ELPASOLITE PLANETARY ICE AND COMPOSITION SPECTROMETER (EPICS): A LOW-RESOURCE COMBINED GAMMA-RAY AND NEUTRON SPECTROMETER FOR PLANETARY SCIENCE. D. D. S. Coupland[1], L. C. Stonehill[1], N. A. Dallmann[1], W. C. Feldman[2], K. E. Mesick[1], S. F. Nowicki[1], S. A. Storms[1], [1]Los Alamos National Laboratory (Los Alamos, NM 87545 USA), [2]Planetary Science Institute (Tucson, AZ 85719).

Introduction: The Elpasolite Planetary Ice and Composition Spectrometer (EPICS) is an innovative, low-resource gamma-ray and neutron spectrometer for planetary science missions, enabled by new scintillator and photodetector technologies. Neutrons and gamma-rays are produced by galactic cosmic ray (GCR) interactions with planetary bodies and their subsequent interactions with the near-surface materials produce distinctive energy spectra. Measuring these spectra reveals details of the planetary near-surface composition that are not accessible through any other phenomenology. EPICS will be the first planetary science instrument to fully integrate the neutron and gamma-ray spectrometers. This integration is enabled by the elpasolite family of scintillators that offer gamma-ray spectroscopy energy resolutions as good as 3% FWHM at 662 keV, thermal neutron sensitivity, and the ability to distinguish gamma-ray and neutron signals via pulse shape differences. This new detection technology will significantly reduce size, weight, and power (SWaP) while providing similar neutron performance and improved gamma energy resolution compared to previous scintillator instruments. EPICS will detect scintillation light with silicon photomultipliers (SiPMs) rather than traditional photomultiplier tubes, offering dramatic additional SWaP reduction.

EPICS is under development with Los Alamos National Laboratory internal research and development funding. Here we report on the EPICS design, provide an update on the current status of the EPICS development, and discuss the expected sensitivity and performance of EPICS in several potential missions.

Gamma-ray and Neutron Spectroscopy: Gamma-ray and neutron spectroscopy are used to perform geochemical analysis of planets and solid bodies such as moons or asteroids. Neutrons are produced by the interaction of galactic cosmic rays (GCRs) with matter. Leakage neutron fluxes provide a sensitive measure of the near-surface hydrogen abundance as well as the average atomic mass of the near-surface.

Gamma-rays are produced by radioactive decay and the interactions of neutrons with matter. Characteristic gamma-rays indicate the abundance of most major and minor rock-forming elements, including H, C, O, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Fe, Th and U.

Previous gamma-ray spectrometer instruments have ranged from scintillators with ~10% energy resolution (FWHM at 662 keV) like BGO to HPGe systems with exquisite energy resolution, and previous neutron spectrometers have used ^{3}He and/or borated plastic or ^{6}Li glass scintillators. Many of the planetary science gamma-ray or neutron spectrometers built and flown in the United States derive significant design heritage from Los Alamos instruments or in fact were designed at LANL, leveraging national security expertise in space-based radiation detection.

Elpasolite Scintillators: Cerium-doped elpasolite crystals produce a bright light output between 20,000 and 50,000 photons per MeV with excellent linearity, yielding gamma spectroscopy energy resolutions as good as 3% at 662 keV. They also provide thermal neutron sensitivity through the ^{6}Li(n,α)T reaction, and the chloroelpasolites enable fast neutron spectroscopy by means of the ^{35}Cl(n,p)^{35}S reaction.

Different scintillation decay times allow gamma-rays to be uniquely distinguished from neutrons using pulse shape discrimination (PSD). By forming appropriate ratios of integrals over different regions of the pulses, gamma-rays and neutrons can be robustly separated. A PSD figure of merit (FOM) is calculated by histogramming the PSD ratio parameter and taking the difference between the centroids of the peaks divided by the sum of the FWHM of those peaks.

The most common of the elpasolites is $Cs_2LiYCl_6:Ce^{3+}$ (CLYC), which exhibits gamma energy resolution of ~ 4% FWHM at 662 keV [1, 2], good thermal neutron sensitivity and some fast neutron spectroscopy, and excellent PSD between gammas and neutrons with 4.55 FOM [3]. Another promising elpasolite is $Cs_2LiLaBr_6:Ce^{3+}$ (CLLB), which offers higher light output than CLYC, resulting in gamma-ray energy resolution of ~ 3.1% [4].

No elpasolites yet have heritage from spaceflight missions, but two CLYC-based instruments are under development for flight. A test of CLYC for a national security mission (PI: Coupland) is scheduled for a 2019 launch to geosynchronous orbit [5] and the LunaH-Map CubeSat mission (PI: Hardgrove, ASU) is planned for the EM-1 launch to the Moon.

Silicon Photomultipliers: All scintillator-based radiation detectors require transduction of scintillation light to measurable electrical signals. SiPMs offer similar gain and noise performance to traditional photomultiplier tubes (PMTs), but are smaller and lighter weight, and require tens of volts of bias rather than kV-scale bias typical of PMTs. Newer SiPMs with good response at blue wavelengths have shown excellent performance with elpasolites [6]. Arrays of SiPMs are required to read out large crystals; controlling the required channel count while maintaining pulse shape integrity is an area of promising ongoing research [7].

EPICS Instrument Concept: The EPICS instrument (Fig. 1) features a thin front elpasolite layer for thermal neutron detection, a large central volume of elpasolite scintillator for gamma-ray spectroscopy and epithermal/fast neutron detection, and plastic scintillator on the five non-nadir sides for fast neutron coincidence and GCR monitoring. All scintillator volumes are read out by SiPMs to reduce SWaP.

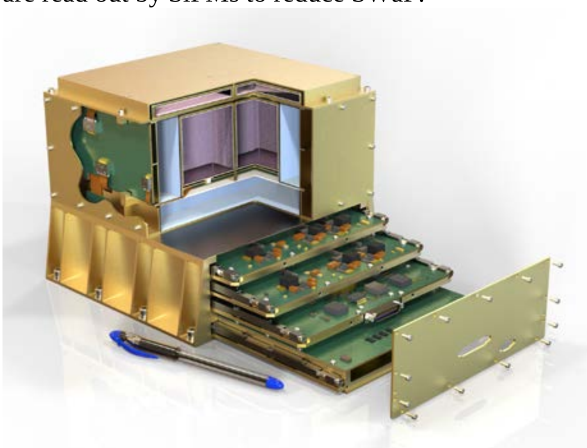

Fig. 1. Rendering of the EPICS instrument.

Baselined with the more mature CLYC scintillator, EPICS has a gamma-ray energy resolution of 5-6% FWHM at 662 keV in the temperature range of -30 °C to +60 °C, accounting for radiation damage incurred over a five-year interplanetary mission. The gamma-ray detection efficiency, expressed as an effective area (detection efficiency × physical area), is >7 cm^2 at the 7.6-MeV iron line and >25 cm^2 at the 609-keV line from uranium decay. The effective area for neutron detection is ~120 cm^2 for thermal neutrons, ~30 cm^2 for epithermal neutrons, and ~1 cm^2 for fast neutrons.

The EPICS readout electronics leverage elpasolite instruments developed at LANL [8, 9]. The preliminary electronics design includes 18 channels to read out SiPM arrays on 14 scintillator volumes.

Performance Simulations: We have performed preliminary simulations to estimate the sensitivity and performance of the EPICS instrument in several potential missions. One potential mission is presented in Fig. 2, which shows the neutron spectra expected from different possible compositions of the Martian moons. Another potential mission is shown in Fig. 3, which displays the gamma-ray spectra expected from possible compositions of a Trojan asteroid, filtered through the EPICS' gamma-ray efficiency and resolution.

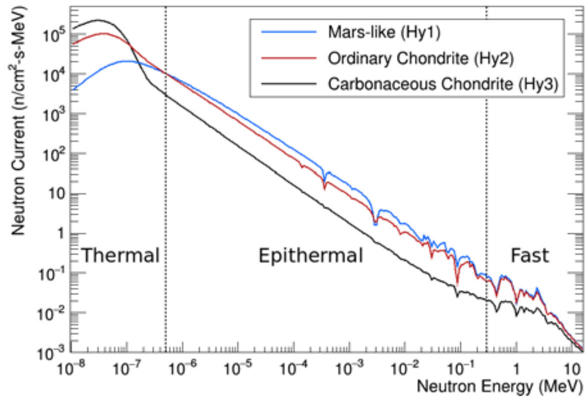

Fig. 2: Simulated neutron energy spectra expected from three planetary compositions. The EPICS instrument's ability to separately detect thermal, epithermal, and fast neutrons permits discrimination between these three compositions.

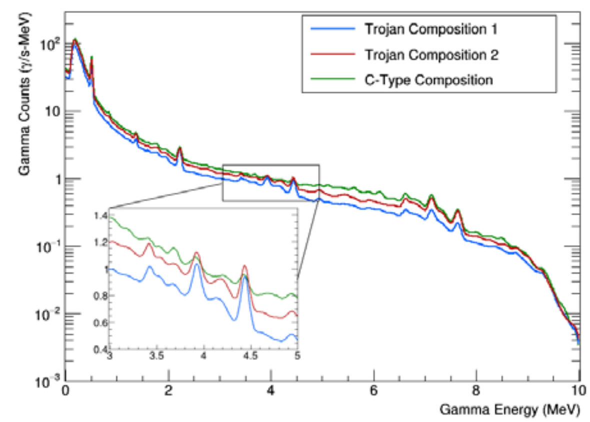

Fig. 3: Simuluted EPICS gamma-ray energy spectra from three astreroid compositions. At the energies of gamma-rays produced by key elements, the spectra permit discrimination between these compositions.

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Acknowledgements: Research presented in this paper was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20170438ER.