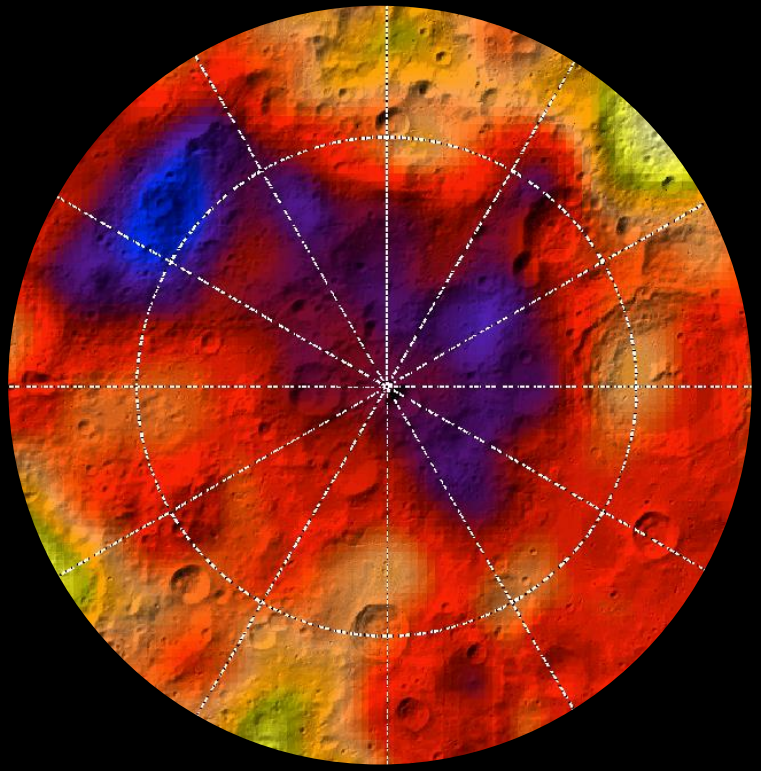
Neutron Spectroscopy: A Prospecting Tool on the Moon

R. C. Elphic,
A. Colaprete, E. Fritzler

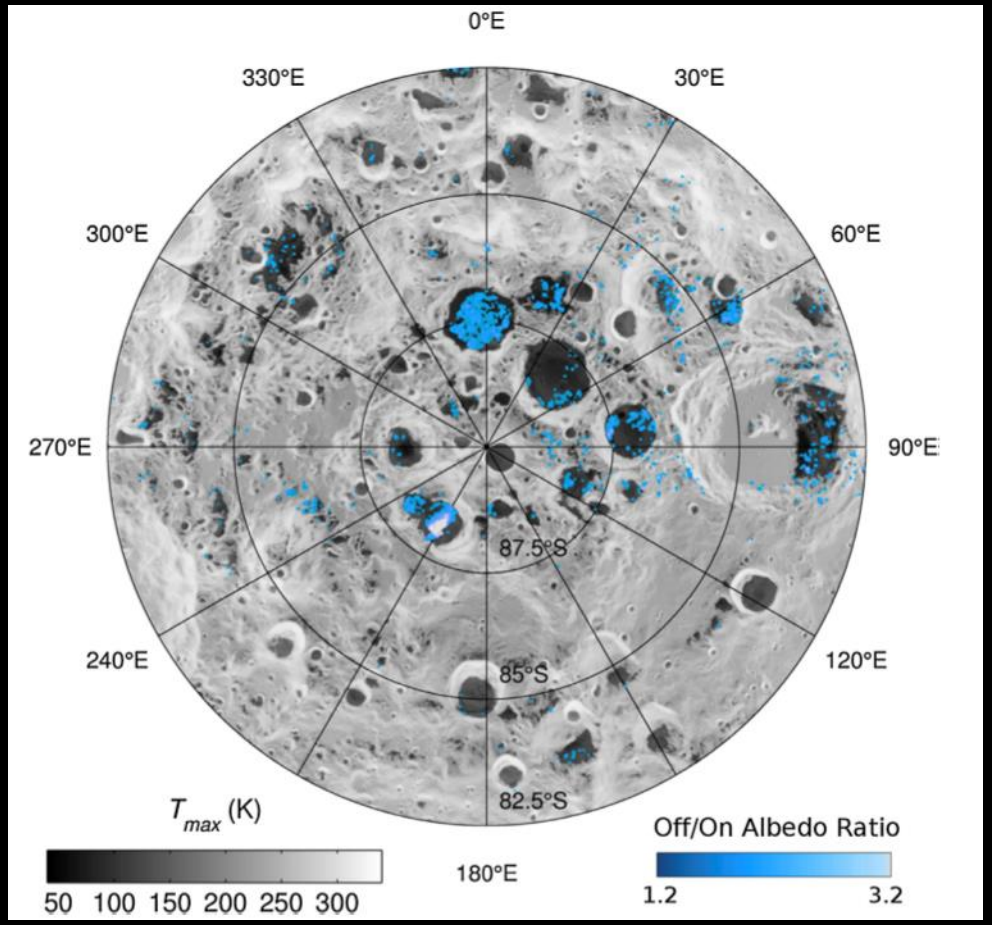
NASA Ames Research Center/Moffett Field, CA

Prospecting for Lunar Polar Volatiles

Volumetric Hydrogen



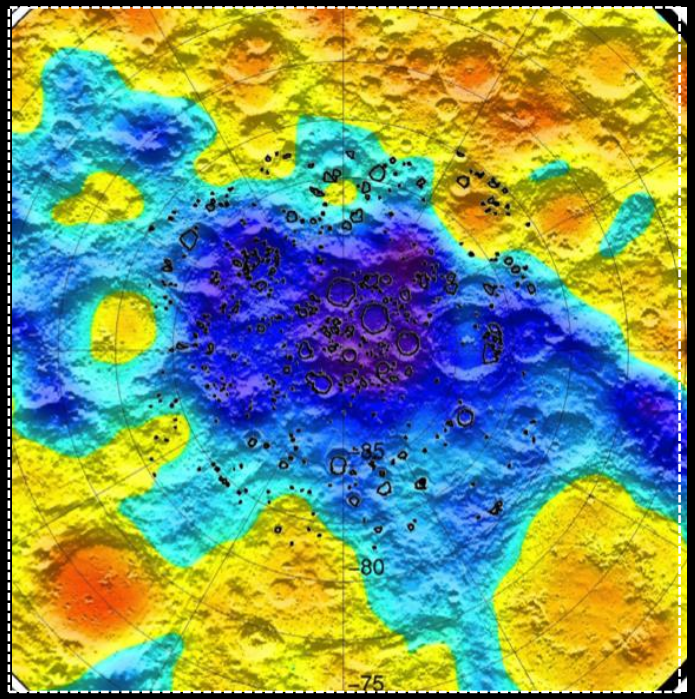
Surface Frost?



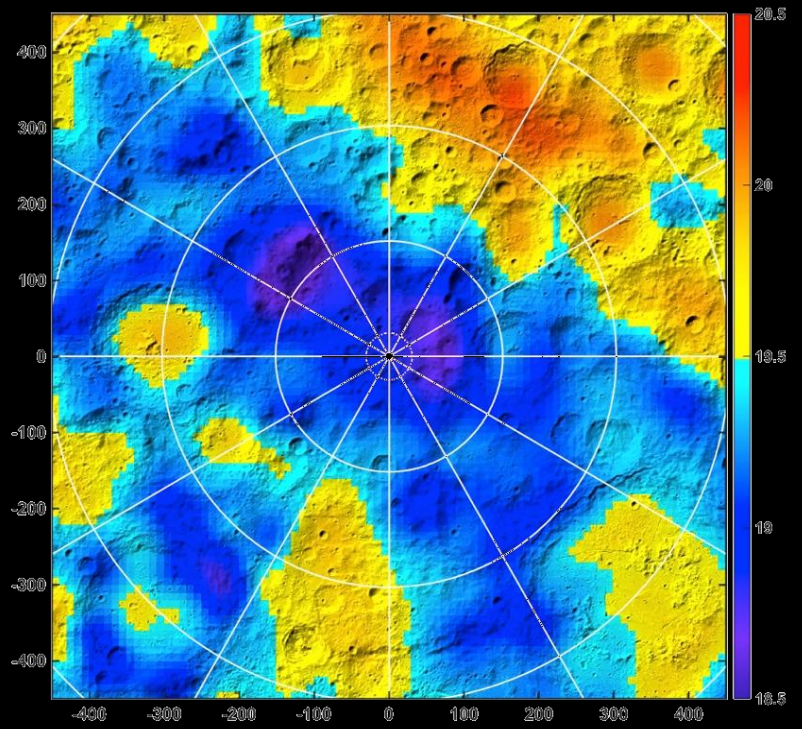
Hayne et al., Icarus, 2015

South Pole Orbital Neutron Datasets

LEND SETN (**uncollimated**)
60-km FWHM Gaussian Smooth

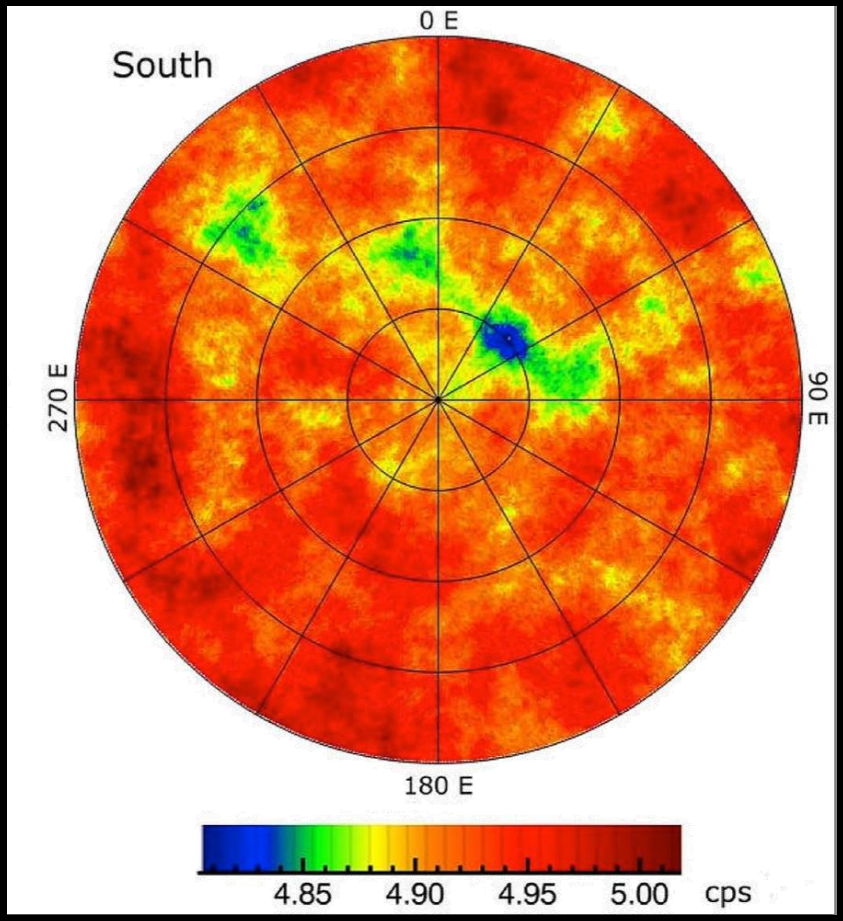


LPNS Epithermals < 35km alt.
60-km FWHM Gaussian Smooth

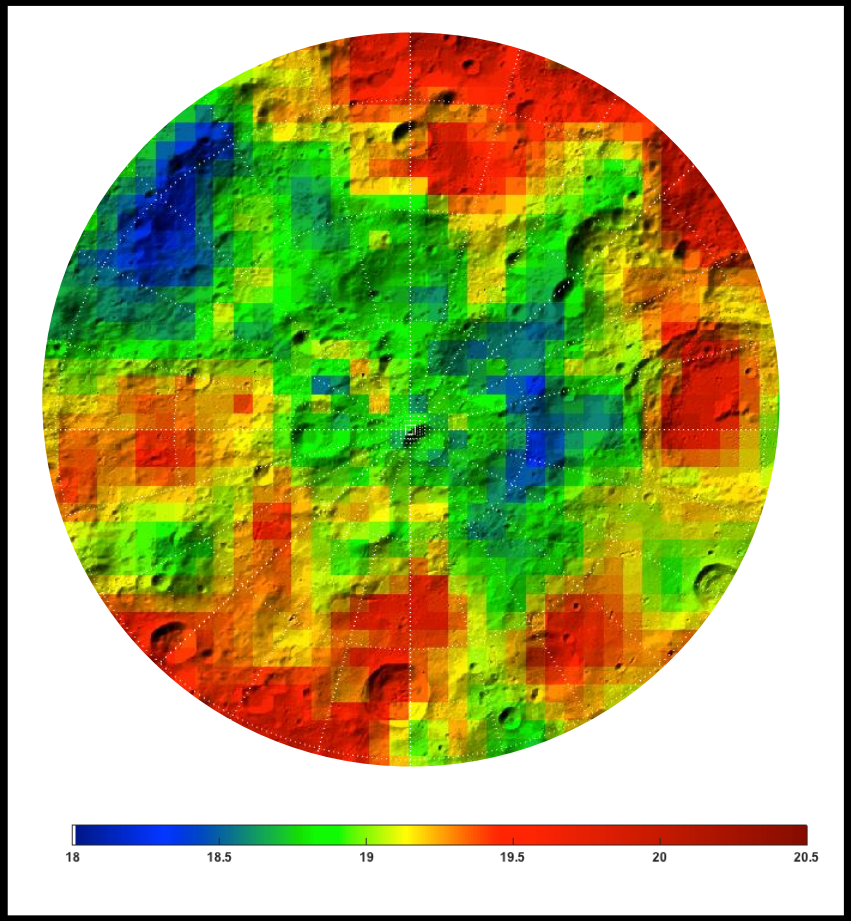


- Some similarity – color table magic
  - Litvak et al. JGR, 2012

LEND CSETN ('collimated')
Total counts/sec



LPNS Adaptive Smooth
(SNR>100)

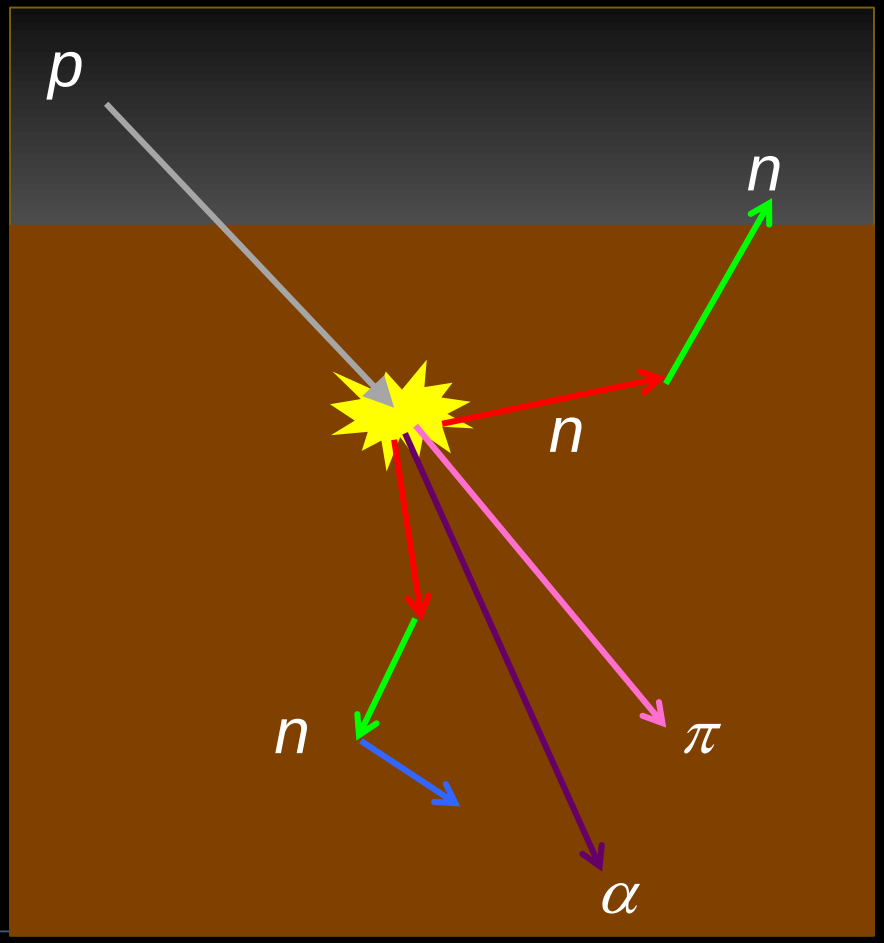


- *Some* similarity – but half of color table range is red
  - CSETN lower signal strength at Cabeus
  - Boynton et al., *JGR*, 2012

Neutron Genesis & Transport

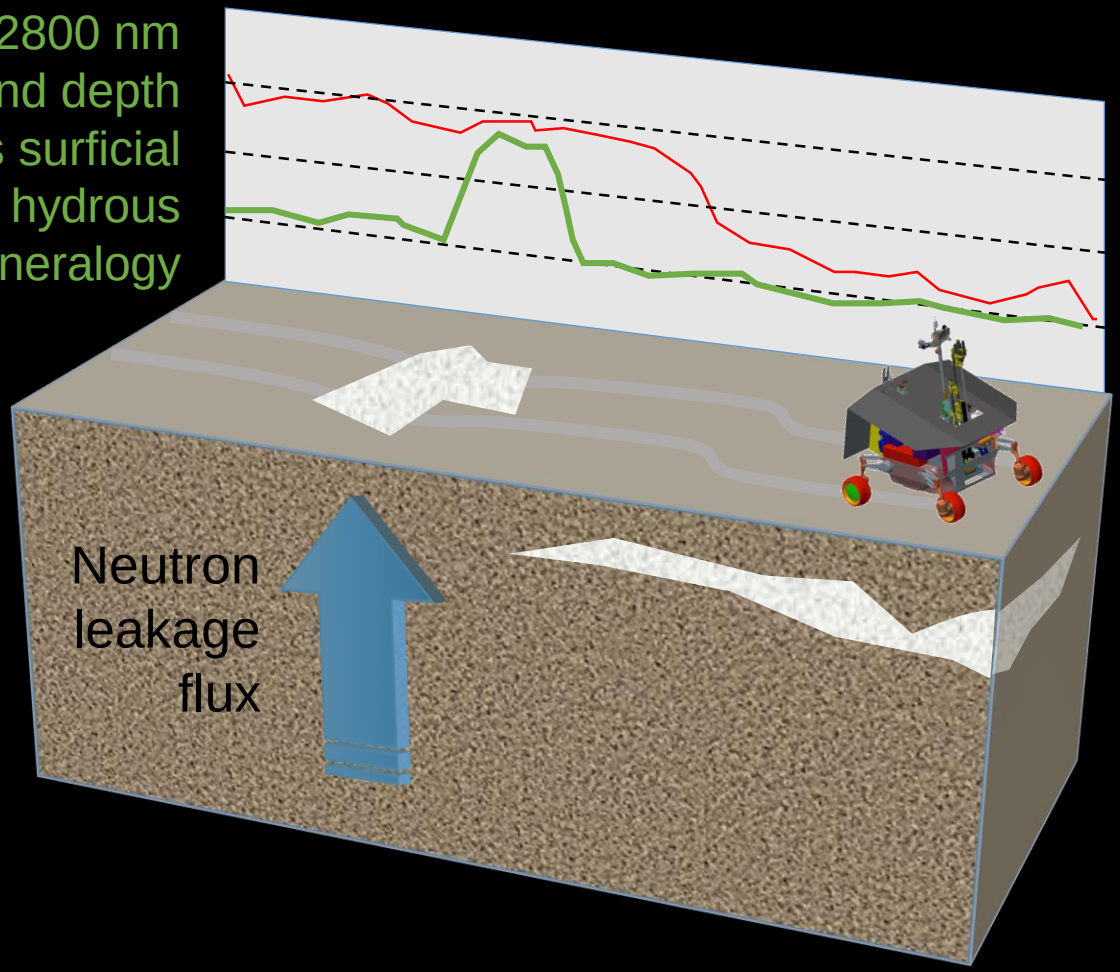
Where do the lunar neutrons come from?

- Incoming galactic cosmic rays (~1 GeV) shatter nuclei
- Neutrons are the longest-lived fragments (15 min lifetime)
- Initial *n* energies > 100 MeV
- Scattering/moderation reduces energy
- Neutrons leak to space, or are captured by nuclei
- Leaked neutrons tell us about near-subsurface composition



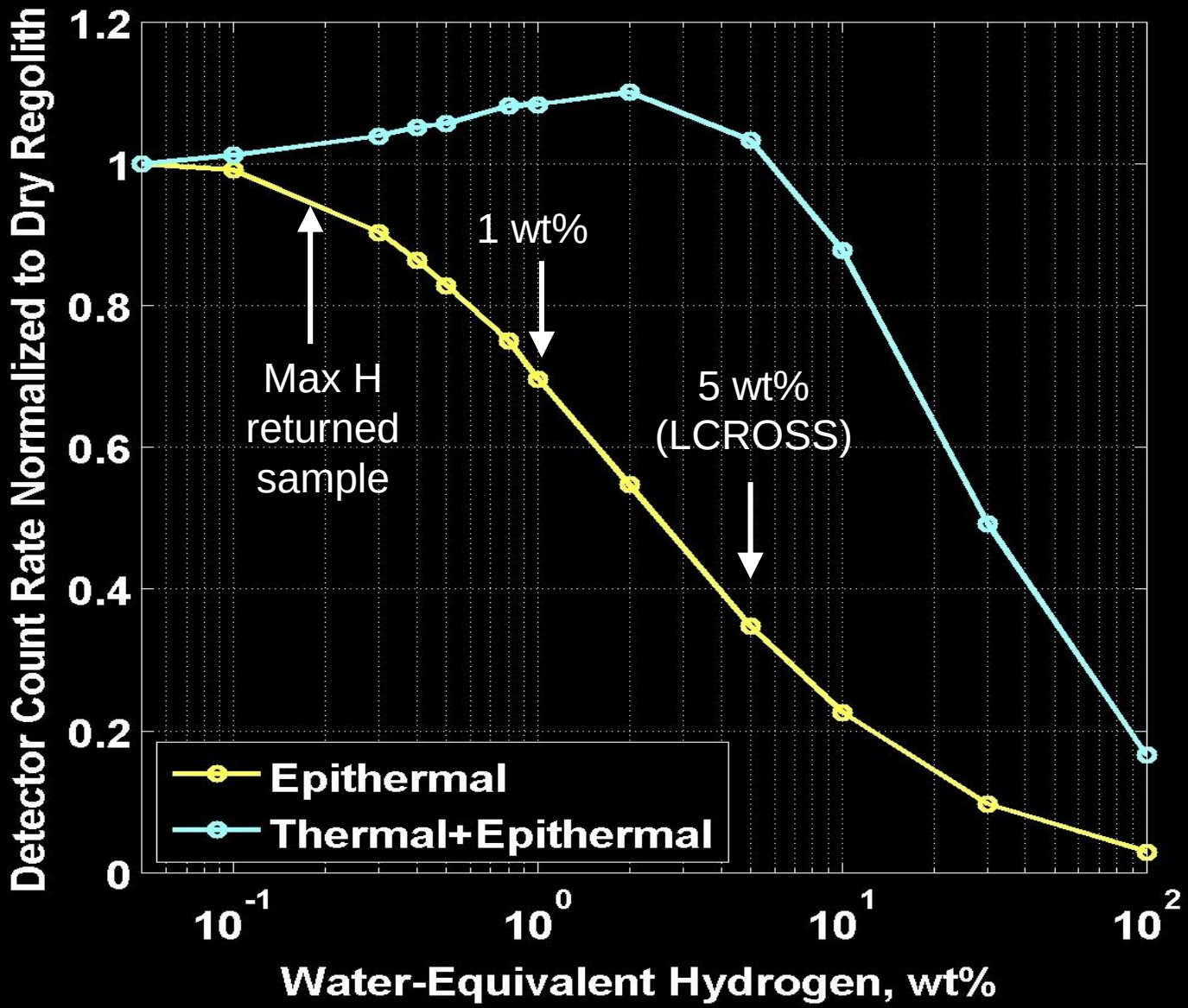
Near-IR and Neutron Spectrometers Work in Tandem on *Resource Prospector*

Near-IR 2800 nm band depth reveals surficial frost or hydrous mineralogy



Epithermal neutron fluxes indicate presence of buried hydrogenous materials

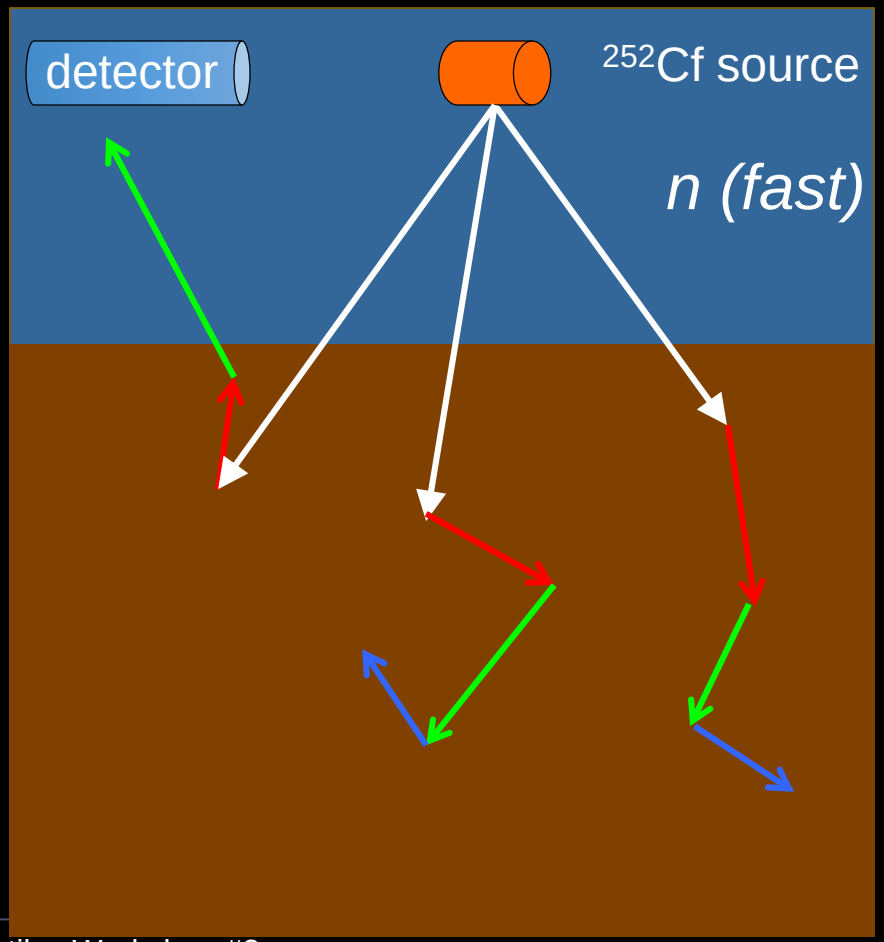
Neutron Flux vs. Water Abundance



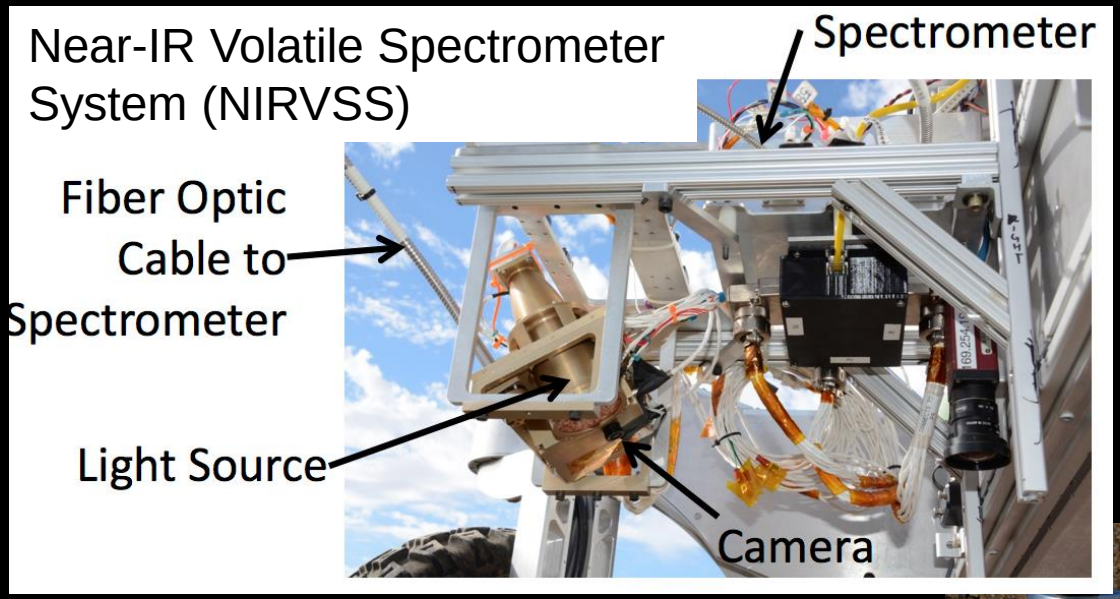
Terrestrial Testing Using a Neutron Source

What do we do on Earth? No galactic cosmic rays…

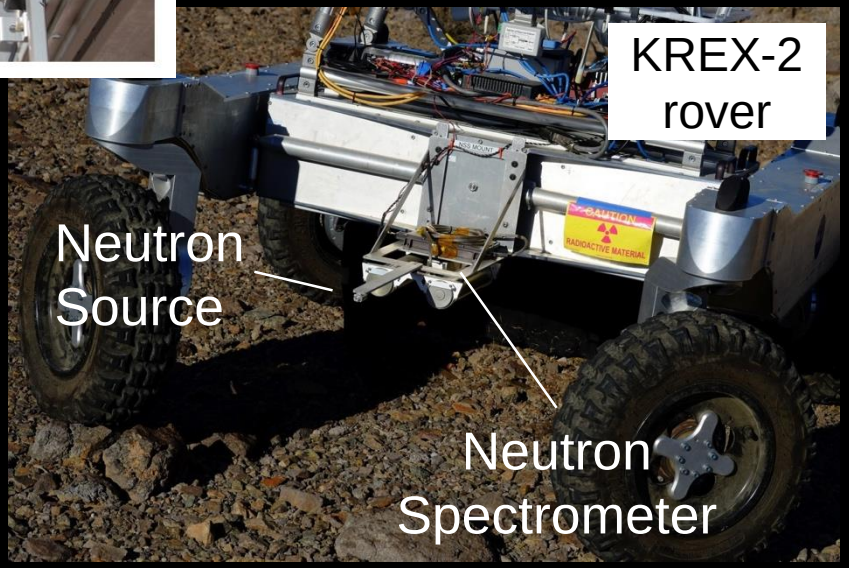
- Must use a radionuclide neutron source (we use Californium-252)
- Neutrons from the source have ~2-3 MeV energy (so-called *fast* neutrons)
- Scattering/moderation reduces energy
- Some neutrons leak back out to be detected. Most do not.
- Leaked neutrons tell us about surface/subsurface – but only up to ~30 cm.



Mojave Volatiiles Project Used Two Resource Prospector Payload Instruments

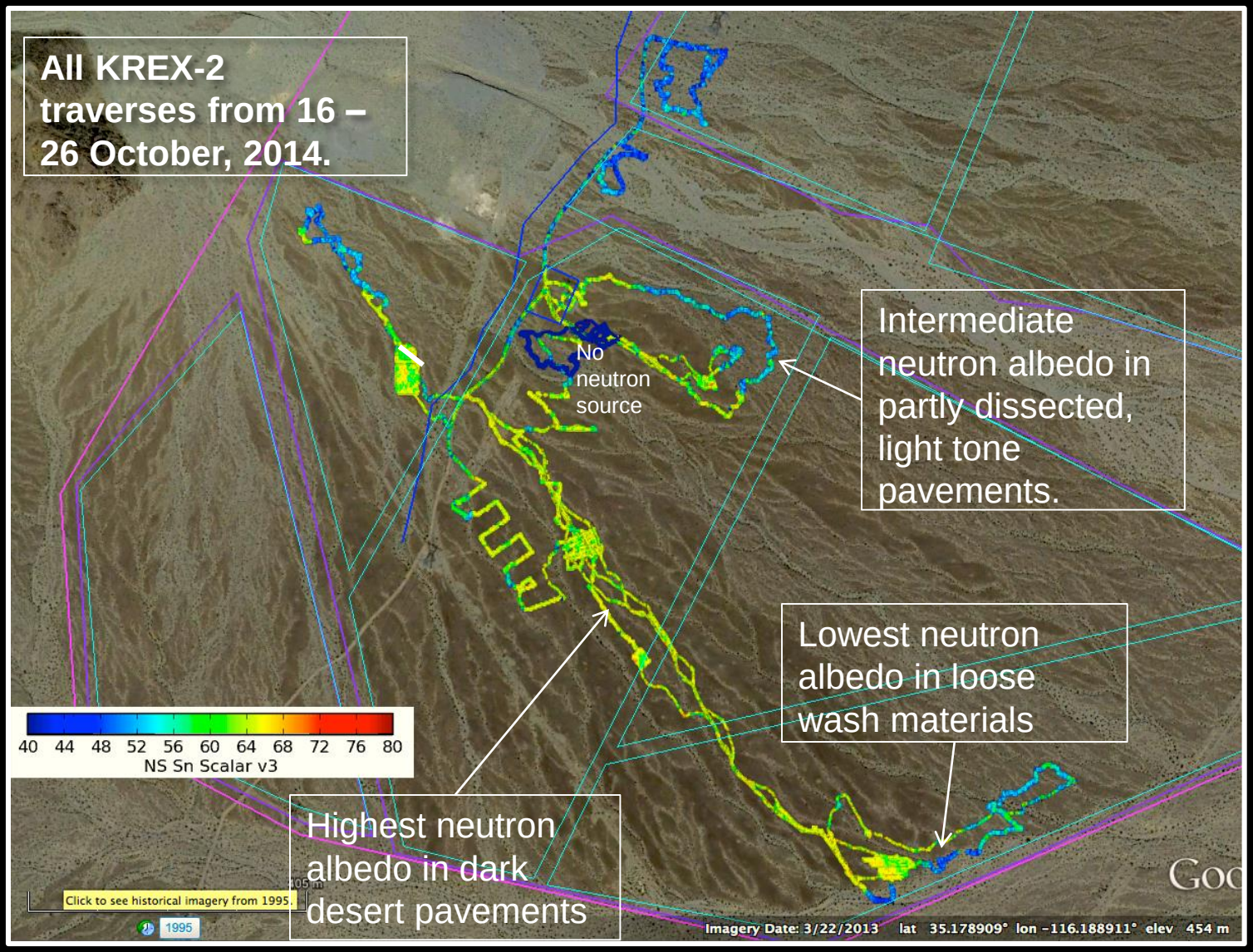


- NIRVSS: Near-IR Volatile Spectrometer System
- 1600 – 3400 nm band
- Covers major H_2O, OH and other mineral features



- NSS: Neutron Spectrometer System
- Thermal and epithermal neutron flux
- Volumetric hydrogen abundance

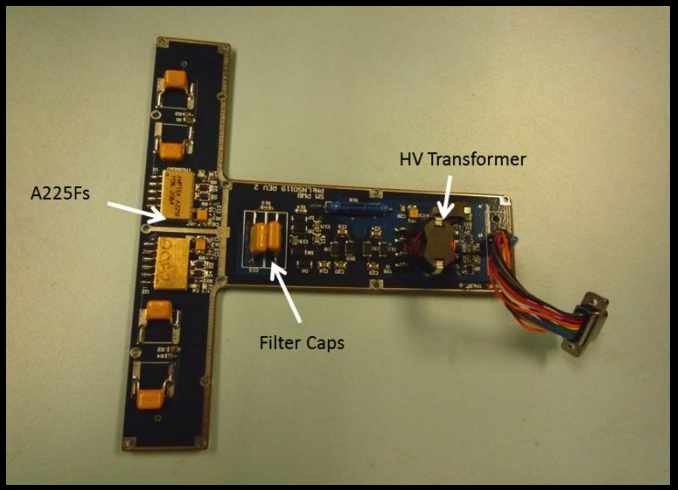
Thermal Neutron Albedo: Hydration Variations in the Mojave Volatiles Project

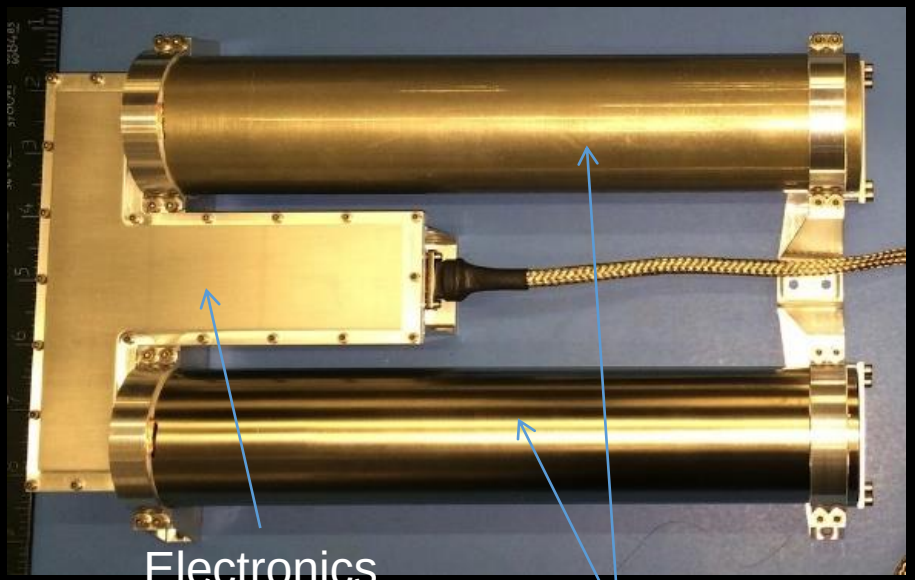


Resource Prospector NSS Design

Sensor Module Subsystem Overview

- Detectors (2 ^{3}He gas proportional counter tubes – GE/Reuter Stokes custom design)
- High voltage power supply (~1600V)
- Front end electronics (charge-sensitive pre-amplifiers)
- 1 electronics board, enclosure, tube holders, tubes
- Located on fixture - forward end of payload



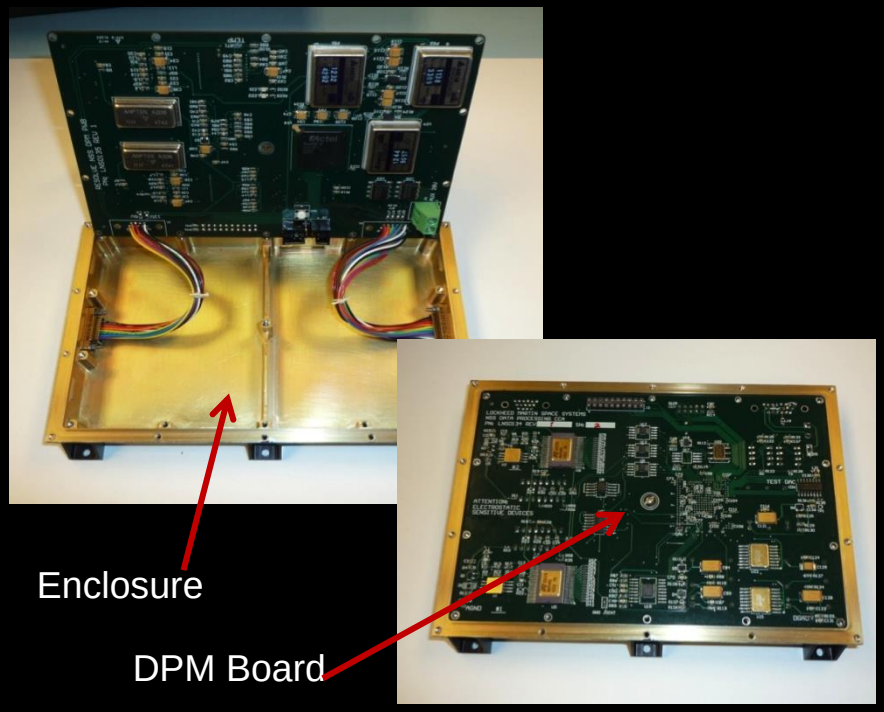


- Enclosure is a 3-chamber shielded design for noise isolation
- Two low-noise front-end amplifiers strings (1 for each detector)
- High Voltage Power Supply
  - Low power
  - Commandable high voltage range 1.5-2.5kV
  - Low ripple and EMI noise
  - No cross-talk to preamp
  - Control loop stability
  - Voltage breakdown margin

Resource Prospector NSS Design

Data Processing Module Subsystem

- Communication with rover payload system
- Housekeeping and Data processing
- State machine (FPGA) controls system
- Low Voltage power supplies
- 1 electronic board and enclosure



Power

–Vin: 23 ~ 34 V @ 1.5 W
–Soft Start limiting In-rush current to 0.5 A
–Isolated DC/DC
–Single point grounding to host chassis via cable harness

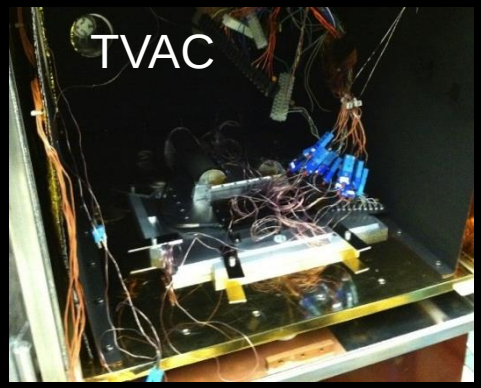
Communication – Command & telemetry

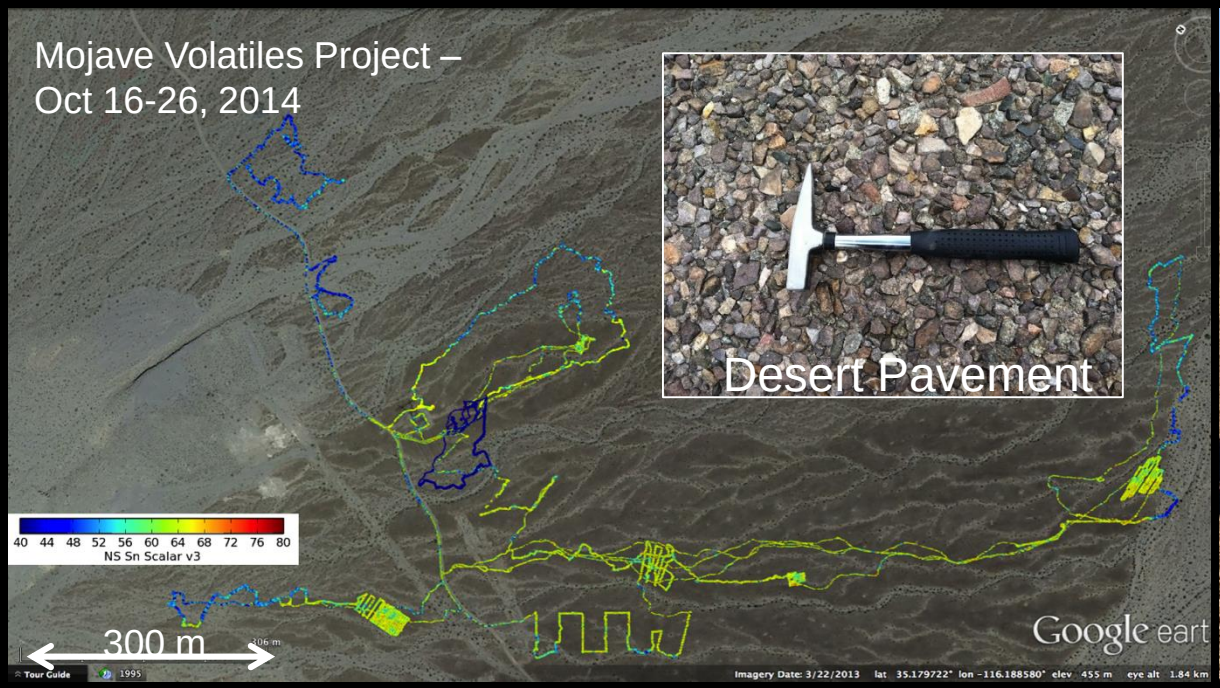
–RS422 transceivers
–9.6 Kbaud, UART protocol
(Start-8bit-data-stop-no parity)
–89 byte data packet, 2 byte commands
–Data rate : one packet / second

FPGA Processing

–Pulse height and total charge analysis
–Scalars for valid neutron counts above threshold
–Housekeeping, SOH, cmd processing
–Controls DACs that set HV, disc. threshold.

NSS Environmental and Field Testing





Neutron Spectroscopy & Lunar Polar Volatiles

Prospecting:

- Passive neutron spectroscopy, using GCR-generated neutrons, senses bulk hydration down to ~1 m depth
- Can be sensitive to small abundances of hydrogen (statistics!)
- Two measurements permit simple 2-layer model of depth to ice-bearing material

Resource Prospector:

- Neutron spectrometer system (NSS) is a key prospecting tool for locating, and characterizing, hydrous materials in top ~1 m of lunar regolith
- Lightweight, robust, simple with high heritage from flight
- 1.6 kg, 1.5 W, 712 bits/sec telemetry over RS422.