

**DEMONSTRATION OF AN ADVANCED NEUTRON SPECTROMETER FOR CREWED OR SCIENCE MISSIONS.** M.J. Christl<sup>1</sup> (Mark.Christl@NASA.Gov), J.A. Apple<sup>1</sup>, C.M. Benson<sup>1</sup>, P.F. Bertone<sup>1</sup>, J.A. Caffrey<sup>1</sup>, K.L. Dietz<sup>1</sup>, B.F. Gibson<sup>1</sup>, H.F. Haviland<sup>1</sup>, M.A Rodriguez-Otero<sup>1</sup>, G.S. Thornton<sup>1</sup>, P.N. Bhat<sup>2</sup>, E.N. Kuznetsov<sup>2</sup>, J.W. Watts<sup>2</sup>, and M.S. Sabra<sup>3</sup>. Affiliations: <sup>1</sup>NASA/MSFC (320 Sparkman Dr, Huntsville AL. 35805), <sup>2</sup>Univ. of Alabama in Huntsville (320 Sparkman Dr., Huntsville, AL. 35805), <sup>3</sup>Univ. Space Research Assoc. (320 Sparkman Dr. Huntsville, AL. 35805)

**Introduction:** A new neutron measurement technique has been developed with improved capabilities for measuring fast neutrons ( $0.1 < E < 15$  MeV) in space environments and suitable for future crewed and science missions in orbit or on the surface of the moon. A technology demonstration flight aboard the International Space Station (ISS) is currently being conducted to evaluate its performance in a space environment under the AES program. The Fast Neutron Spectrometer (FNS) was transported to the ISS in Oct 2016 and operations commenced in Dec 2016. The FNS has operated nearly continuously for the past 6 years at various locations within the ISS. This neutron measurement technique uses the proton recoil signals in a plastic scintillator to determine the neutron energy spectrum and a Li6-doped glass scintillator to identify initiating particles as neutrons. Composite plastic-glass scintillators have been fabricated and tested in the lab and at particle accelerators to study the detectors performance, and a data analysis process has been developed for analyzing the data acquired on the ISS in Low Earth Orbit. The operations will continue through April 2023. This paper describes key results of this instrument technique, the technology demonstration flight and identifies potential future missions.

**Instrument Design:** The FNS instrument uses Hamamatsu photomultiplier tubes coupled to the composite scintillator, and readout by custom electronic boards, to record the signals in the detector. Flight software communicates directly with the instrument, transferring uplinked commands to the instrument and downlinking data through TDRSS where it is transferred to NASA/MSFC for analysis.

**Future work:** A neutron counting version of this instrument has been developed for flight on Astrobotic Peregrine Mission 1, the Neutron Measurement at the Lunar Surface (NMLS) instrument [1]. The NMLS uses two identical neutron counters, one wrapped with cadmium and the other wrapped with tin, to measure the full and epi-thermal count rates at the lunar surface over the course of a Lunar day and is expected to launch in 2023.

**Key conclusions:** From the ~6 years of operations, we have demonstrated the instrument measures the radiation exposure over a broad range from 20 to 1000

$\mu\text{Sv/day}$ , average in a space environment. We anticipate the radiation environment at the lunar surface and on-board Gateway in lunar orbit, to be within this range. This composite scintillation neutron capture technique is robust, requires modest resources and has demonstrated capabilities suitable as NASA's operational instrument.

**References:** [1] Haviland et al 2020, LPSC 2935.

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