DEVELOPMENT OF A LUNAR DUST INSTRUMENT TO STUDY THE DEPOSITION OF MICRO DUST PARTICLES ON THE LUNAR SURFACE.

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Introduction: The Lunar Cave Analog Test Sites (LCATS) program hosted by the WEX Foundation, is working on a student payload to the moon that is centered around the Quartz Crystal Microbalance (QCM). The QCM is designed to determine the rate of deposition of lofted dust particles on the lunar surface and form a predictive model to estimate the deposition over a larger area. Charged dust particles lofted on the lunar surface pose an issue to both humans and equipment[1]. These predictions will help future missions work around the abrasive dust particles and potentially extend the sustainability of their instrumentation. The QCM was selected because of its highly sensitive piezo-electric properties that determine the mass on its surface by calculating the frequency shift.

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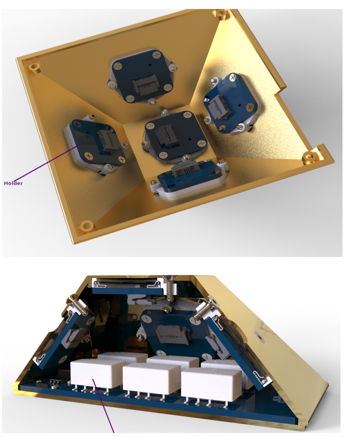

Figure 1. The final design of the QCM.

Current Stage: The payload encompasses the housing structure, control system, and the QCM. The payload is currently at a Technology Readiness Level (TRL) of 5. The final design of the QCM (Figure 1) was developed after going through multiple prototypes and tests in simulated lunar environments. The housing structure and the control system of the payload (Figure 2) were designed and tested by undergraduate seniors from the University of Texas at San Antonio. The payload is currently scheduled for a radiation test, which if successful, will classify the payload as a TRL of 6. The pyramid structure for the QCM was selected to analyze the behavior of the particle's adhesion on surfaces at different angles. The device also has a temperature sensor mounted on each side to correlate the effects of temperature variations caused by lunar day and night. The onboard microcontroller is designed to retrieve data at specific time intervals to provide a wider range of data sets to help understand accumulation rates and get a more precise estimate with the added layers of dust on the crystal.

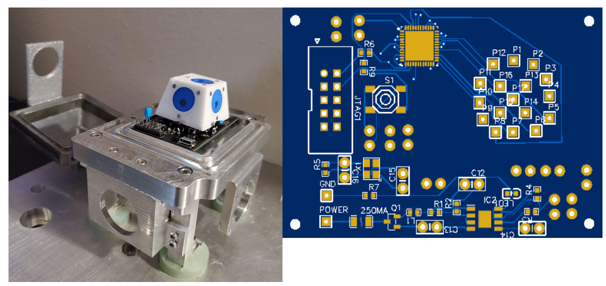

Figure 2. Housing structure and control system developed by the students.

Analysis: The QCM detects minute changes in the mass accumulated on the crystal surface by recording the shift in the frequency of the oscillation. The QCM's hypersensitivity helps calculate micro dust particles as light as a few nanograms. However, the hypersensitivity has a major drawback, where the smallest disturbance or vibration while active, can hinder the accuracy of the data collected. This was taken into consideration while developing the payload module. The housing structure has an internal accelerometer to detect any disturbance caused by an external force. The data from the accelerometer readings will be taken into calculations to account for frequency shifts not caused by mass accumulation. The calculations for the rate of deposition of microparticles on the surface of the crystal is commonly calculated with the Sauerbrey equation,

$$\Delta m = -\frac{A\sqrt{\rho_q * \mu_q}}{2f_0^{2}} * \Delta f$$

which defines the mass-frequency relationship, however it does have its limitations. For example, the Sauerbrey equation does not take both the Gaussian distribution of mass sensitivity and the influence of the metal electrodes into consideration[2]. The application of the formula based on the data collected has a significant impact on the accuracy of the calculations. As observable in the plotted frequency vs time graph (Figure 3), the graph has rough shifts in data, which has to be assumed as a significant change in mass on the crystal. Taking into consideration the frequency tends to stabilize when the accumulated mass remains the same, we split the graph into key shifts and calculate the individual portions that will provide a more accurate estimation of the mass accumulated at specific time intervals.

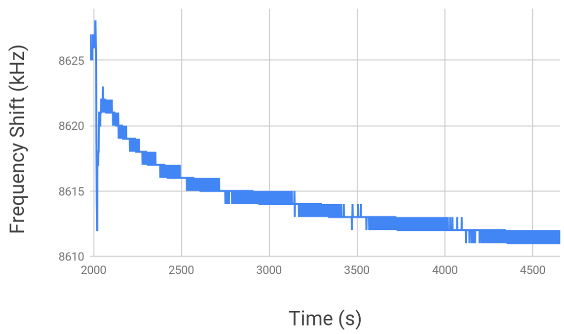

Figure 3. Frequency vs Time.

Another factor that could hinder the accuracy is the build-up of micro dust particles over some time that is not removed completely between trials. The resonant frequency for the crystal is set at 10 Mhz, however, after a couple of tests the resonant frequency drops. For example (Figure 3) has the base oscillation around 8 Mhz. With all of these taken into consideration, the data (Figure 3, Figure 4) was sorted into multiple time intervals based on each switch and estimated at 4.71 micrograms at the rate of 28.5 nanograms per second. The estimate while using the Sauerbrey equation with the data set as a whole was 71.04 micrograms at the rate of 28.5 nanograms per second.

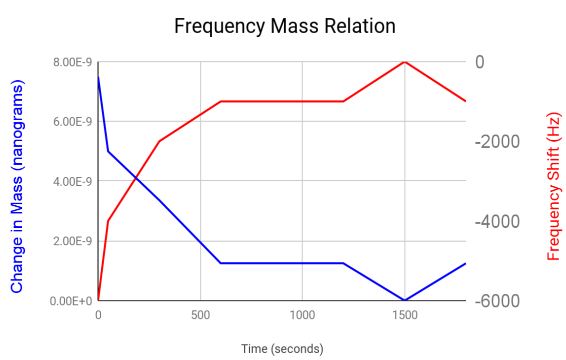

Figure 4. The inverse relationship between the change in mass and the frequency shift.

Conclusion and Future Tests: Further studies are required in order to obtain an absolute value for the mass on the crystal. The next few stages of our work will include finding a precise control to calculate the percent of error between the calculations,as well as the incorporation of a vacuum grease, Apiezon H. The grease will enable the dust particles to form a stronger bond to the surface reducing the bouncing effect causing minor shifts in the oscillations. The adhesive grease has been successful on a sticky QCM on the Chang'E 3 mission to the lunar surface [3]. For the payload, the next couple of stages will include passing the radiation exposure test and moving forward on the TRL scale, with the goal of the deployment of a QCM lunar dust instrument to demonstrate and validate in situ mass accumulation measurements.

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