THEIA – A THERMAL HISTORY EXPLORATION INSTRUMENT FOR ARTEMIS.

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Introduction: In situ thermoluminescence (TL) measurements on the Moon can determine the thermal and radiation environment of lunar surfaces and the subsurface in real-time. This is relevant to scientific exploration and in situ resource utilization. With lunar resource (i.e., volatiles) capture, sequestration, and retention being time (e.g., several tens of My) and temperature-dependent, conventional temperature observations in the present (i.e., measured/modeled) have the disadvantage of not revealing the temperature of volatile-harboring cold traps in the past. This poses a problem because lunar cold traps are permanently shadowed regions primarily located on slopes experiencing landslide, boulder movement, and impact cratering events [1]. Such geologic processes may disturb their thermal regime, which may cause certain volatile deposits to sublime and escape or recondense if conditions were suitable.

Therefore, determining the time-integrated temperature history of a potential cold trap would support lunar exploration, surface operations, and resource prospecting; an instrument for in-situ TL measurements can provide such information over the past several 10 My in real-time when deployed onto the lunar surface [2-4].

Here we describe our progress in designing and building the first flight-scale TL instrument prototype for cold trap prospecting, raising the Technology Readiness Level from 3 to 4.

Instrument design: The instrument consists of four modules needed for a TL measurement with the objectives named earlier:

(1) *Heating module:* We use a Watlow Ultramic 12 by 12 mm resistance heater to raise the sample temperature from ambient to ~800 K via PID (proportional–integral–derivative) control. Peak power consumption is 30 W.

(2) *Light detection module:* a Hamamatsu H7828 photon counting head device containing a 19-mm diameter head-on photomultiplier tube, a high-speed photon counting circuit, and a high-voltage power supply circuit. A filter A counting board converts pulses into photon counts per second (cps). Peak power consumption is 0.3 W.

(3) *Irradiation (X-ray) module*: a Moxtek X-ray source is used to artificially irradiate the sample with a known dose rate to calibrate the natural TL signal. The x-ray source uses a tungsten filament and a rhodium target with a beam current of around 0.1 mA and a peak power consumption of 5 W.

(4) *Processing unit:* a Raspberry Pi 4 is used as a central processing unit, with a peak power consumption of 4.5 W. The computing unit controls the hardware and records all data.

Mode of Operation: For a TL measurement, a ~4 mg sample is delivered into the heating module, where the sample is heated from ambient to ~800 K within 90 seconds. The light detection module measures the intensity of the light emitted from the sample, whereby the temperature and light intensity is recorded by the data processing unit. In addition to measuring the natural TL, a second TL measurement after artificial irradiation (using an x-ray tube) of the sample is necessary to constrain the thermal and radiation history of the sample. The x-ray module is used when the heater and light detection module are idling. Therefore, the peak power consumption of THEIA is 35 W. The system's total weight is less than 1 kg. The instrument requires low downlink bandwidth to stream the data to Earth. Uncompressed file size collecting data points every 0.25 seconds is ~40 KB, with the option to reduce data collection intervals to 1 per second, reducing the file size by a factor of four.

Timeline and Future Developments: We anticipate finishing the construction of the first THEIA prototype instrument by the summer of 2022, followed by data verification with our large-scale TL rig currently used to study lunar regolith samples through NASA ANGSA (Apollo Next Generation Sample Analysis) program [3].

We have also begun designing a laser-based heating module, allowing TL measurements to be performed without a sampling mechanism attached to the side or bottom of a rover, onto a robotic arm, or handheld by astronauts named THEIA2.

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References: [1] 2018 PSR Atlas [2] Sehlke & Sears (2021) NASA ESF & ELS Abstract, [3] Sehlke, Sears and the ANGSA Science Team (2022) 53rd LPSC Abstract #1267 [4] Sehlke & Sears (2020) AGU Fall Meeting Abstract V013-0006