Hardware Prototype for Passive Sounding of the Moon and Solar System Objects

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Project Objective:

Evidence suggests lunar lava tubes exist in the Moon's subsurface:

- Gravity measurements with GRAIL (Chappaz et al., 2017)
- Low frequency sounding with LRS on SELENE (Haruyama et al., 2009)

Passive sounding using the Sun and Jupiter as radio sources (Romero-Wolf et al. 2015 & 2016, Schroeder et al 2016, Carrer et al 2018, Peters et al 2018) offers a low-resource means of finding lunar lava tubes from orbit and characterizing them with small rovers.

(1)Build a hardware prototype of a passive sounder that uses radio emission from Jupiter to probe the Moon and other Solar System objects.

(2) Demonstrate the concept requires only the low mass, power, and processing capability of a smallsat or small rover implementation.

FY18/19 Results:

Milestone 1: Instrument requirements (Completed)

- Definition of the on-board data processing architecture (Figure 3).
- Lunar passive sounding delay maps.
- Passive synthetic aperture radar (SAR)
- Quantification of number of sounding opportunities (Figure 4).

Milestone 2: Hardware prototype (In Progress)

- Coordinated the development of the three main threads: prototype board construction, firmware architecture, and implementation.
- The hardware schematics completed.
- Currently defining the FPGA real-time correlation and spectrogram architecture.

Milestone 3: Field tests (start in mid-FY20).

Benefits to NASA and JPL:

The inherently lower resource needs of this approach could enable:

- low-cost smallsat or small rover missions aimed at revealing the Moon's subsurface lunar lava tubes.
- Low-cost planetary sounding instruments.
- Distributed arrays for sounding Earth and solar system bodies.

References:

Arya, A., et al., 2011. Curr. Sci. 100 (4) (00113891); **Blair**, D.M., et al., 2017. Icarus 282, 47–55.; **Carrer**, L., et al., 2018, Planetary and Space Science, 152, 1-17; **Clarke**, T.E., et al., 2014, JGR: Space Physics, 119, 9508-9526; **Haruyama**, J., et al., 2017, Lunar and Planetary Science Conference, vol. 48.; **Horz**, F., 1985., Lunar Bases and Space Activities of the 21st Century, pp. 405–412; **Karras** J., et al., 2016, 3rd International Workshop for Instrumention for Planetray Mission, Contribution No. 1980; **Olhoeft**, G., **Strangway**, D., 1975, Earth Planet.Sci.Lett. 24 394. ; **Peters** et al., 2018, IEEE TGRS, 56, 12; **Prager** S., et. Al. IEEE Radar Conference, Oklahoma City, KA, April 2018.; **Romero-Wolf** et al., 2015, Icarus, 248, 463; **Schroeder** et al., 2016, P&SS, 134, 52; **Romero-Wolf** et al., 2016, P&SS, 128, 118

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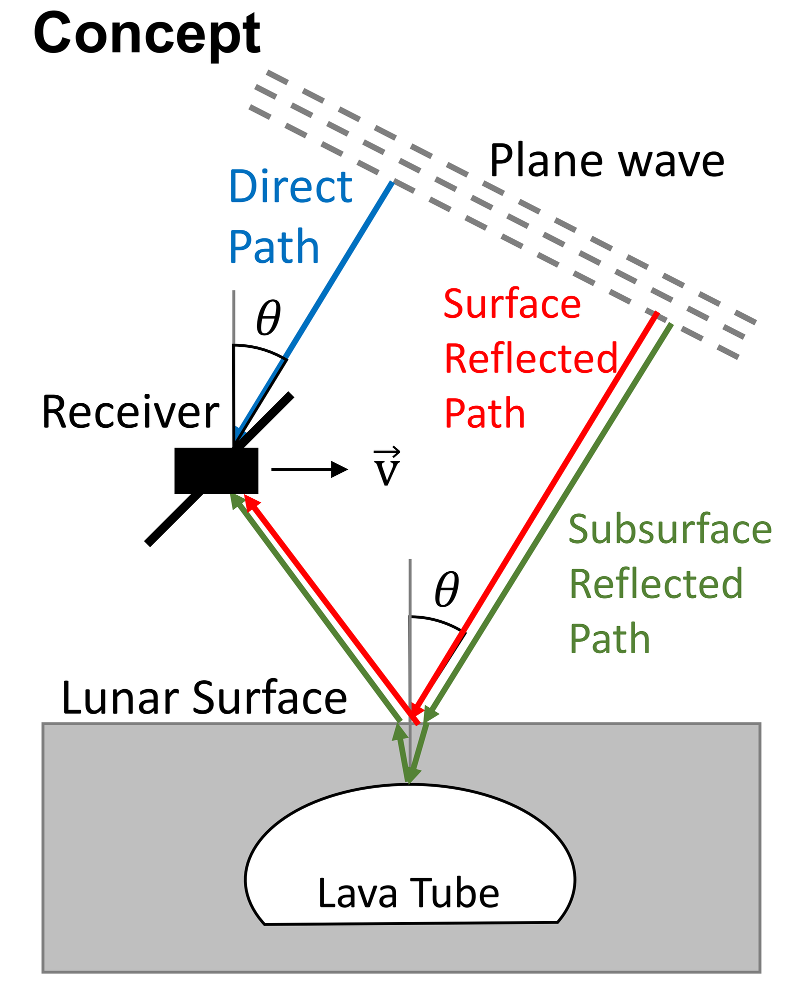
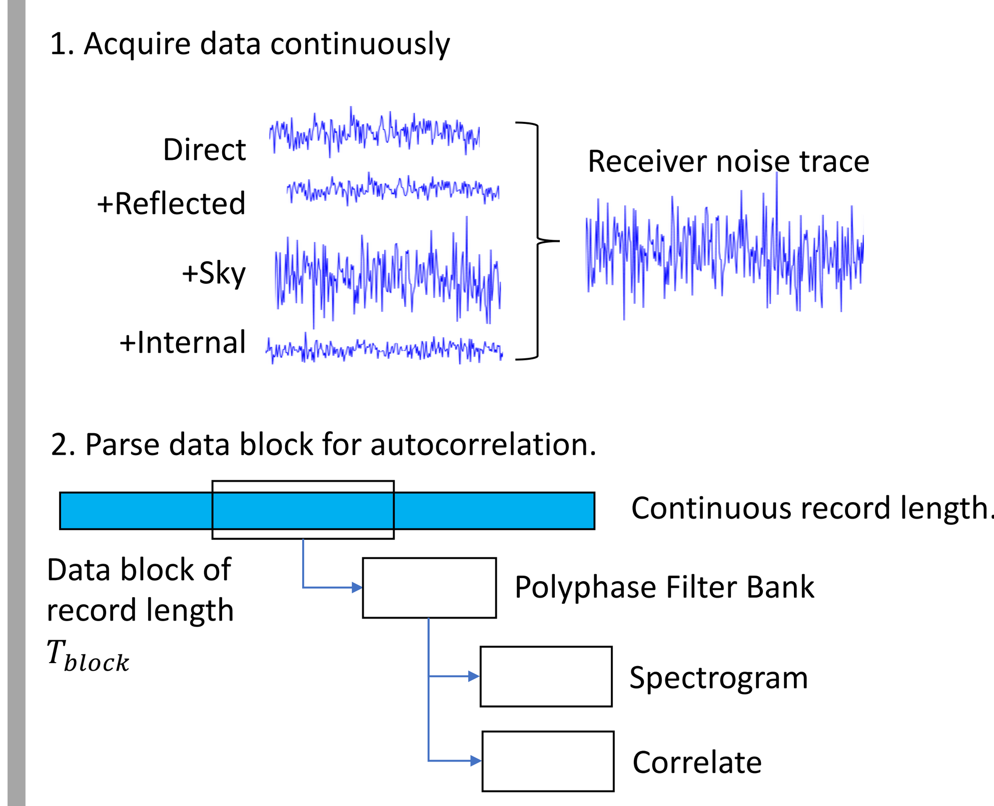
Concept



Measurement



Reflections are extracted from delayed correlations of the receiver noise trace.

Instrument

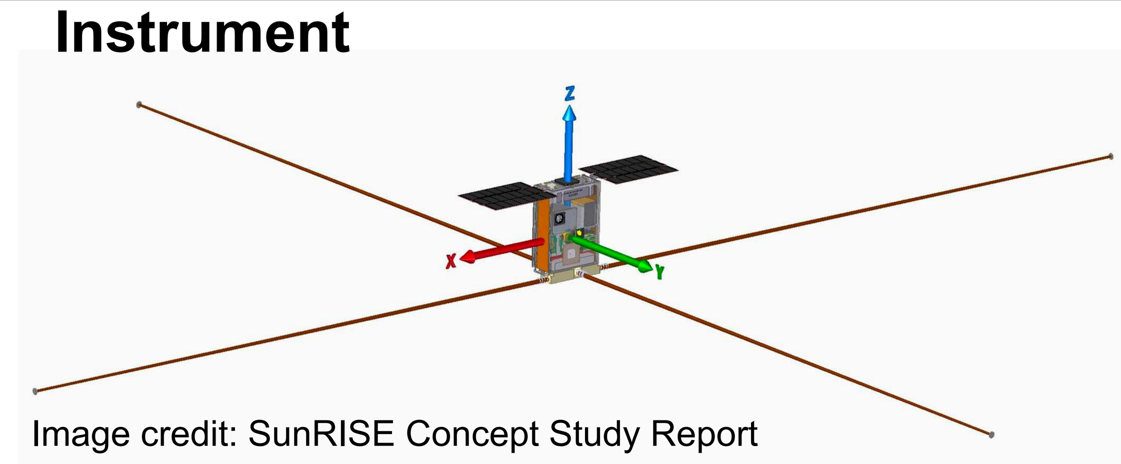
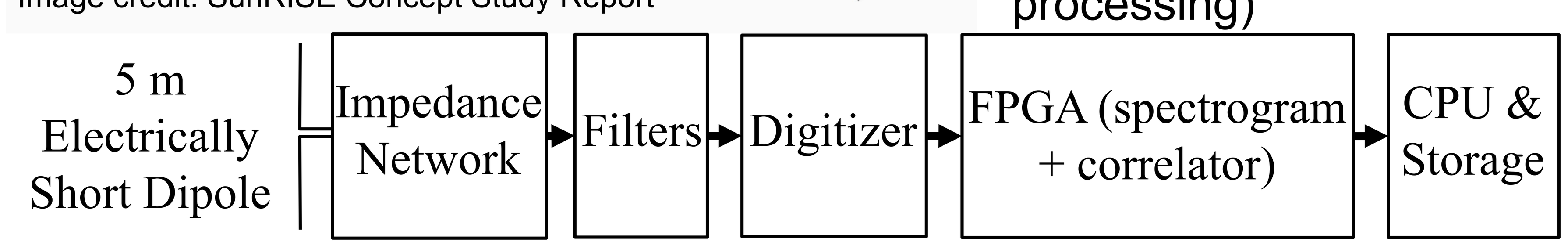


Image credit: SunRISE Concept Study Report

SmallSat implementation based on NASA's SunRISE system design (electrically short antenna + on-board processing)



Expected Performance

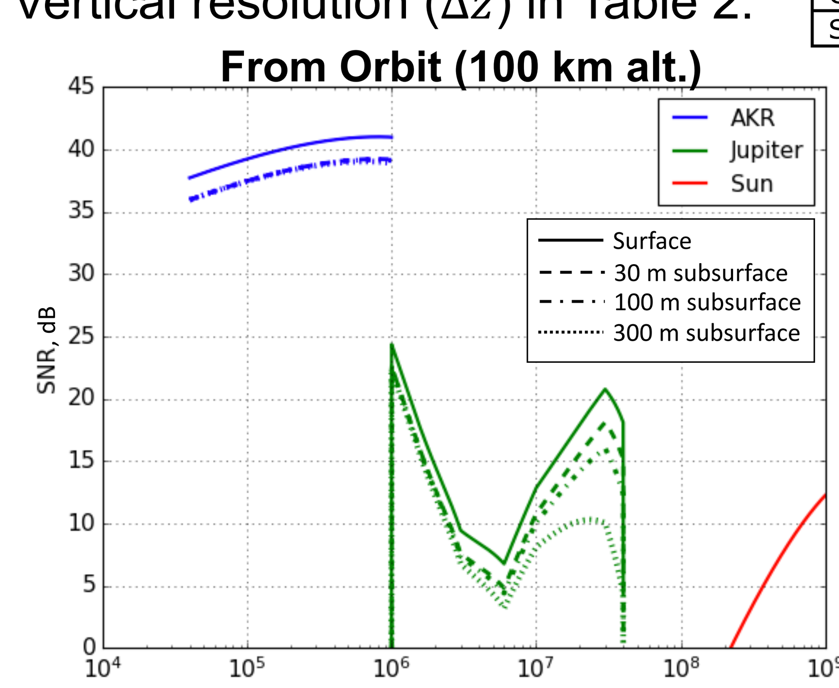
Estimates assume galactic noise, surface roughness, dielectric losses, source bandwidths, source size, and durations. Vertical resolution (Δz) in Table 2.

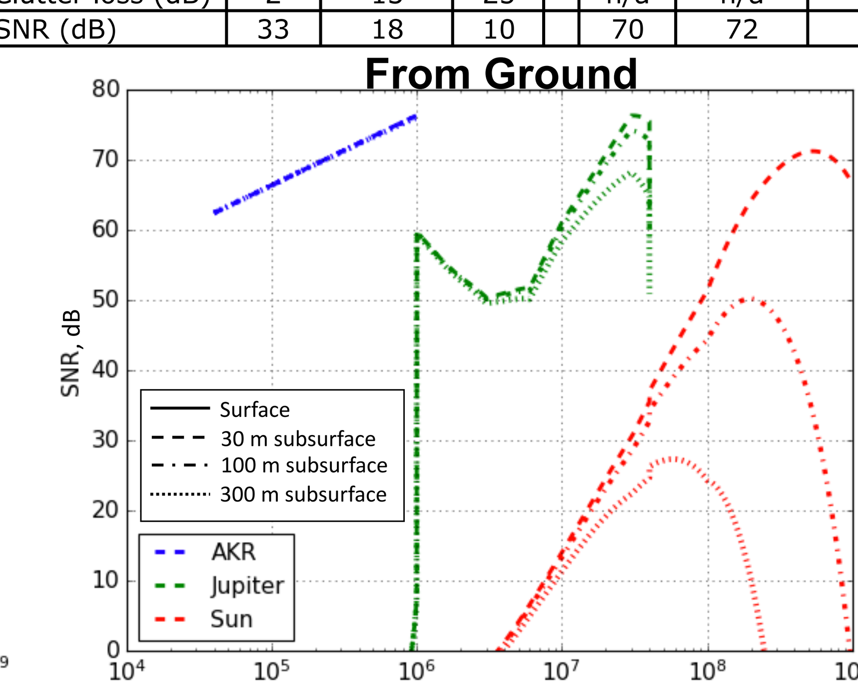
Table 1: passive sounding parameters by source

Source	AKR	Jupiter	Sun
λ (m)	600	10	1.5
Δf (MHz)	1	3	100
Slope RMS	1.2°	2.8°	4.8°

Table 2: passive sounding expected performance by source

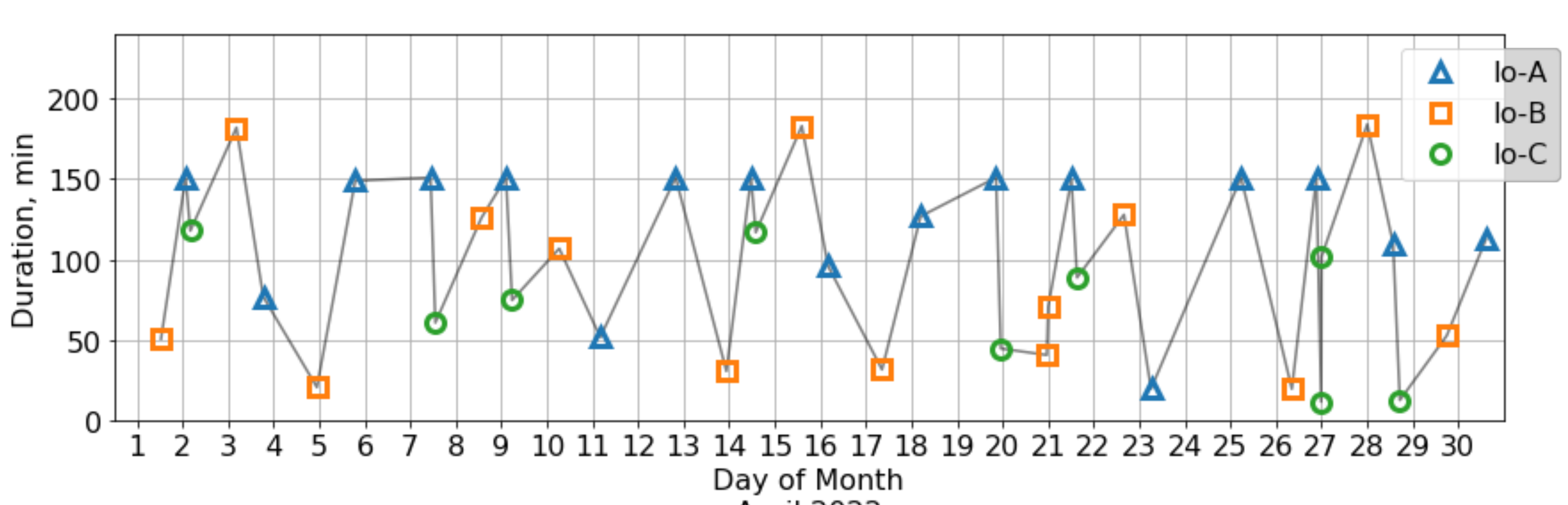
	Orbiter at h=50 km				Rover		
Source	AKR	Jupiter	Sun		AKR	Jupiter	Sun
Δz m	300	50	3		300	50	3
D_F km	11	1.4	0.55		1.2	0.06	0.008
Clutter loss (dB)	2	13	25		n/a	n/a	n/a
SNR (dB)	33	18	10		70	72	68





Jovian bursts

- Bursts occur every 20 hours (median) with a median duration of 110 minutes (comparable to the orbital period of low lunar orbit).
- Observations are viable for incidence angles up to ~60 degrees enabling large coverage around the Moon's equator.



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