Mini-FND –
The Miniaturized Fast Neutron Detector

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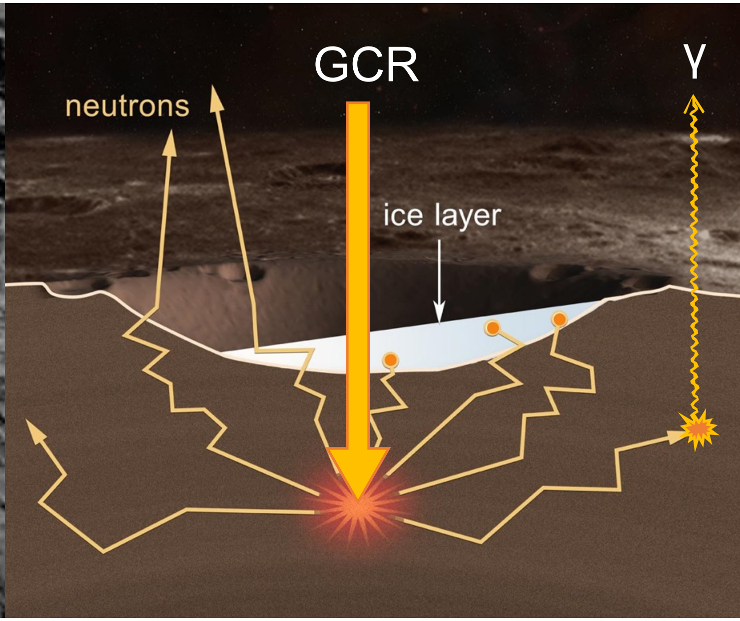
Lunar surface radiation is a distinct environment from deep space



Lunar regolith absorbs galactic cosmic radiation (GCR) to produce secondary albedo neutrons

- High-energy, fast neutrons cause direct cellular damage
- Fast neutrons also produce ionizing radiation
- Estimates of surface neutron doses vary widely
- Effects of lunar surface radiation on bioprocessing are unknown

Lunar Explorer Instrument for space biology Applications: a South Pole Lunar surface investigation

Motivation.
- What are the radiation health risks for crewed exploration of the lunar surface?
- Will proposed mitigations for crew health using in-space biomanufacturing be effective beyond low Earth orbit?

Approach.
- Engineer yeast strains to test growth and metabolism for sensitivity to radiation.
- Measure biologically relevant radiation in transit and on the lunar surface.

Expected Outcomes and Impact.
- Determine cellular sensitivity to the lunar environment.
- Evaluate feasibility of bioproduction on the Moon.
- Test genetic strategies to enhance cellular tolerance to the lunar environment.
- Determine ground truth radiation risks for crew.

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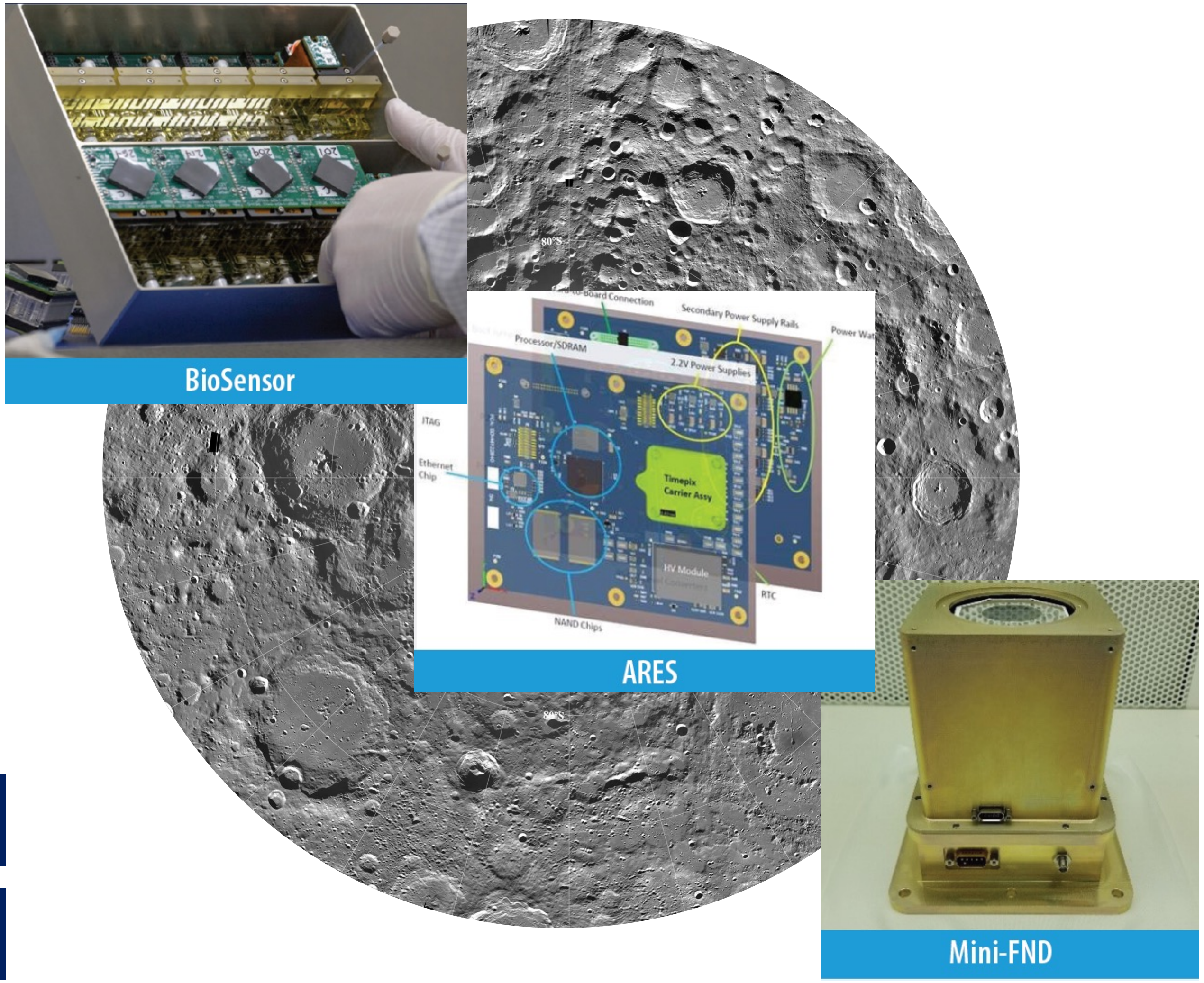
For more information: https://www.nasa.gov/press-release/nasa-selects-new-instruments-for-priority-artemis-science-on-moon

LEIA Instruments



Mini-FND –
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What is Mini-FND?

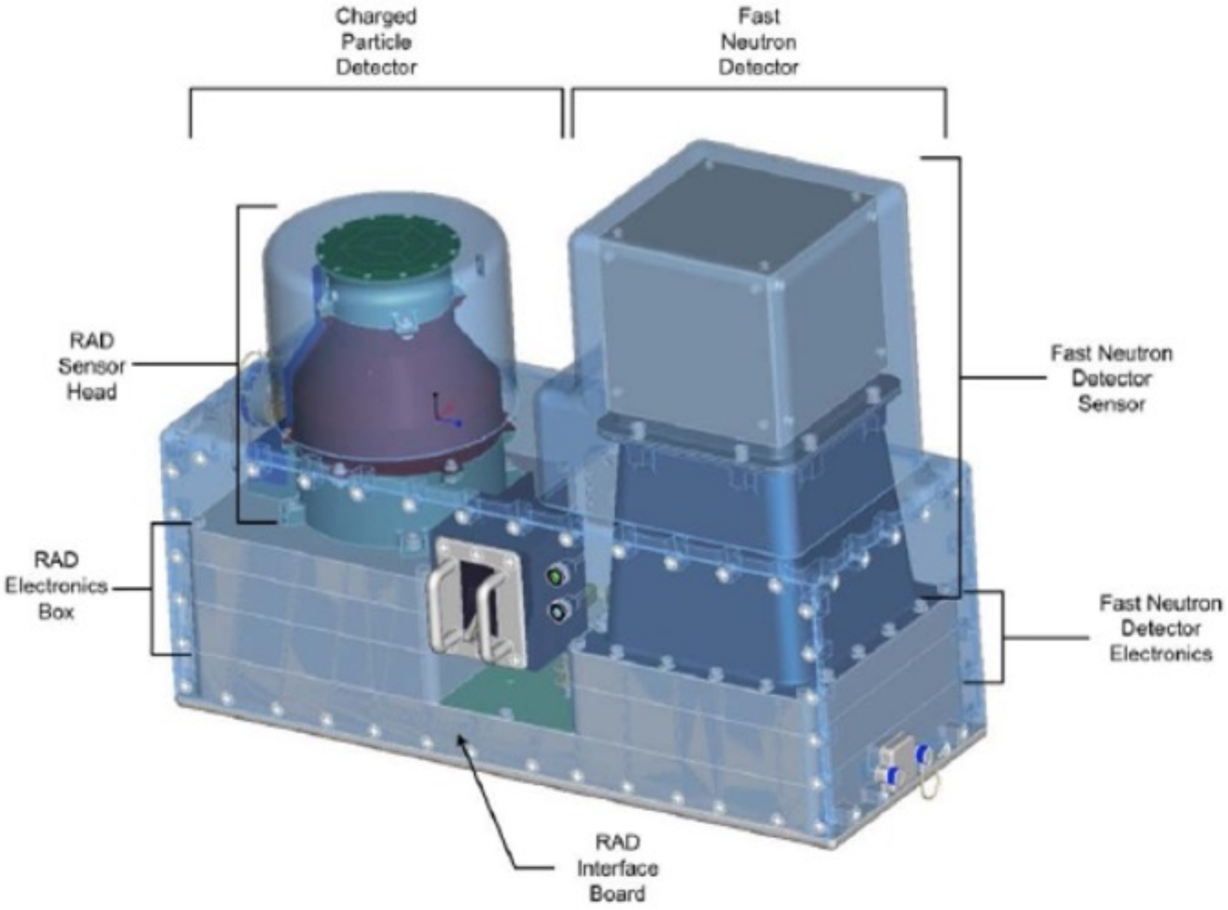
- Detector designed to measure fast neutrons
- “Fast” neutrons are neutrons with energies >300 keV

Why “Mini”-FND?

- Based on the ISS/RAD FND that is operating on ISS since 2016
- Design changes to reduce mass & volume

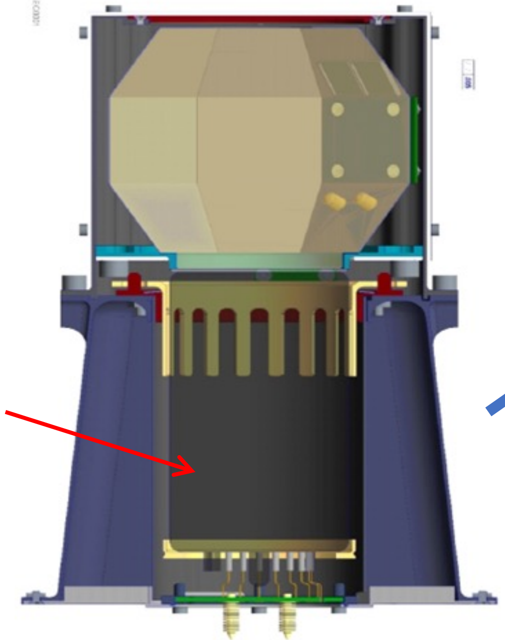
ISS/RAD FND

- ISS/RAD consists of a Charged Particle Detector (CPD) & a Fast Neutron Detector (FND) with accompanying electronics
- On ISS, requirements for mass, volume & power were less restrictive
- ISS/RAD FND is relatively large & heavy
- Not ideally suited for planetary or deep space missions with tight constraints on mass, volume & power

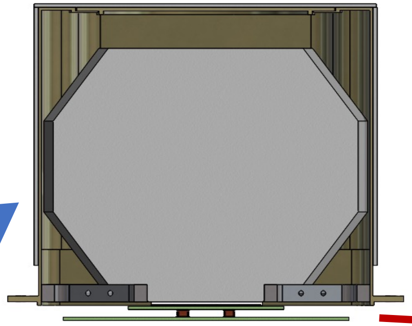


Miniaturizing FND

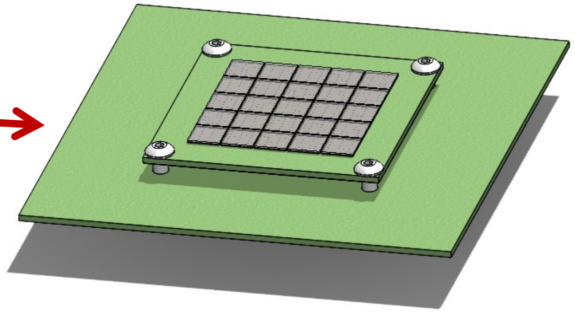
- ISS/RAD FND has a large Photomultiplier Tube (PMT) as read-out detector and requires a high voltage power supply
- Mini-FND is read-out by an array of small Silicon Photomultipliers (SiPMs) (no high voltage required)



ISS/RAD FND
Sensor Head w/ PMT



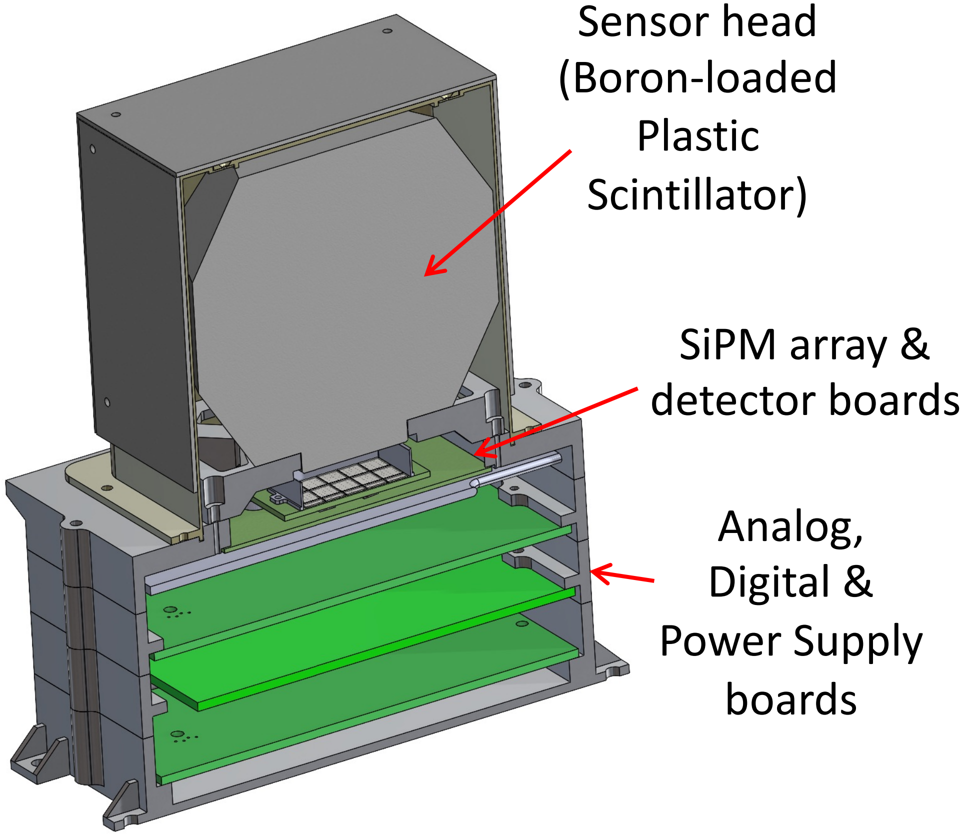
Mini-FND
Sensor Head w/ SiPM readout



SiPM array & board

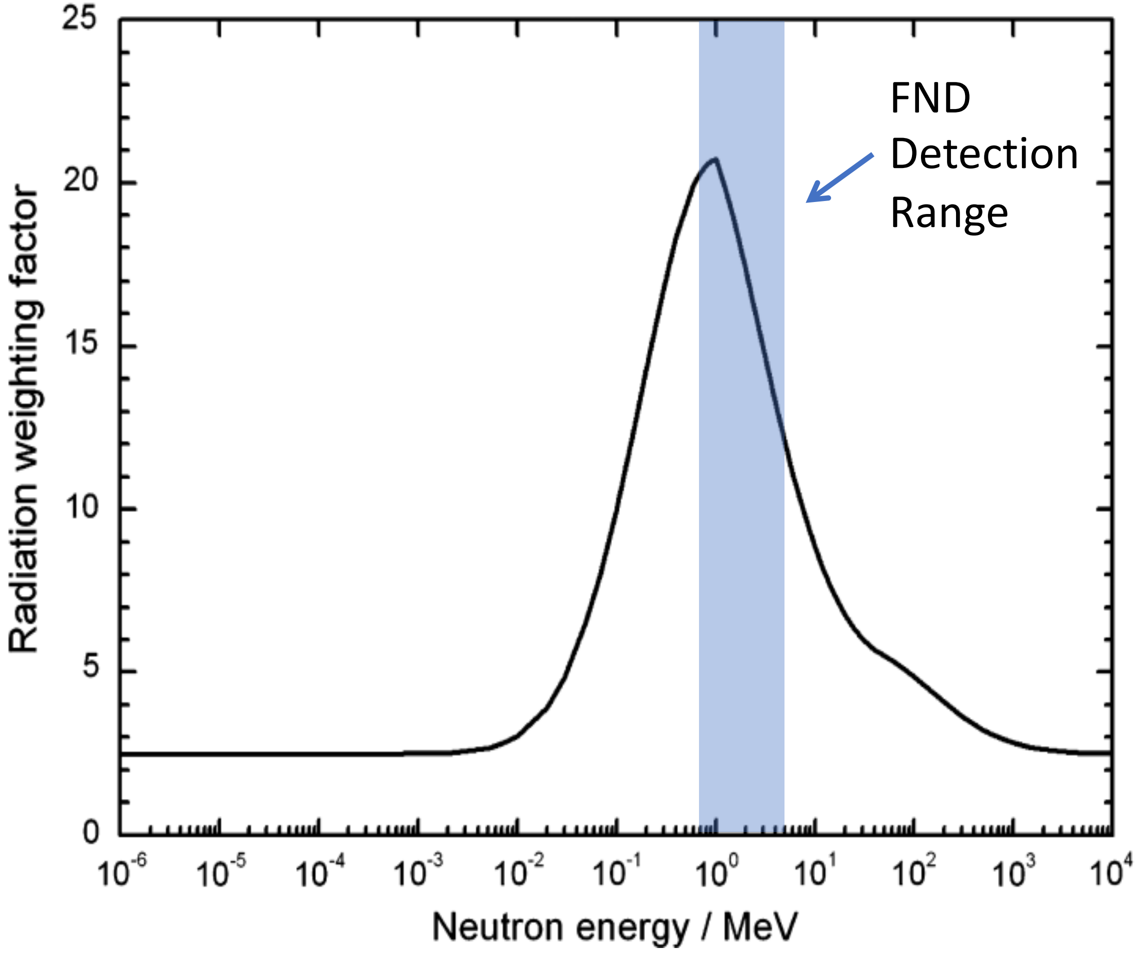
Mini-FND Overview

- Mass: 2.8 kg
- Volume: 15.8 x 14.5 x 16.6 cm^3
- Power: 4.0 W
- Mini-FND measures neutrons in the energy range 0.4 – 10 MeV…
- … and provides integrated flux and energy spectra information
- By measuring the neutron radiation during and in between the times of the LEIA biology experiments, Mini-FND provides information to assess the influence of the neutron radiation on the biological samples
- Mini-FND ground-truth measurements of the lunar neutron radiation are highly important to understand potential health risks for future human exploration of the moon



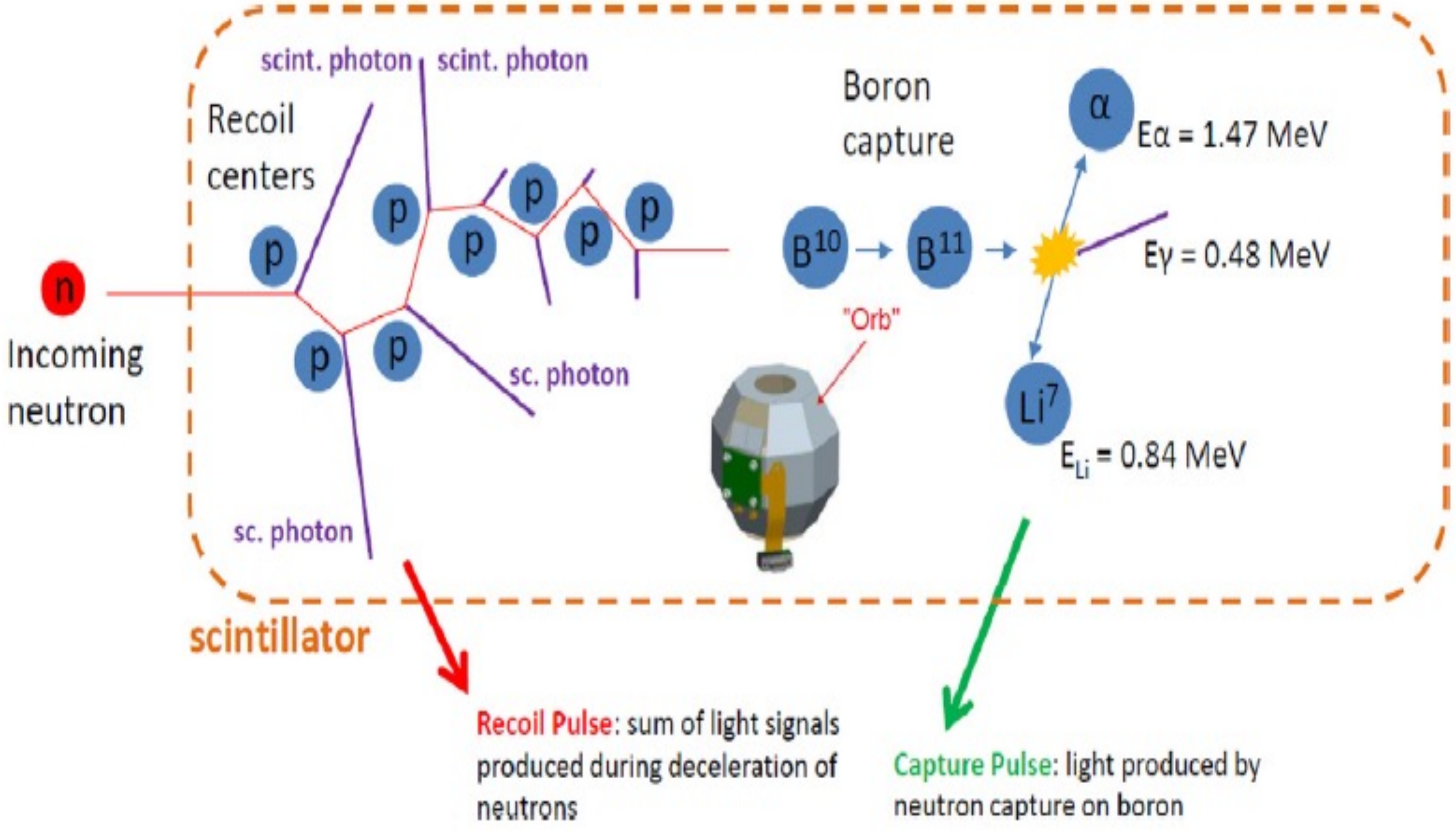
Why are neutron measurements important?

- Common shielding materials are not well suited to shield against neutrons (low interaction cross section with most materials)
- However, neutrons have a high interaction cross section with hydrogen
- Thus, neutrons have a high biological relevance as expressed in the neutron radiation weighting factor
- The required Mini-FND energy detection range (0.5 – 5 MeV) is sufficient to cover the peak of the weighting factor curve



Mini-FND Neutron Detection Scheme – Capture Gating Method

- Mini-FND has a boron-loaded plastic (BLP) scintillator with high hydrogen content (high cross section for neutron interactions)
- Neutrons interacting with the hydrogen lose energy and create a scintillation light pulse
- If the neutrons reach low enough (thermal) energies, the neutron will be captured by a boron atom in the scintillator, producing a second characteristic light pulse in the scintillator (capture pulse)
- The timing of these two pulses can be used to identify the interacting particle as a neutron (known as capture gating method)
- The intensity of the first, recoil pulse is directly related to the incident neutron energy, allowing to derive neutron energy spectra from the Mini-FND measurements



From Zeitlin et al., Life Sciences in Space Research (2023)

LEIA expected outcomes

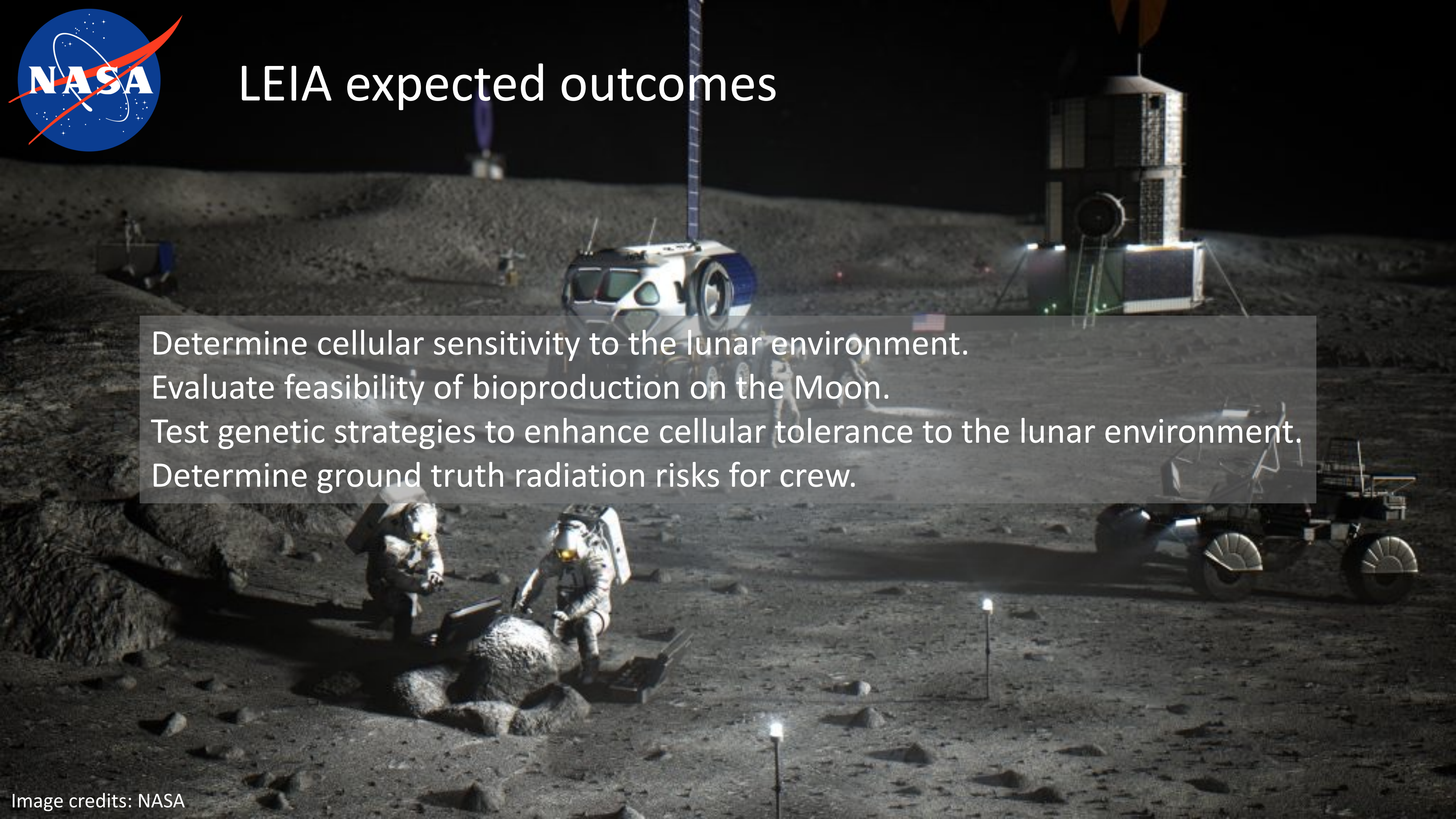


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Image credits: NASA