FARSIDE SEISMIC SUITE (FSS): SURVIVING THE LUNAR NIGHT AND DELIVERING THE FIRST SEISMIC DATA FROM THE FARSIDE OF THE MOON. M. P. Panning[1], S. Kedar[1], N. Bowles[2], D. Bugby[1], S. Calcutt[2], J. Cutler[3], J. Elliott[1], R. F. Garcia[4], T. Kawamura[5], P. Lognonné[5], E. Miller[1], C. Nunn[1], W. T. Pike[6], G. Pont[7], S. de Raucourt[5], I. Standley[8], W. Walsh[1], R. Weber[9], C. Yana[7], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]University of Oxford, [3]University of Michigan, [4]ISAE-SUPAERO, [5]Institut de Physique du Globe de Paris, [6]Imperial College, London, [7]CNES, [8]Kinematrics, Inc., [9]NASA Marshall Space Flight Center

Introduction: The Farside Seismic Suite (FSS), recently selected for flight as part of the NASA PRISM (Payloads and Research Investigations on the Surface of the Moon) program and planned for flight in 2024 or 2025, would deliver two seismometers (both flight-proven through the InSight mission to Mars [1]) to Schrödinger Crater. The vertical Very BroadBand (VBB) seismometer is the most sensitive flight-ready seismometer ever built [2], while the Short Period (SP) sensor is the most sensitive and mature compact triaxial sensor available for space application [2]. Packaged as a self-sufficient payload, with independent power, communications and thermal control allowing survival and operation over the long lunar night, the FSS will outlive the commercial delivery lander, and provide a long-lived seismic experiment capable of answering key scientific questions.

Science Goals: FSS will address three science objectives with this project:

1. *Investigate deep lunar structure and the difference between near and farside activity*. Understanding the absence of farside seismicity recorded on Apollo seismometers [3] is fundamental to our understanding of the lunar deep interior. Does it reflect a nearside-farside difference in activity rate, or does seismic attenuation from partial melting in the mantle prevent observation of distant events [e.g. 4]? Direct recording of farside activity, as well as possible recording of known repeating nearside moonquakes or events determined from impact flash observations will illuminate these questions.

2. *Understand how the lunar crust is affected by the development of an impact melt basin*. Dynamic models of impact processes [e.g. 5] predict deep structure beneath a well-preserved peak ring impact basin like Schrödinger Crater that can only be revealed through geophysical techniques based on receiver functions [e.g. 6,7] and autocorrelation of ambient noise and/or event codas [e.g. 8,9,10].

3. *Evaluate the current micrometeorite impact rate and local tectonic activity*. Directly constraining micrometeorite impact rates has important implications for future lunar occupation. The lunar background seismic noise is modeled to be driven by micrometeorite impacts [11]. FSS will record 4 months of lunar background hum created by micrometeorite impacts.

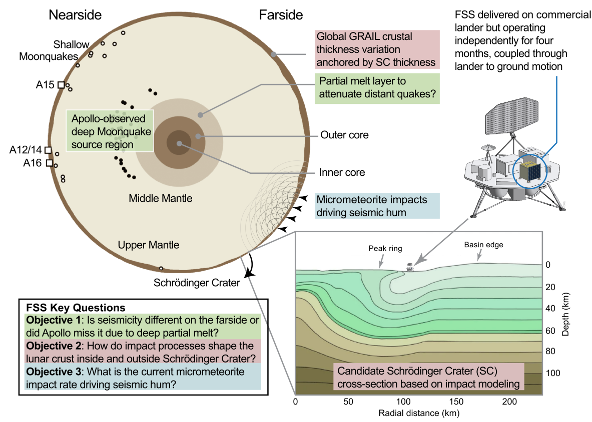

Figure 1. FSS will return data with unprecedented sensitivity from Schrödinger Crater over multiple lunar diurnal cycles after outliving the delivery lander. FSS provides: (1) The first seismic data probing the deep lunar interior and determining the differences between near and farside activity (green); (2) Measurement of crustal thickness and layering that illuminates the process of crater formation (pink); (3) Current micrometeorite impact rate through recording of background seismic vibrations (blue). Figure adapted from [12] and [5].

Instrumentation: FSS is based on two complementary seismic instruments. The VBB instrument is the most sensitive planetary seismometer ever flown, capable of measuring accelerations of a few tenths of a nm/s^2 [2], which should be more sensitive than the Apollo instrumentation by a factor of 3 near the peaked sensitivity of the Apollo long period seismometers at ~0.5 Hz [e.g. 13], and by more than an order of magnitude away from that peak. The VBB will be a single flight-spare instrument from InSight rotated to measure only the vertical component of motion. The SP instrument is a compact, capable micromachined silicon design [2,14] which is a new build based on the InSight SP design. The SP will provide 3-component sensitivity to complement the ultrasensitive vertical component VBB.

Package Design: While FSS will be delivered by a commercial lander to Schrödinger Crater, it needs to function independently of the lander in order to continue operating beyond the first lunar day. The FSS requires its own independent power, communications, and command and data handling system, since the lander is expected to cease functioning at the end of the first lunar day. The package will be powered by a single solar panel mounted to the side of the package (suitable for the high latitude of Schrödinger Crater), with sufficient batteries to operate the seismometer continuously through the night.

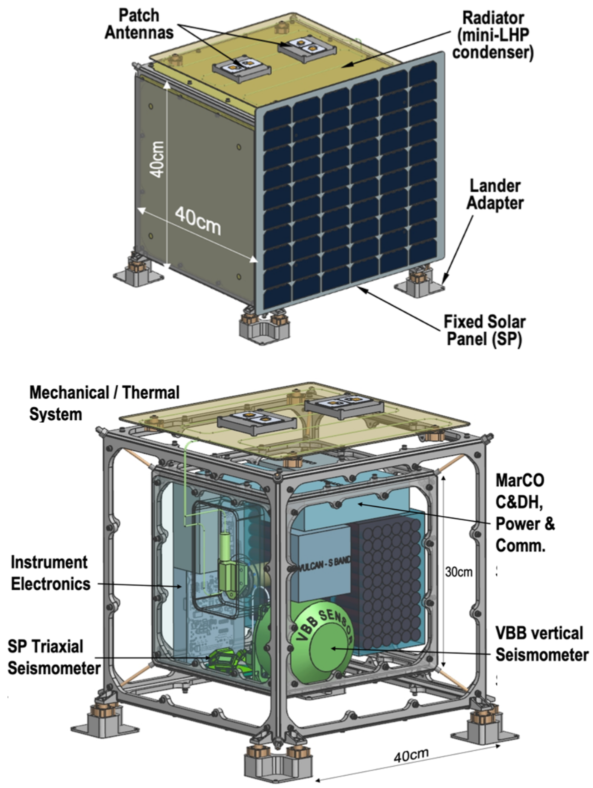

Figure 2. FSS utilizes a "cube within a cube" design (bottom) with insulation between the cubes providing excellent thermal isolation to remain warm through the night, while an efficient thermal switch and mini-loop heat pipe system keeps it cool during the day.

In order to allow operate efficiently through the cold night and hot day, FSS requires an innovative thermal design. It is based around a cube within a cube design, with spacerless multi-layer insulation separating the two cubes, to permit the dissipation of the heat from the seismometer systems to maintain overnight temperatures, while daytime temperatures are controlled by an efficient thermal switch and mini-loop heat pipe (mini-LHP) system connected to an upward-facing radiator.

The Command and Data Handling (C&DH) and power system is built on flight spare equipment from the MarCO CubeSat mission which was the first interplanetary CubeSat which flew along with InSight and successfully returned data from the InSight entry, descent and landing process on Mars. Communication will be enabled by a Vulcan S-band radio communicating with a relay satellite provided by a commercial vendor. Communication will only happen during the day to minimize power usage overnight.

Conclusions and Future Directions: FSS is designed to answer several key lunar science questions from a single station on the farside of the Moon. The FSS will also allow for key technical advancement and risk reduction for future missions, such as the Lunar Geophysical Network, a candidate New Frontiers 5 mission [15]. Because deployment increases cost and complexity, assessing the need for deployment and characterizing the lander seismic noise environment will be key. In addition, measuring the lunar seismic noise floor beyond what was possible with the Apollo data will permit better requirements definition for future lunar seismic missions and future astrophysics observatories sensitive to lunar ground stability.

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