LASSO Program Overview

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Space Resources Roundtable

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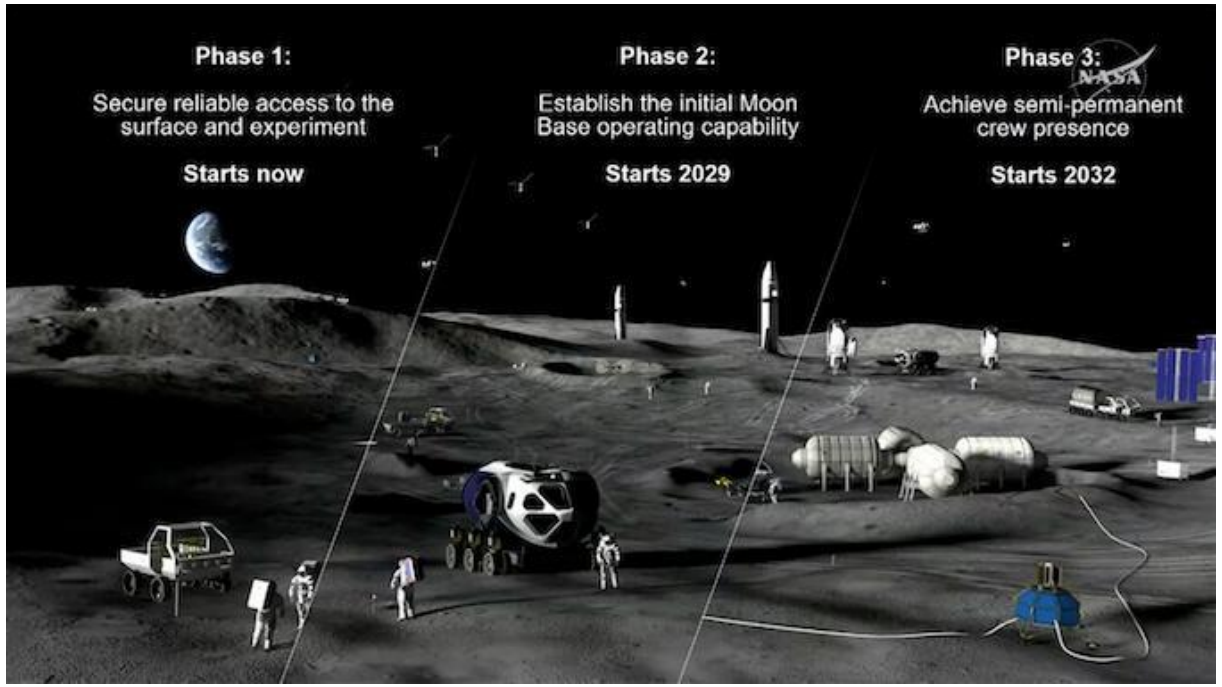
DARPA

DARPA's Lunar Hypothesis



NASA's Ignition initiatives: accelerated plan for a moon base

DARPA's Hypothesis:

- Lunar commercial infrastructure will catalyze economic activity and
- Lunar water ice is a supporting keystone resource

What LASSO is doing:

- Developing an autonomous very low altitude (10km) lunar orbiter to identify water ice deposits in high resolution
- Creating economic/commercial impact by funding innovative performers
- Partnering with NASA, USGS, and NRL

What LASSO is not doing:

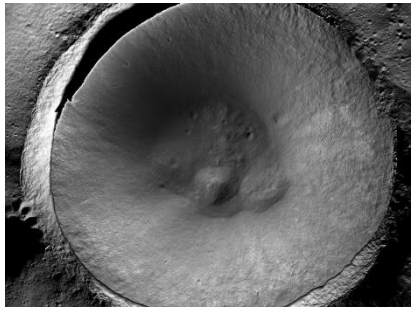
- Landing/operating on the lunar surface

Better lunar water ice knowledge catalyzes economic activity

Limitations of the Current Paradigm

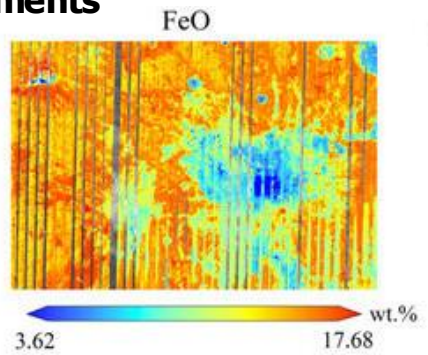
Water – used for human exploration, mining and fuel resupply

Surface Measurements



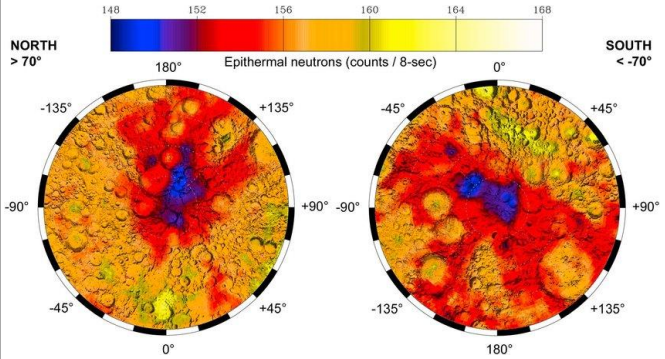
NASA/KARI/ Arizona State Univ via the NY Times

Passive Imaging
(No Concentration)

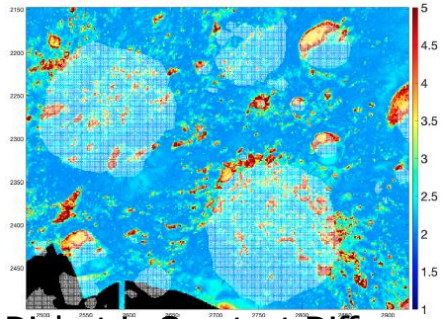


Passive Imaging Spectrometer[1]
(Surface Level Imaging)

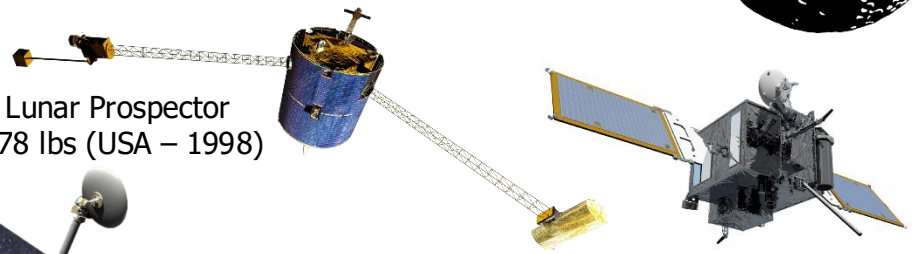
Subsurface Measurements



Neutron Spectrometer (Course Resolution)
Epithermal neutron flux at the Moon's north and south poles (taken from *Feldman et al.*, 2001)



Dielectric Constant Difference
(Inferring the Variability of Dielectric Constant on the Moon from Mini-RF S-band Observations, Shukla, et al. 2024)

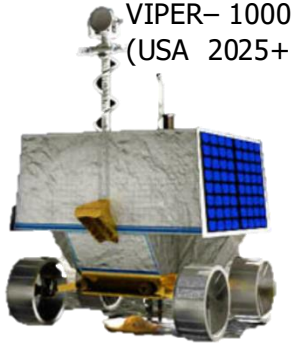


Lunar Prospector
278 lbs (USA – 1998)

LRO
4200 lbs (USA – 2009)

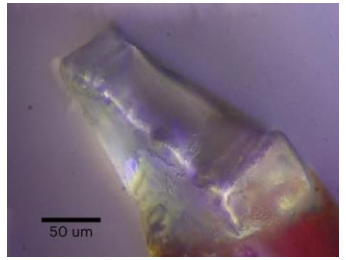
KPLO
1500 lb (Korea - 2022)

Remote Detection – Limited Resolution



VIPER– 1000 lbs
(USA 2025+)

Chang'e 5 – 7100 lbs (China 2020)



Chang'e 5 discovered 40% Water in non-polar region

In Situ Sampling – Limited Coverage

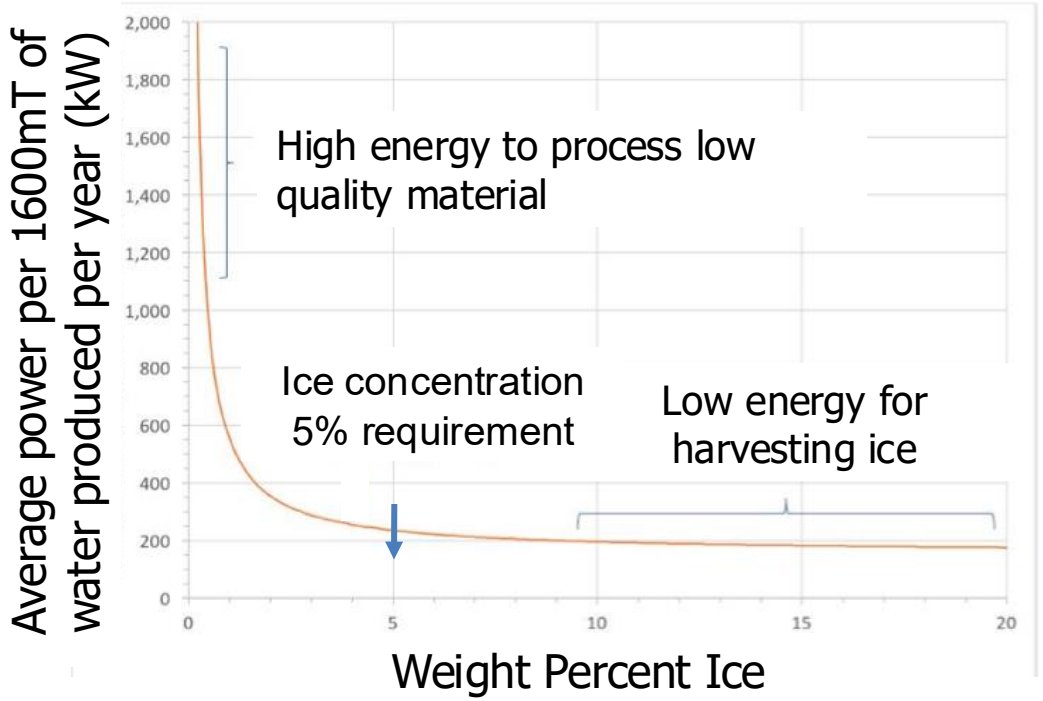
LRO-Lunar Reconnaissance Orbiter
FeO- Iron Oxide
KPLO- Korea Pathfinder Lunar Orbiter

[1]Quantitative Inversion of Lunar Surface Chemistry Based on Hyperspectral Feature Bands and Extremely Randomized Trees Algorithm (taken from *Wu et al.*, 2022)

LASSO Provides Necessary Lunar Surface Resolution and Coverage

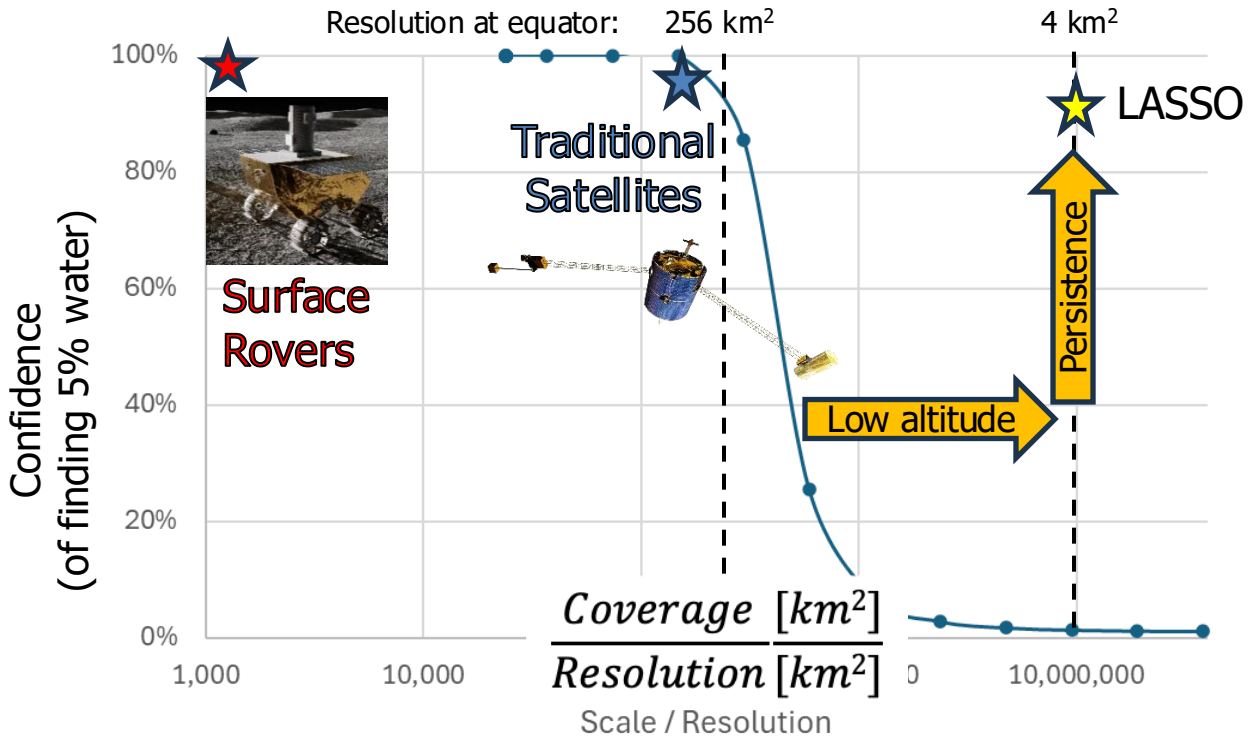
- Current mature sensing systems do not provide sufficient confidence except for in-situ direct sampling
- LASSO is going to exploit current and high TRL sensors and leverage advances in NAV and propulsion

Targeting >5% concentration regions yields maps with ISRU-relevant information



Ice Mining in Lunar Permanently Shadowed Regions (taken from *Sowers et al., 2019*)

Challenge: Measure 5% content of water over entire surface



Identify all regions as small as 4 square km of 5% resources with 90% confidence

(U) TRL- Technology Readiness Level
mT – metric tons

Confidence: Probability of detection of 5% water
Coverage: Area of the lunar surface covered [km²]
Resolution: Size of a region resolved by sensor [km²]

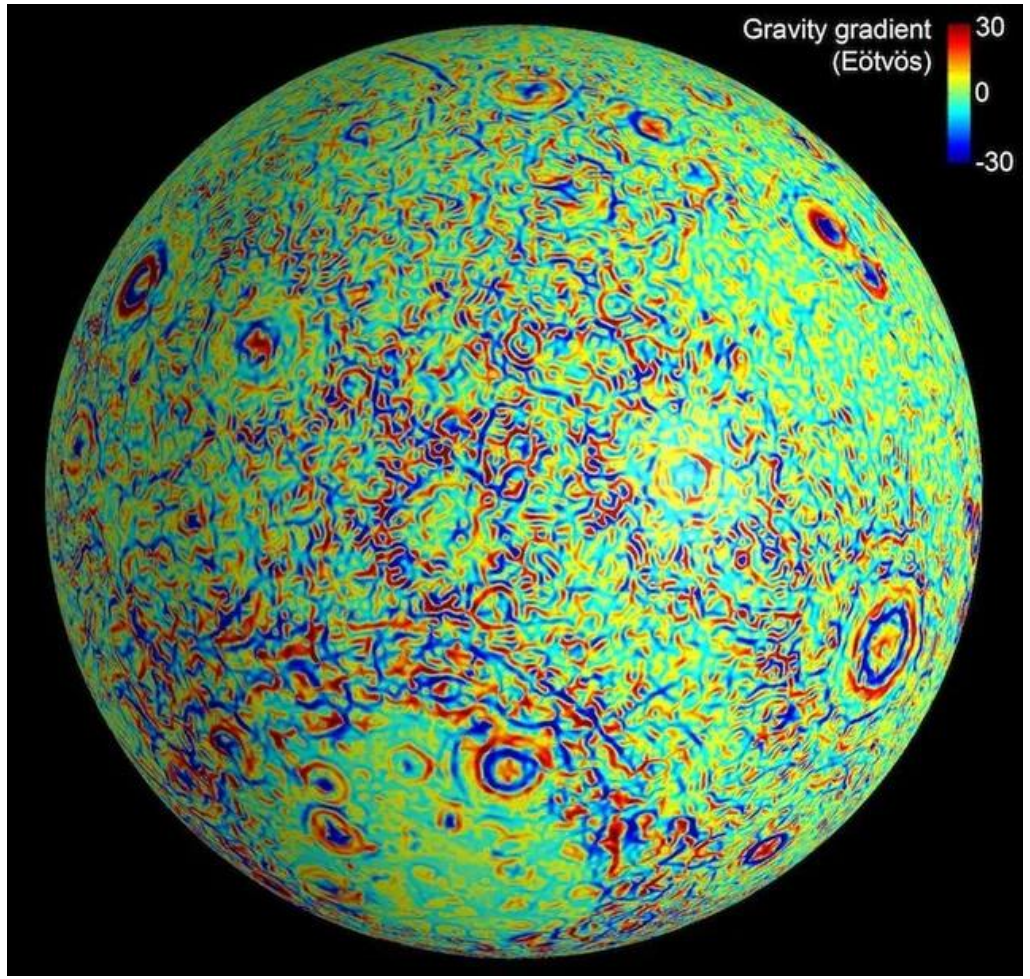
LASSO Program Metrics and Constraints

LASSO Prospecting Metrics	
Description	Value
Metrics:	
Concentration	Identify subsurface water concentration >5%
Resolution	4 sq km size regions (2kmx2km)
Confidence	90% probability of detection that identified region is greater than 5% water
Constraints:	
Lunar Coverage	Map entire lunar surface
Launch Compatibility	ESPA Standard
Map entire lunar surface for water	< 4 years
Positioning and Navigation	Do not rely on strategic DSN infrastructure for autonomous positioning and navigation
Disposal	End-of-life safe disposal

Gather high-resolution data to contribute to identifying future lunar proven reserves

ESPA- Evolved Expendable Launch Vehicle (ELV) Secondary Payload Adapter
DSN- Deep Space Network

What challenges does LASSO face?



NASA's Grail spacecraft data | NASA JPL

Why is this hard?

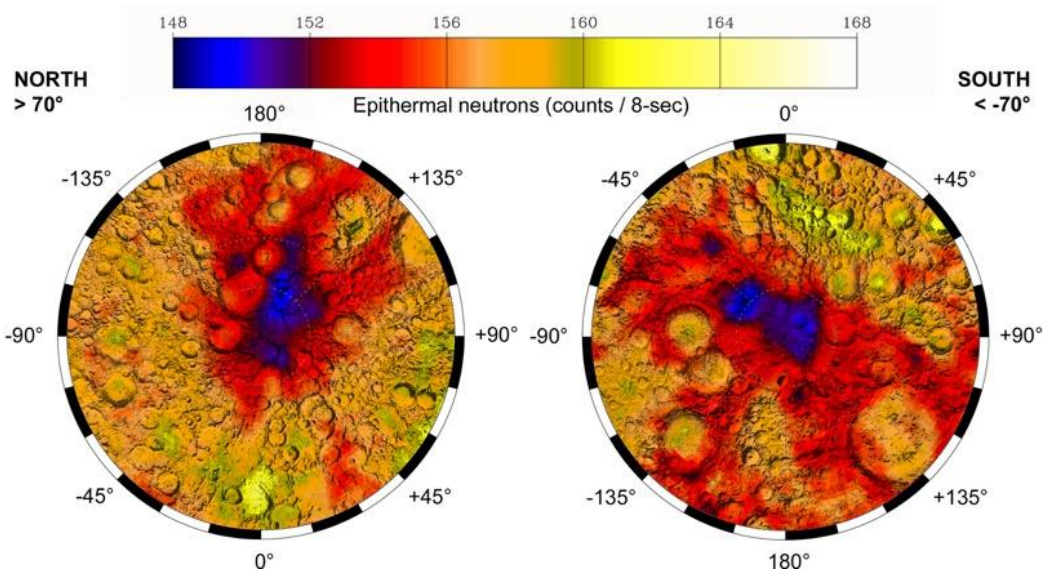
1. Needs to be at a very low altitude to get good data
2. Lunar mass concentrations (Mascons) drive instability in lunar orbit.
3. Terrain has changes in elevation (+/- 10km)
4. Frequent, low thrust orbital trajectory updates are required
5. Comms challenges when in eclipse

Technical leaps to address the challenges:

1. Autonomous navigation that doesn't require frequent human input
2. Flexible, efficient and durable propulsion to complete a long mission

Lots of spacecraft design challenges that are truly DARPA-hard!

LASSO Neutron Measurement

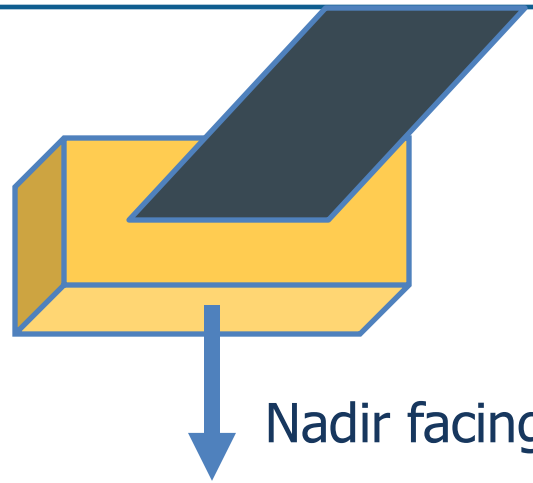


Epithermal neutron flux at the Moon's north and south poles (taken from *Feldman et al.*, 2001).

- Epithermal neutrons have been mapped at both poles of the Moon.
  - Count-rate decreases are consistent with the presence of enhanced hydrogen, and by inference, increased water abundances
  - Broad spatial resolution of existing measurements does not resolve any small-area (<40 km^2) water enhancements
- Requirements to accomplish LASSO measurement objectives:
  - Maximize sensor size and epithermal neutron sensitivity to improve statistical precision
  - Low-altitude measurements (~10 km or lower) to achieve small-area feature detection
  - Account for non-hydrogen systematic uncertainties, especially for non-polar measurements

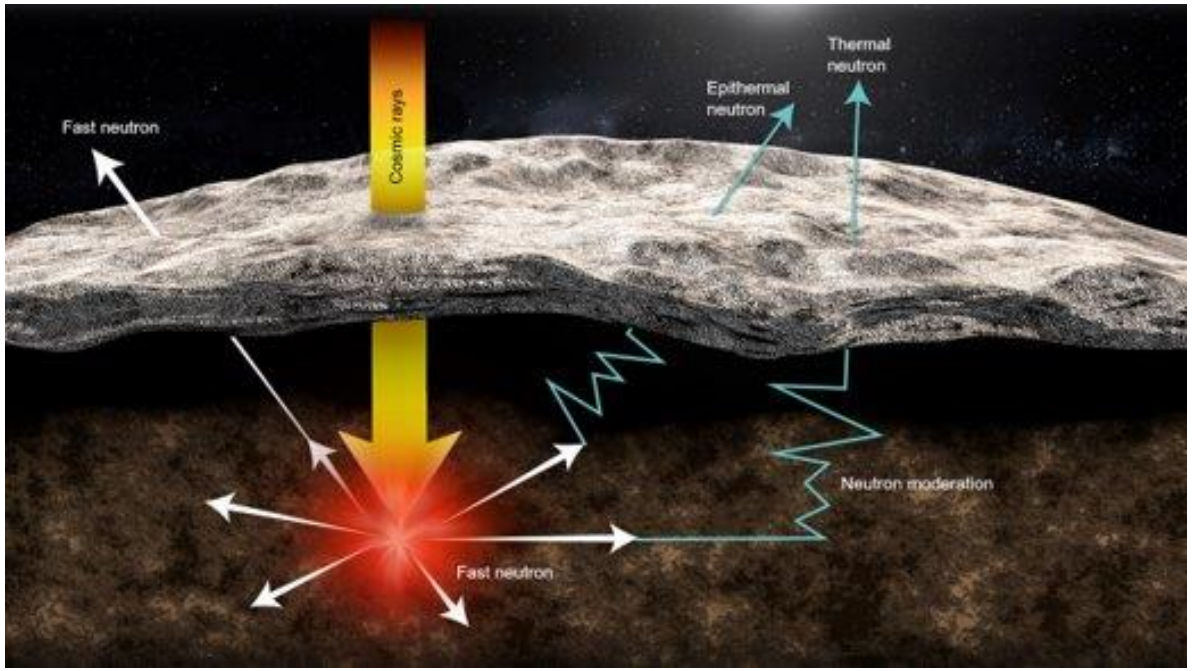
The Instrument

The LASSO Neutron Spectrometer (NS) is a variant of a TRL-9 heritage design from NASA's Psyche mission with multiples of the same type of ^{3}He sensor. The LASSO NS also has legacy to the spectrometer for JAXA's Megane.



To meet the LASSO Metrics, the LASSO NS:

- Uses multiple ^{3}He sensors to increase sensor area by over an order of magnitude
- Surrounds sensors with layer of polyethylene to maximize sensitivity to epithermal neutrons, further increasing statistical precision
- Stares continuously at the surface of the moon and streams events to the spacecraft as they occur for storage and transmission to Earth



Synopsis: What are LASSO's long-term benefits?

Create Autonomous GNC for unstable orbits

Reduce Reliance on Earth based PNT

Create smaller more scalable spacecraft for US operations.

Create a framework for future Proven Reserve Model for water on the Moon

Explore Propulsion Systems that combine different levels of thrust (efficiency) while maximizing Delta V

Quantify water as a keystone resource for a lunar economy

Don't miss the LOGIC meeting on 21 July where we'll discuss lunar water ice data interoperability!

www.darpa.mil