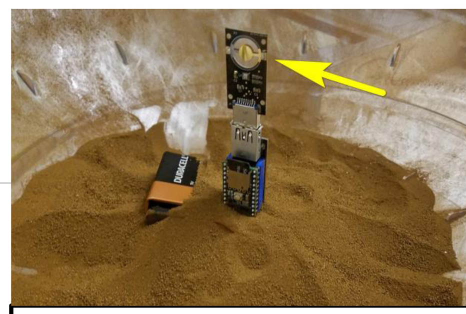
Modified from a commercial off-the-shelf (COTS) device, our QCM payload has been in development for the last 18 months as a student "payload to the Moon" program. The breadboard instrument configuration has achieved a rating of Technology Readiness Level (TRL) 4 through a stratospheric (120,000 ft.) balloon flight experiment for which we have done sensor calibration and interpretation of measurement data. QCM testing includes: A) another high-altitude balloon launch for comparison measurements with previous flight data; B) a low-altitude rocket launch to test stability of the quartz crystal under nominal launch and vibration loads; and C) "dirty" (dusty) thermal vacuum testing to:

1. Characterize the quartz crystal frequency-temperature relationship in a vacuum;
2. Assess particle collection on the quartz crystal surface in various orientations;
3. Assess electrostatic particle coupling to the quartz crystal at multiple voltages; and
4. Assess particle coupling to the quartz crystal surface using adhesive materials.

PATH FORWARD

Our technology development plan advances our QCM technology from TRL 4 to TRL 7 by 2020 in preparation for lunar surface deployment in 2021. The proposed work includes building and testing a QCM lunar dust prototype instrument to demonstrate, calibrate, and validate in-situ dust counting measurements.



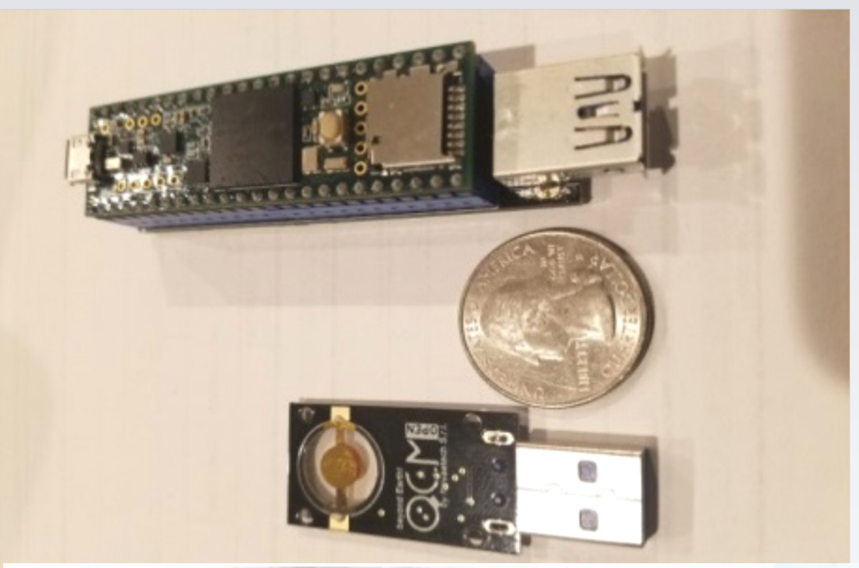


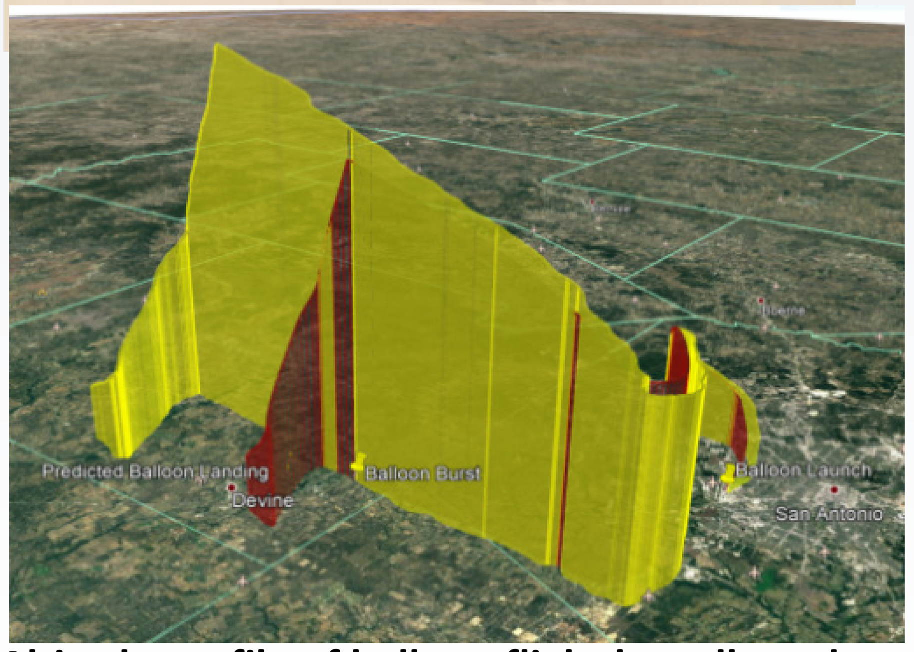
QCM breadboard instrument testing in a simple dirty vacuum chamber. Arrow points to round quartz crystal resonator.

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

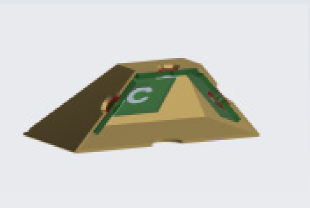
COTS Field Test-Fall 2017		Upper Atmosphere Test-Summer 2018			Fall 2018	Spring 2019	Summer 2019	2019 - 2020		2020		1Qtr 2021	2021
Notional Design	Model / Simulation	Breadboard Design	Breadboard Built	Breadboard Verification	Brassboard Design	Brassboard Built	Brassboard Verification	Prototype Design	Prototype Built	Prototype Verification	Tested in Simulation Operational Environment	Launch and Lander Payload Integration	Flight Operations (Technology Demo)

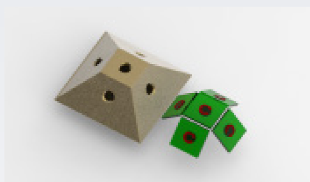
weighing mass deposition down to 1 billionth of grams



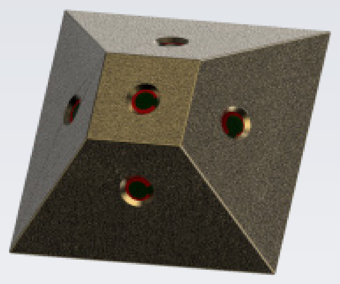


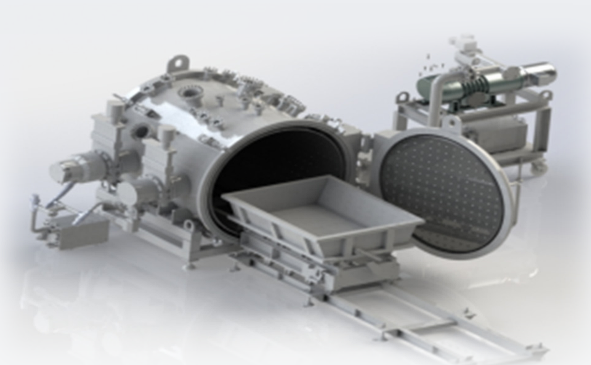
Altitude profile of balloon flight breadboard test





Breadboard dust lofting test in low vacuum desiccator

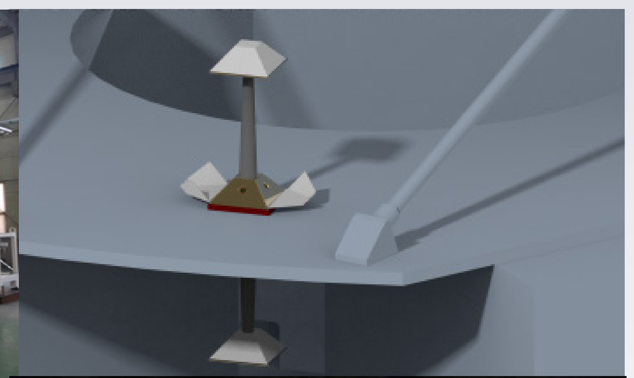




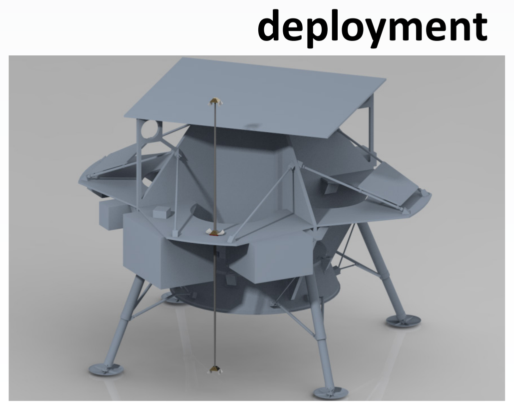
Brassboard testing in KICT Φ1.0 m Pilot "Dirty" Thermal Vacuum Chamber (DTVC)

Balloon and sub-orbital rocket flight brassboard tests

Prototype verification tests in KICT Φ4.0 m "Dirty" Thermal Vacuum Chamber (DTVC); full boom zenith and nadir deployment



Prototype test in operational environment



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