National Aeronautics and Space Administration

Rover-Deployable Distributed Acoustic Sensing

Principal Investigator: Andrew Klesh (312); Co-Investigators: Mark Panning (322), Issa Nesnas (347), Zhongwen Zhan (Caltech)

Program: FY22 R&TD Topics
Strategic Focus Area: Lunar Science

Objectives

Most seismic networks consist of discrete sensors that are hand-placed for tight ground coupling. These networked sensors often have a spatial density of one sensor to cover multiple square kilometers. DAS is fully dependent upon the layout of a tether, but can have a density of measurements along the cable at ~1 m spacing and up to thousands in number. At current maximum length (and techniques are improving regularly), a DAS system can make measurements fully along a 100 km tether. As Axel has a pre-existing tether with embedded optical fibers, we can simultaneously take DAS and DTS measurements upon deployment. Rather than needing to deploy a massive and power-hungry instrument at every desired sensing location, the DAS interrogator instrument can remain at the lander, and only the fiber needs to be deployed, providing a dense network of seismic data.
This effort had two objectives:

- Evaluate Axel's deployment and operation of a >300 m DAS fiberoptic tether to enable ~1 measurement/meter in two configurations: (a) horizontal and (b) under strain.
- Evaluate the SNR of a >1 km tether with multiplexed fibers containing both data and DAS signals at a density of greater than 1 measurement / meter.

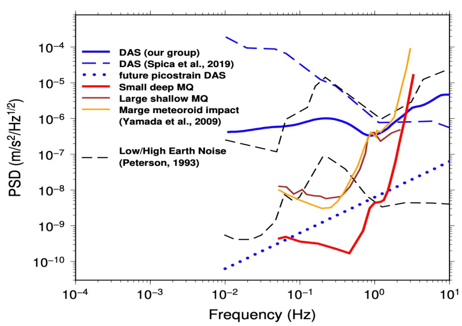
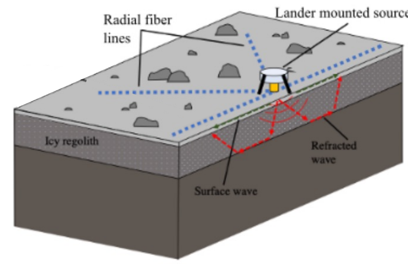


Figure 1: Comparison of DAS noise figures. W. Wu, et al., Fiber seismic network on the Moon, in preparation, Icarus, 2021.

Background

Few seismic monitors have been placed on planetary surfaces, and, like InSight's SEIS, they can be very complex and delicate devices. Distributed Acoustic Sensing (DAS) is a robust and novel method to interrogate optical fibers with a laser-based instrument to determine seismic activity along the fiber. As a dense seismic network, DAS can not only record earthquakes, but can potentially provide high-resolution structural images of the crust and mantle. Funded by KISS and Caltech's Space Innovation Council, Caltech conducted numerical simulations of lunar seismic wave propagation to show that a DAS array would help suppress noise from shallow Moon heterogeneities and provide significantly clearer images of the lunar interior than previous studies. Thus, DAS will likely play an important role in many fields of passive seismology in the near future.

Figure 2: Schematic diagram of a possible survey geometry with a lander-mounted source and radially deployed fiber lines acting as seismic receivers. A-Team recommended.



Approach and Results

We utilized existing COTs DAS instruments and the Axel rover to perform the tasks in this effort. Axel houses a spool that can support a 300–350 m tether with a diameter of 4 mm that can support its ~60 kg mass. Tethers in excess of 1 km tethers require smaller diameters used for surface deployments only (not rappelling), or an alternate spooling mechanism. For objective 1), because the existing Axel tether management system was limited in both tether diameter and length, a new mechanism was designed and manufactured. Both material sourcing and mechanical design challenges led to significant delays in mechanism development, final field testing was not accomplished. To provide a proxy, simple mechanical spool carts were used to deploy tethers both on paved and rugged terrain. Tether ground-coupling was evaluated on 1 and 3 km segments (including via parallel field efforts at Kilauea). Though active (Axel) or passive (spool) tether management can maintain a set tether tension, there is no feedback from the ground terrain, which can lead to tether suspension on particularly rugged areas. In part, this can be accommodated by DAS software averaging and channel spacing, but in practice has been adjusted by field personnel.

An A-team study evaluated the future use of rovers vs simpler deployment for near-term lunar DAS feasibility – the complexity of rovers, including tether management, strongly indicated that spring-launch or crew deployment would be better pursued rather than rover deployment due to the complexity or mass costs. Additionally, uncertainty in how to control the rover over long distances given rugged terrain diminishes its usefulness.

At Caltech, a DAS instrument was integrated with the existing Caltech / Pasadena fiber loop. Here, simultaneous DAS and multiplexed data testing was completed (both on-lab and off). Analysis of data show that will be able to be shared with DAS measurements with little to no degradation. As some lunar concepts already have fiber-based systems being deployed for data transfer, this strongly indicates that combining DAS with other efforts may be the correct path forward.

Significance/Benefits to JPL and NASA

NASA and JPL have long sought a lunar seismic network, beginning with the Surveyor and Apollo missions. Axel and DAS seek to revolutionize this field by providing a high-density seismic network exploiting assets already in place – Axel's existing tether, or even a lunar base's telecommunication network. DAS arrays also open up active source techniques, which rely on dense network recordings of known seismic sources potentially supplied by vibrational sources on a lander or controlled impacts.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#
Poster Number: RPC#

Publications:

None

PI/Task Mgr. Contact Information:

Email: Andrew.T.Klesh@jpl.nasa.gov